APPENDIX 6D

ECOLOGICAL LAND CLASSIFICATION

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION

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BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
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EXECUTIVE SUMMARY

The purpose of ecological land classification (ELC) is to delineate and describe ecologically distinct areas of the Earth's surface. One of the most common ELC applications has been to support decision-making in natural resource management. Since an ELC that provides a foundation for identifying and mitigating potential project impacts to wildlife is not currently available for north Baffin Island, it was necessary to develop an ELC that could specifically address the planned activities associated with the Mary River Project and its regional study area (RSA).

Thus, the purpose of this report is (1) to describe the approach that was used to develop the Mary River ELC, (2) to present the results of the analyses used to produce the Mary River ELC, and (3) to address the role of the Mary River ELC in predicting potential project impacts on wildlife. The Mary River ELC includes a descriptive and a quantitative component. The descriptive component was derived from work done by the Federal Government of Canada in the late 1970s and early 1980s. The quantitative component involved the development of a GIS-based model using field data, maps of habitat conditions, statistical analyses, and spatial modeling. A total of 45 variables related to wildlife habitat were incorporated into the model.

The model was designed to (1) predict the abundance of selected plant species and/or guilds for the RSA from continuous spatial habitat data, (2) use these maps of plant species/guilds as well as spatial habitat data to characterize habitat suitability for wildlife valued ecosystem components (VECs), and (3) analyze and present environmental impact scenarios for wildlife VECs.

Modelling of the avian VEC habitat suitability utilized the ELC model, habitat ratings (expert opinion), field data, and regression analysis to produce habitat suitability maps for these VECs. A ranking of these models from most to least accurate includes the following: Red-Throated Loon habitat at 89.9%, Eider habitat at 89.3%, Falcon nesting habitat at 87.9%, Falcon foraging habitat at 83.4%, and Snow Goose habitat at 82.5%. The habitat suitability maps generated from this work were subsequently used to quantify potential project impacts on avian VEC habitat, in the Environmental Impact Statement for the Mary River Project.

Caribou habitat suitability and impacts are also addressed in the Environmental Impact Statement.

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

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(REF. NO. NB102-181/25-5)

TABLE OF CONTENTS

PAGE

TABLES

FIGURES

APPENDICES

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BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
(REF. NO. NB102-181/25-5)

SECTION 1.0 - INTRODUCTION

The purpose of ecological land classification (ELC) is to delineate and describe ecologically distinct areas of the Earth's surface. Fundamental to this task is the characterization of ecological composition, which is determined by physical attributes such as climate, geology, physiography (including soils), and hydrology, as well as biological attributes including vegetation, wildlife, and human activity. Ultimately, the interactions among and between these attributes are used to identify the boundaries of an ecological land unit. Although ELCs have been applied for many purposes, one of the most common applications has been to support decision-making in natural resource management, ranging from resource extraction to nature protection (Lee et al. 1998; Gallant et al. 2004).

The *National Ecological Framework for Canada* (Ecological Stratification Working Group 1995) provides delineation of three ecoregions and eight ecodistricts (NEF-ELC) for the regional study area (RSA) of the Mary River Project. However, because boundary delineations are not explained and minimal ecological knowledge is available for each ecodistrict, the NEF-ELC is inadequate to support resource management associated with the Mary River Project. Since this is the only ELC available for northern Baffin Island, and since it is inadequate for this project, a site-specific ELC that will not only describe the ecology of the Project landscapes, but will also provide a foundation for identifying and mitigating potential project impacts is needed.

The purpose of this report is (1) to describe the approach that was used to develop the Mary River ELC, (2) to present the results of the analyses used to produce the Mary River ELC, and (3) to address the role of the Mary River ELC in predicting potential project impacts on wildlife. The Mary River ELC includes a descriptive and a quantitative component. The descriptive component was derived from work done by the Federal Government of Canada in the late 1970's and early 1980's (Department of the Environment and Indian and Northern Affairs Canada 1981), prior to the development of the NEF-ELC. Although the descriptive component of the Mary River ELC lacks predictive capability, it does provide a solid foundation to focus on the basic ecology of the landscapes within the Mary River RSA. Such a foundation is critical to "improve our understanding of geographic and ecological phenomena associated with biotic and abiotic processes occurring in individual regions and also of processes characteristic of interactions and dependencies among multiple regions" (McMahon et al. 2004, pg. S111).

The more we understand about the ecology of the landscape, the more accurate our predictions of potential impacts to wildlife due to resource development will be. Our ability to predict such impacts has improved substantially with the recent advent of computer-based GIS (geographic information systems) and remote sensing technologies. Using these two technologies, it was possible to develop a quantitative component to the Mary River ELC model, which is capable of producing maps of wildlife habitat suitability at reasonable levels of accuracy. These computer-generated maps were then used as the basis for evaluating potential project impacts on the habitat of selected wildlife species.

In the process of developing and applying the descriptive and quantitative ELCs, many research articles and case studies were collected and reviewed. These papers were organized into an “electronic library” and have been annotated in Appendix A. The published papers and reports in this electronic library are available for use at Knight Piésold Ltd., North Bay.

SECTION 2.0 - STUDY AREA AND METHODOLOGY

2.1 STUDY AREA

The boundary of the RSA for the development and application of the Mary River ELC is shown on Figure 2.1. This boundary was chosen because it represents the limits of the field data collected for birds in 2007, which are the widest ranging of the species studied for this project. In addition, the boundary includes the plots for all other biological field investigations, except for some of the aerial caribou observations. The RSA is roughly 100 km wide - 50 km either side of the project infrastructure including the transportation corridors, 250 km long, and therefore about 25,000 km^2 in size. The southern end of the study area centres on Steensby Inlet, the northern portion includes Milne Inlet and Tay Sound, and the central portion includes many large lakes to the south and west of Angajurjualuk Lake, which is the largest lake in the RSA.

2.2 METHODOLOGY

The Mary River ELC includes both a descriptive and a quantitative component. The descriptive ELC was derived from data available on the Land Use Information Series Maps for the RSA (Department of the Environment and Indian and Northern Affairs Canada 1981). The quantitative ELC is a GIS (geographic information systems; ESRI 2008) model that utilized available digital map data, empirical field data, and statistical analyses to predict wildlife suitability using significant ecological relationships (e.g., Host et al. 1996; Hargrove and Hoffman 2005).

2.2.1 Descriptive Ecological Land Classification

The six Land Use Information Series Maps used to produce the descriptive ELC included Erichsen Lake (47E), Icebound Lakes (37G), Milne Inlet (48A), Phillips Creek (47H), Pond Inlet (38B), and Steensby Inlet (37F). Each Land Use Map included an ecological overview that provided qualitative information for terrain, water, and vegetation, which is related to land units with boundaries shown on each land use map. This information was obtained by the Department of the Environment and Indian and Northern Affairs Canada (1981) from literature reviews, satellite images, aerial photographs, low-level oblique colour slides, over-flight observations, and ground observations. In addition, general climate data are provided on these maps. These boundaries were digitized using ArcView (ESRI 2008) to produce a single composite map connecting the ecological land units (ELU) shown on all six land use maps.

The information from each ELU description was then used to prepare tables and figures that present comparisons of ELU features. Some features were compared statistically using a sequential rating system. For example, on the land use maps, relief was rated using seven categories of increasing relief from very low to high. Thus, for this analysis, very low was assigned a value of 1 and high was assigned a value of 7; the other five categories were assigned the values 2 through 6. These values were then compared between and among samples. Other features that were ranked and compared statistically included lake cover, vegetation productivity, and mean abundance for sedges, avens, herbs, willows, mosses, and lichens. Analysis of variance (Minitab 2000) was used to identify significant differences between category means for each of these features.

2.2.2 Quantitative Ecological Land Classification

An empirical, scientific approach was used to produce an ELC model that can (1) predict the abundance of selected plant species and/or guilds for the RSA from continuous spatial habitat data, (2) use these maps of plant species/guilds as well as spatial habitat data to characterize habitat suitability for wildlife valued ecosystem components (VECs), and (3) analyze and present environmental impact scenarios for wildlife VECs. This was accomplished by integrating field data, maps of habitat conditions, statistical analyses, and GIS modeling.

2.2.2.1 Field Data

For the Baseline Vegetation Program, Burt (2007, 2008) collected field data within 5 x 5 m plots along an approximate 250 km transect following the transportation corridor from Steensby Inlet in the south to Milne Inlet in the north within the Mary River Project RSA. A total of 594 of Burt's vegetation plots were used for this study. In each plot, plant species were identified and assessed for abundance (%cover), substrate conditions were assessed, and soil moisture was rated using five categories from wet to dry. Aspect, slope, elevation, and geographical coordinates were also measured.

2.2.2.2 Spatial (Map) Habitat Data

Several digital vector maps of surficial geology (Geological Survey of Canada 2005) for the RSA were (1) combined into one data layer using ArcView (ESRI 2008), (2) rasterized using the "polygon to raster" tool in ArcView, and (3) re-defined by combining and reducing categories resulting in ten surficial geological types: alluvial deposits, bedrock, end moraine, glacial lacustrine sediments, ice-contact stratified drift, marine sediments, proglacial outwash, talus, till blanket, and till veneer.

The surficial geology for two areas within the RSA has not yet been mapped by Natural Resources Canada. One of these areas is located east of the Mary River Camp and the other is located in the extreme southeast portion of the RSA. Two potential sources of surficial geology data were assessed to determine whether they could be used to fill these gaps. One source was a more general and much older surficial geology map for Baffin Island and the other was a radar backscatter-derived surficial geology map for northern Baffin Island. Both of these alternative sources proved inadequate for our needs. Thus, the only alternative was to create new moisture index and vegetation abundance models without the use of surficial geology as an independent predictor variable. These models were used only for the areas with missing surficial geology mapping.

A digital elevation model (DEM) was created by joining all relevant digital vector maps of elevation contours (60 m intervals, from Natural Resources Canada) for the RSA and converting them into a rasterized data layer using the "topo to raster" tool in ArcView Spatial Analyst.

The DEM was then processed in ArcView to produce maps of moisture, solar radiation, aspect, and slope for the RSA. The method developed by Iverson et al. (1997) was used to produce a moisture index map using the following tools in ArcView Spatial Analyst: “hillshade” (40% weighting), “flow direction” and “flow accumulation” (30% weighting), “curvature” (10% weighting), and the “reclass” tool to rate water holding capacity (from 0 to 100) of surficial geological types (20% weighting) based on mean field moisture rankings as follows: marine - 0, talus - 10, glacial lacustrine sediments - 10, proglacial outwash - 10, bedrock - 43, end moraine - 65, till veneer - 65, alluvial deposits - 83, till blanket - 100, ice-contact stratified drift - 100. Lab analysis of soil core samples taken in four of these surficial geological types for the Mary River Engineering Design Program verified that these four types were ranked correctly based on moisture content.

The solar radiation map was created using the “area solar radiation” tool in ArcView Spatial Analyst. Specific settings for this calculation included: July 1 to September 15, one-hour interval, and 14-day interval for timing, the middle of the RSA for latitude, 200 for sky size, and 8 for azimuth divisions. The slope map (in degrees) was produced using the “slope” tool in ArcView Spatial Analyst and the aspect map was created using the “aspect” tool in ArcView Spatial Analyst. The “terrain ruggedness” tool in ArcView developed from Sappington (2007) was used to create a terrain roughness data layer.

Lastly, models were developed to characterize the suitability of areas within water bodies for those VECs that use aquatic habitat including red-throated loon, eiders, and snow geese. This was completed for five different water body sizes and marine areas based on VEC affinity for distances from shorelines. To accomplish this, a water bird expert produced ratings for each water body size and marine area that defined the relative preference by each water bird VEC for the different distance categories. By combining an aquatic habitat suitability map with a terrestrial habitat suitability map (produced and reported on separately from this work), a single habitat suitability map representing both aquatic and terrestrial habitat suitability for each water bird VEC was produced for the entire RSA (Appendix B).

2.2.2.3 Relationships between Plant Species/Guilds and Habitat

Initially, the plant species abundance data for 121 species in 594 vegetation plots were ordinated using detrended correspondence analysis (DCA; Hill and Gauch 1980). This was done to determine the potential for predicting the spatial patterns of the plant community types identified by the Baseline Vegetation Program from habitat conditions and known plant-habitat relationships. Due primarily to high variation within and among plant community types, it was determined that the spatial nature of these community types could not be reliably predicted.

However, the DCA results were useful for characterizing relationships between habitat conditions and plant species composition in the RSA. This was completed by correlating the 594 DCA sample scores for axes 1 and 2 with field habitat variables including surficial geology variables (% cover of rocks, gravel, bedrock, and sand), water variables (moisture rated from 1-low to 5-high, standing water, and flowing water), aspect (using solar radiation derived from GIS analysis), slope (%), and elevation (GPS in m).

In order to estimate plant species/guild abundance throughout the entire RSA, the relationships between habitat and plant species were identified and quantified. First, the most common plant species in the RSA (>.4800 mean %cover; total of 26) were identified by ranking all species by mean abundance. Added to this group were the plant guilds identified by Krebs et al. (2003), which included grasses and sedges (one guild), herbs, mosses, Saxifraga spp., and willows. Cotton grasses and rushes (as one guild) and foliose and fruticose lichens (as one guild) were also added because of their value to wildlife.

The responses of these 33 plant species/guilds to variations in surficial geology (10 types) were then evaluated using analysis of variance (ANOVA). Surficial geology was chosen as the starting point for this analysis of habitat relationships because (1) it is the most reliable habitat data layer having been generated from aerial photo interpretation rather than topographic interpolation and modeling, (2) gravel, rocks, and bedrock were all significantly correlated with plant community composition (DCA axis 1), and (3) no other habitat data layer exhibited as many significant relationships (p<.101) with plant species/guild abundance (14 in total). These 14 plant species/guilds were selected for further analysis.

Relationships between the 14 plant species/guilds and the five other habitat data layers (solar radiation, moisture, elevation, slope, and aspect) were also identified by comparing mean abundances of each species/guild among classes within each habitat layer using ANOVA (p<.101). The solar radiation gradient was initially partitioned equally into six classes, but due to very small sample sizes in the two highest classes, these two classes were combined resulting in a total of five classes. The two highest classes for the moisture index were also combined due to small sample size resulting in a total of four classes. Elevation and slope were partitioned equally into four classes, and aspect was partitioned into flat, north, east, south, and west using azimuth values.

2.2.2.4 Spatial Plant Species/Guild and Habitat Type Data

Continuous spatial coverage of abundance for the 14 significant plant species/guilds throughout the RSA was estimated by assigning the mean species/guild abundance in a surficial geological category to all locations in the RSA where that category occurred. If the mean abundance of a species/guild was not significantly related to gradients within the other five habitat variables (moisture, solar radiation, elevation, slope, and aspect), then those abundance values remained unmodified.

However, if the plant species/guild was significantly related to another habitat variable, the mean abundance within each category for that habitat variable was rescaled to a percentage of the maximum value and multiplied by the mean abundance of the species/guild in each surficial geological category that occurred in the other habitat variable category. This process continued until all habitat variables showing a significant relationship with a plant species/guild were included in the analysis.

This rescaling resulted in artificially reduced species/guild abundances, which became more pronounced with each habitat variable rescaling. To address this reduction in abundance values, the final predicted abundance values were scaled back up by the ratio of the mean of the original 594 sample values to the mean of the 594 predicted values. Finally, all predicted abundances for a species/guild that were higher than the maximum from the sample values were re-assigned to the sample maximum value.

The accuracy of each plant species/guild model was evaluated in four ways: (1) the paired T-test was used to compare the mean of the 594 observed (field) values to the mean of the 594 final GIS-predicted values for each species/guild, (2) Pearson product-moment correlations were used to evaluate relative changes between the observed and predicted values due to model inaccuracies, (3) mean absolute difference provides some indication of variance due to model predictions, and (4) the % of observed range represented by the mean absolute difference relates the model variance to the variation in the observed data.

A digital map of plant community types (or habitat types) produced from Landsat satellite imagery by the Canada Centre for Remote Sensing (Olthof 2008) was also used as a variable (or data layer) in the habitat suitability modeling.

SECTION 3.0 - RESULTS

3.1 DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION

In 1981, the Environmental Conservation Service and Land Resource Research Institute of the Canadian Federal Government identified and described 17 ELUs that are located within the Mary River RSA. The boundaries of these units are shown on Figure 3.1. These units vary in size from 4,100 ha (unit 7) to 592,965 ha (unit 8) with a mean size of 158,616 ha. Uplands make up approximately 58% of the RSA, dominating on the east side, and plains make up about 42%, dominating on the west side as shown on Figures 3.2 and 3.3, respectively. On average, elevation in the uplands is roughly 2.4 times greater than elevation on the plains. In the uplands, elevation varies from 0 to 960 m with a mean of 426 m, whereas elevation on the plains varies from 0 to only 540 m with a mean elevation of 177 m. This major difference in elevation between the east and west side of the RSA has had a variable but significant effect on terrain, water bodies, and vegetation in the RSA.

3.1.1 Terrain

Table 3.1 provides descriptions of terrain features for each ELU in the RSA. Relief varies from very low to high and is approximately 43% greater (T=1.96, p=.079) in the uplands (mean rating of 4.0) compared with the plains (mean rating of 2.8). Land texture varies from almost level, primarily on the plains to hilly landscapes and some rugged areas, mainly in the uplands. A variety of surface material types are found throughout the RSA and no major patterns are evident in the plains compared with the uplands. However, surface material depth is “deep” throughout the plains but is highly variable in the uplands ranging from “shallow” to deep.

It is likely that these thinner soils (including more exposed bedrock) in the uplands coupled with harsher climate conditions results in land productivity that is 50% higher on the plains (mean productivity rating of 4.0) compared with the uplands (mean productivity rating of 2.7), and 100% higher in the valleys and riparian areas (mean productivity rating of 5.8) relative to the uplands.

The “other” land component category consists of less common site types typified by low moisture, rocky substrates, and hilltops, which on average are slightly less productive (mean productivity rating of 2.5) than upland areas (mean productivity rating of 2.7). Frost polygons and frost boils are most often but not always associated with ELUs that have year-round presence of snow and ice including snow patches, snow fields, ice fields, and glaciers. Ten of the 17 ELUs have year-round ice and snow, which occurs on the plains as well as the uplands.

3.1.2 Water Bodies

The most striking difference between the water bodies on the plains compared with those in the uplands relates to aerial extent of lakes as shown on Table 3.2. In the plains, the aerial coverage of lakes (mean of 20%) is roughly four times greater (T=-3.75, p=.010) than in the uplands (mean of 4.6%). However, coverage of lakes on the plains varies widely from 5% to 30%, whereas variation is less in the uplands ranging from 1% to 15%. Lake turbidity appears to be slightly higher on the plains.

In contrast to lakes, stream density is lower on the plains (mostly rated as "low") compared with the uplands (mostly rated as "moderate"). Most stream channels are not entrenched, and only in the uplands are some channels poorly developed and bedrock controlled.

3.1.3 Vegetation

3.1.3.1 Plant Communities

There is a total of 22 plant community types in the Mary River RSA according to the Land Use Information Maps as shown on Table 3.3. Although six plant species/guilds are listed in the descriptions of these communities (avens, herbs, lichen, moss, sedge, willow), only sedges, herbs, and avens dominate (those species/guilds that are listed first). Thus, lichen, moss, and willow occur only as sub-dominant components of these plant communities. The sedge-dominated, herb-dominated, and avens-dominated communities are found on all four land components in the RSA: the plains, the uplands, the valley and riparian areas, and the "other" landscapes.

The most common community types in the RSA are those dominated by sedges, which are twice as common as both the herb-dominated and avens-dominated community types. The sedge-willow-avens-moss (9 occurrences) and the sedge (monoculture; 7 occurrences) communities are the most frequent of the sedge-dominated communities. Of the herb-dominated communities, the herb-avens-moss-lichen (3 occurrences), herb-lichen (3 occurrences), and herb-avens-lichen (2 occurrences) are the most common. The avens-herb-lichen (4 occurrences) and the avens-sedge (2 occurrences) communities are the most common of the avens-dominated community types. Throughout the entire RSA, 13 community types had only one occurrence.

Valleys and Riparian Areas

These landscapes include drainage ways; gentle slopes; lower slopes; lowlands; poorly drained depressions; stream, lake, and pond margins; and valley bottoms. Table 3.4 shows that the greatest variety of plant community types (14) occurs in the valley and riparian landscapes, where the sedge-dominated communities are most common. Ten community types have only one occurrence in these landscapes. All ELUs have valleys and/or riparian areas except for ELU-2 as shown on Table 3.5. In addition to their great diversity of plant community types, valley and riparian areas are the most productive of the four land components as shown on Figure 3.4, ranging in value from 3 to 8, with a mean of 5.8. ELUs 1 and 13 in the uplands, and 5 and 9 on the plains have the highest plant community diversity, as shown on Table 3.5.

Uplands

There are eight community types in the uplands; the most common are dominated by herbs, as shown on Table 3.4. Five community types have only one occurrence in the uplands. Productivity ranges from 1 to 7, with a mean of 2.7 as shown on Figure 3.4.

Both the upland and the other landscapes are much less productive than both the plains (mean of 4.0) and the valleys and riparian areas (mean of 5.8), as indicated on Table 3.6. Most upland ELUs (6 or 67%) have only one plant community type that is not associated with valleys and riparian areas, and which is primarily dominated by herbs and avens.

Plains

Table 3.4 shows that sedge-dominated plant communities are the most common of the seven community types that occur on the plains. Herb- and avens-dominated communities are also common. Five community types there have only one occurrence. As shown on Table 3.7, productivity on the plains ranges from 1 to 7 with a mean of 4.0, which is less than the valleys and riparian areas but more than the uplands and other landscapes as shown on Figure 3.4. Three of six ELUs have only one plant community type that is not associated with valleys and riparian areas. ELU-5 has the greatest number of community types that are not associated with valleys and riparian areas.

"Other" Landscapes

In the "other" landscapes, there are only four community types, each with only one occurrence. The herb-dominated communities are most common, but sedge and herb-avens communities also occur as shown on Table 3.4. Table 3.8 shows that productivity ranges from 1 to 5 with a mean of 2.5, which is the lowest of the four land components as shown on Figure 3.4.

3.1.3.2 Plant Species

The plant community descriptions on the Land Use Information Series Maps include six plant species and/or guilds. In order of decreasing abundance, these include sedges (30.1%), avens (24.8%), herbs (23.2%), willows (9.2%), mosses (7.7%), and lichens (4.8%) as shown on Figure 3.5. In general, the sedges, avens, and herbs are three to seven times more abundant than the willows, mosses, and lichens. However, the distribution of abundance for plant species/guilds differs within valleys and riparian areas, plains, and uplands.

Table 3.9 presents the distribution of mean abundance for the six plant species/guilds in the three major land components. Sedges are the most abundant species in both the valleys and riparian areas (48.5%) and the plains (27.8%). However, on the plains, both herbs (25.6%) and avens (20.9%) are very similar to sedges in abundance, whereas in the valleys and riparian areas, the second-most abundant species is avens (17.5%), which is 64% less abundant than sedges. In the uplands, herbs (30.9%) and avens (27.9%) are most abundant. Lichens in the uplands are the third most abundant species (13.4%), and are roughly twice the abundance of lichens on the plains (7.5), and about 22 times more abundant than lichens in the valleys and riparian areas (0.6). Herbs (9.6%), mosses (9.5%), and lichens (0.6%) have the lowest abundance in the valleys and riparian areas, lichens (7.5%) and mosses (3.8%) have the lowest abundance on the plains, and willows (8.2%) and mosses (6.2%) are the least abundant species/guilds in the uplands. Willows are intermediate in abundance in the valleys (14.0%) and on the plains (14.1%).

Sedges are most abundant in the valleys and riparian areas; avens, herbs, and lichens are most abundant in the uplands; willows are most abundant on the plains and in the valleys and riparian zones, and mosses are most abundant in valleys and riparian areas.

3.2 QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION

Ordination of the 594 field vegetation plots classified by plant community types, as shown on Figure 3.6, indicates that there is too much overlap or redundancy among field-based plant community types to effectively predict an individual community type from habitat conditions. For example, within the cluster of non-tussock sedge wetlands (shown with green dots on Figure 3.6), ten other plant community types are also present. This intermingling of samples representing different plant community types was verified with the results of an ordination of vegetation plots classified by surficial geology as shown on Figure 3.7. This figure indicates that none of the surficial geology types have a unique plant community composition. In fact, the norm is multiple and excessive overlap of plant species composition when grouped by surficial geology categories. For example, both “bedrock” and “end moraine” samples cover nearly the entire ordination space (entire extent of all points in the two-dimensional plot).

Instead of mapping plant community types using field data for developing wildlife habitat suitability models, plant community/habitat type data were obtained from satellite imagery. Interpretation of the imagery (Landsat bands 4, 5 and 3) was performed by the Canada Centre for Remote Sensing (Olthof 2008), and was based on relevant published literature as well as ground-truthing of field plots throughout Baffin Island. As shown on Figure 3.8, the following ten plant community types or habitat types have been mapped for the RSA: barren; bare soil with cryptogam crust-frost boils; sparsely vegetated bedrock; sparsely vegetated till-colluvium; prostrate dwarf shrub-dryas/heath, usually on bedrock; moist to dry non-tussock graminoid/dwarf shrub tundra: 50-70% cover; dry graminoid prostrate dwarf shrub tundra: 70-100% cover; tussock graminoid tundra; wet sedge: graminoids and bryoids; and wetlands.

Although the ordination results could not be used to characterize plant community types for GIS modeling, they were useful for identifying and quantifying relationships between physical habitat conditions and plant community composition. Table 3.10 shows that surficial geology variables (rocks, bedrock, gravel, and sand) had the greatest number of significant relationships (six significant correlations) with plant community composition (DCA axes 1 and 2). In addition, four water variables, slope, and elevation were significantly correlated with plant community composition. Axis 1 of the DCA results explained about 60% of the variation in plant community composition and Axis 2 explained about 43% of the variation.

The relationships between plant community composition and physical habitat conditions were used as the basis for projecting data for plant species and guilds from sample plots to mapped abundance for the entire RSA. The plant species to be mapped for abundance were identified by ranking them by mean abundance (%cover from field data) as shown in Table 3.11. The plant species with a mean %cover greater than .4800 (total of 26 species) were then evaluated for their relationship with surficial geology, which was the most important physical habitat variable due to its multiple correlations with plant community composition as shown in Table 3.10. Nine plant species had at least one significant statistical relationship (p<.101) with surficial geology including *Dryas integrifolia*, *Vaccinium uliginosum*, *Luzula confusa*, *Carex atrofusca*, *Oxyria digyna*, *Carex scirpoidea*, *Saxifraga oppositifolia*, *Ledum palustre*, and *Luzula nivalis*, as shown on Table 3.12.

Of the plant guilds, only cotton grasses and rushes, grasses and sedges, mosses, and willows were significantly related (p<.101) to variation in surficial geology as shown on Table 3.12. Although foliose and fruiticose lichens were not significantly related to surficial geology (F=1.30; p=0.231), they were included for further analysis due to their importance as a food source for caribou, snow geese, and song birds. Foliose lichens are leaf-like in both structure and appearance, and they adhere loosely to their substrate. Fruticose lichens are often round in cross-section, have no distinct top or bottom, and their thalli may be shrubby, upright, or hanging strands (De Santis 1999).

In addition to surficial geology, the other habitat variables used to produce RSA abundance maps for the 14 selected plant species/guilds included moisture, solar radiation, elevation, slope, and aspect. Maps of these six physical variables are shown on Figures 3.9 to 3.14. The statistical relationships between the habitat variables other than surficial geology and the 14 selected plant species/guilds are shown on Table 3.13. For this study, a statistically significant relationship occurred when the probability (p) level was less than 0.101.

As shown on Table 3.13, *Carex atrofusca* was statistically related only to surficial geology. *Carex scirpoidia* was statistically related to the moisture index (p=0.059). Cotton grasses and rushes were statistically related to solar radiation (p=0.008) and elevation (p=0.009). *Dryas integrifolia* was statistically related to solar radiation (p=0.061), elevation (p=0.014), and aspect (p=0.019). Grasses and sedges were statistically related to elevation (p=0.036). *Ledum palustris* was statistically related to the moisture index (p=0.059), solar radiation (p=0.000), elevation (p=0.000), slope (p=0.016), and aspect (p=0.002). Foliose and fruiticose lichens were statistically related to solar radiation (p=0.054) and slope (0.019). *Luzula confusa* was statistically related to elevation (p=0.062). *Luzula nivalis* was statistically related to solar radiation (p=0.000), elevation (p=0.000), and aspect (p=0.011). Moss was statistically related to the moisture index (p=0.098) and solar radiation (p=0.039). *Oxyria digyna* was statistically related to the moisture index (p=0.029), solar radiation (0.002), elevation (0.035), and slope (0.030). *Saxifraga oppositifolia* was statistically related to solar radiation (p=0.001) and elevation (p=0.000). Vaccinium uliginosum was statistically related to moisture index (p=0.000), solar radiation (p=0.000), elevation (p=0.000), slope (p=0.000), and aspect (p=0.005). Finally, willow was statistically related to solar radiation (p=0.003) and elevation (p=0.008).

Once a GIS model using physical habitat variables was constructed to predict abundance for each species/guild, the predicted abundance values for the field sample points were compared with the observed values for these points to evaluate model accuracy. The paired T-test, Pearson product-moment correlations, mean absolute difference, and % of observed range were used for this evaluation, as shown on Table 3.14. Many of the observed and predicted mean abundance values were identical and the others differed very little. This is because the first iteration GIS-generated (predicted) values were adjusted by a constant to facilitate matching means for the observed and predicted values. None of these new means were found to be statistically different for any of the 14 predictor variables (all T-values had $p>.100$), as shown on Table 3.14.

In addition, observed and predicted abundance values for all variables were significantly correlated ($p<0.051$), as shown on Table 3.14. The mean absolute difference between the observed and final predicted abundance values ranged from 0.7 for *Luzula nivalis* to 13.6 for grasses and sedges. This high mean absolute difference for grasses and sedges translated into 14.6% of the observed range, which was the highest difference between observed and predicted values for the 14 predictor variables. In contrast, the lowest mean absolute difference as a percentage of the observed range was 2.7% for *Carex scirpoidia*. The maps of abundance for the 14 predictor species/guilds are presented on Figures 3.15 to 3.28.

SECTION 4.0 - WILDLIFE HABITAT SUITABILITY MODELLING AND IMPACT ANALYSIS

In order to produce maps of wildlife habitat suitability for the Mary River RSA using the ELC quantitative model, it is necessary for an expert biologist to rate the importance of each of the independent habitat variables relative to the wildlife species of concern (e.g., the VECs). These habitat variables include 14 plant species/guilds, ten plant community or habitat types, and seven physical habitat features. The aquatic habitat ratings for the three water bird VECs (red-throated loons, eider, and snow geese) are built-in to the ELC model.

Once the project footprint is identified and mapped, the disturbed portion of each habitat suitability category for each wildlife VEC can be determined using the habitat suitability maps. These habitat maps will also be used to evaluate a variety of potential project impacts to wildlife including noise and dust.

The VEC habitat suitability mapping for Peregrine Falcon, Red-throated Loon, Snow Geese, and Eider is described in Appendix B. The impact analysis for the bird VEC habitats is provided in a separate report. The VEC habitat suitability mapping and impact analysis for caribou is also reported on separately from this work.

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SECTION 6.0 - CERTIFICATION

This report was prepared, reviewed and approved by the undersigned.

Prepared by:

Peter Quinby, Ph.D.
Senior Environmental Scientist

Reviewed by:

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Approved by:

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TABLE 3.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
TERRAIN FEATURES IN THE RSA

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ELC Unit	Land Component	Size (ha and %)	Relief	Land Texture	Surface Material Type	Surface Material Depth	Total Productivity [1]	Outcrops	Snow and ice	Frost Polygons & Boils	Calcareous	Other
1	uplands	79,632 (3.0%)	moderate	rolling to hilly	coarse to fine textured moraine, residuum and colluviums over sedimentary bedrock	shallow to deep	3.5	numerous				
2	uplands	184,121 (6.8%)	low to moderate	Gently rolling to hilly to undulating uplands; rolling, broad valleys	coarse to medium-textured moraine and fluvial deposits over metamorphic or sedimentary bedrock	shallow to deep	4.5	a few to many outcrops, usually with shallow or deep colluvial debris;	patches in depressions and on north-facing slopes	frost polygons on well-drained uplands;	noncalcareous or weakly calcareous,	
3	uplands	12,604 (.5%)	moderate	Low, rounded hills	coarse-particled residiuum and colluvium over metamorphic bedrock	shallow	3.5		numerous snow patches in depressions and on north-facing slopes	frost polygons on some summit positions		
4	uplands	140,789 (5.2%)	moderate	Rolling, well-dissected plateau	coarse textured residiuum and colluvium over flat-lying sedimentary bedrock	shallow	3.5		snow patches in depressions and on north-facing slopes, ice fields and snow fields common at high elevations	frost polygons and frost-boil features in some areas	noncalcareous to weakly calcareous,	some areas rugged
5	plains	121,347 (4.5%)	low to moderate	Gently rolling to rolling to undulating, broad valley and slightly inclined plains	coarse to medium-textured fluvial deposits and moraine over sedimentary bedrock	deep	3.5		snow patches in some sheltered areas and north facing slopes	frost polygons and frost-boil features in some areas	noncalcareous or weakly calcareous,	
6	uplands	37,501 (1.4%)	moderate	Rolling, well-dissected plateau and upland	coarse textured residiuum and colluvium over sedimentary bedrock (limestone, dolomite)	shallow	3.0	outcrops common along valleys			strongly calcareous	some areas rugged
7	uplands	4,100 (0.2%)	low to high	Rolling to undulating inclined uplands	coarse to fine-textured moraine and colluvium over metamorphic bedrock	shallow to deep	4.5	many outcrops				
8	uplands	592,965 (22.0%)	moderate to high	Hilly to rolling, highly dissected plateaux and inclined uplands	variably textured residiuum over metamorphic bedrock; variably textured colluvium over sedimentary and metamorphic bedrock	shallow to deep	3.0		ice fields and snow at high elevations; glaciers in some valleys; snow patches common in narrow depressions and on north-facing slopes	extensive areas of frost polygons		
9	plains & uplands	367,376 (13.6%)	low to high	Gently rolling to rolling plain or rolling to hilly upland	coarse textured moraine or variable-depth colluvium shallow morine, block fields, and outcrops of metamorphic bedrock		4.0		snow patches in depressions and on north-facing slopes	extensive areas of frost polygons	deep to thin weakly calcareous	
10	plains	217,831 (8.1%)	low	Gently rolling plain	coarse-textured mornaine and a few block fields over sedimentary bedrock	deep	2.0		snow patches in sheltered areas and on north-facing slopes;	numerous areas of frost-boil features	strongly calcareous	
11	plains	326,047 (12.1%)	moderate	Hummocky to rolling plain, rippled surfaces with hillcrests oriented north-south, many bouldery surfaces	coarse to medium-textured moraine	deep	5.0					
12	plains	54,853 (2.0%)	low to moderate	Rolling, occasionally hummocky plain	medium to coarse-textured moraine and fluvial deposits over igneous bedrock (granite)	deep	6.7	some bouldery surfaces and outcrops		extensive areas of frost polygons		
13	uplands	219,323 (8.1%)	moderate to high	Hilly to rolling upland	colluvium, shallow moraine, block fields, and outcrops of metamorphic bedrock	variable-depth	4.5	uplands often dissected by deep canyons	snow patches in depressions and north-facing slopes			
14	uplands	147,971 (5.5%)	moderate to high	Hilly to rolling coastal upland	coarse textured moraine and coarse-particled colluvium over metamorphic bedrock	shallow	5.0	many outcrops, raised beaches near the coast	snow patches in some depressions and northern exposures		noncalcareous	block fields common
15	uplands	89,477 (3.3%)	moderate to high	Hilly upland	coarse-textured moraine and coarse-particled colluvium in some areas, metamorphic bedrock, dissected by deep bedrock fissures	shallow to deep	5.0		snow patches in fissures and depressions and on northern exposures			block fields common
16	plains	45,985 (1.7%)	very low to low	Almost level to undulating, gently inclined coastal plain	fine- textured marine sediments and some coarse-textured beach materials	deep	5.0					
17	uplands	54,555 (2.0%)	very low to low	Undulating to almost level upland	coarse-textured marine deposits (raised beached) and moraine over metamorphic bedrock	deep	3.7			numerous areas of frost-boil features		

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]EcoLandClassifications

NOTES:

1. PRODUCTIVITY VALUES: 6.7=HIGHEST; 2=LOWEST.
2. SHADING MEANS NO ENTRY.

0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 3.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
WATER FEATURES IN THE RSA

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ELC Unit	Land Component	Lake Size	Turbidity	Lake Cover (%)	Stream density	Channels	Summer Flow	Other
1	uplands	very small to small to medium	clear	15	low-moderate	poorly developed		
2	uplands	very small to small to medium	clear	10	low-moderate	not entrenched		some braided networks
3	uplands	very small	clear	2	low	not entrenched	very little	
4	uplands	small	clear	1	moderate-high	not entrenched		braided networks in broad valleys
5	plains	very small to large	clear to slightly turbid	30	low-moderate	not entrenched	high	
6	uplands	very small to small	clear to slightly turbid	1	moderate			very broad floodplains common
7	uplands	very small	clear	1	low-moderate	not entrenched		
8	uplands	very small to medium	clear to highly turbid	5	low-moderate	not entrenched to strongly bedrock controlled		
9	plains & uplands	very small to large	clear	20	low-moderate	not entrenched		meanders, rapids and falls along Philips Creek
10	plains	very small to medium	clear to slightly turbid	20	low	not entrenched		
11	plains	very small to large		30	low-moderate			near-surface flow common
12	plains	medium to small, deep	clear	15	low			
13	uplands	small	clear	1	moderate	bedrock controlled		
14	uplands	very small to medium	clear	5	moderate	bedrock controlled		
15	uplands	very small to large		5	low	strongly bedrock controlled		rapids on many streams
16	plains	very small to medium	clear to slightly turbid	5	low	not entrenched		near-surface seepage common
17	uplands	very small to medium	clear	5	low	poorly developed	little	ponds common in depressions

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NOTES:

1. SHADING MEANS NO ENTRY.

0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 3.3

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
PLANT COMMUNITY TYPES IN THE RSA

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Community Type	Land Component	Frequency
sedge-willow-avens-moss	plains, valley & riparian	9
sedge	valley & riparian, other	7
sedge-moss	valley & riparian	5
sedge-willow	plains, uplands, valley & riparian	4
sedge-herb-avens	plains	1
sedge-moss-willow-avens	uplands	1
sedge-willow-herb-moss	valley & riparian	1
sedge-dominated	*ALL*	*28*
herb-avens-moss-lichen	plains, uplands	3
herb-lichen	plains, uplands	3
herb-avens-lichen	valley & riparian, other	2
herb-avens	other	1
herb-avens-lichen-moss	uplands	1
herb-avens-willow	valley & riparian	1
herb-avens-willow-moss	valley & riparian	1
herb-willow	valley & riparian	1
herb-dominated	*ALL*	*13*
avens-herb-lichen	plains, uplands, other	4
avens-sedge	uplands, valley & riparian	2
avens-herbs	uplands	1
avens-herb-sedge	valley & riparian	1
avens-herb-willow	plains	1
avens-willow	valley & riparian	1
avens-willow-herb-moss	valley & riparian	1
avens-dominated	*ALL*	*11*

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0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 3.4

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
PLANT COMMUNITY TYPES FOR ALL LAND COMPONENTS IN THE RSA

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Land Component	Community Type	Frequency
Valley & Riparian	sedge	6
	sedge-moss	5
	sedge-willow-avens-moss	5
	sedge-willow-avens-moss	3
	herb-willow	1
	avens-willow-herb-moss	1
	sedge-willow-herb-moss	1
	avens-sedge	1
	avens-herb-sedge	1
	herb-avens-willow	1
	herb-avens-lichen	1
	avens-willow	1
	sedge-willow	1
	herb-avens-willow-moss	1
Uplands	herb-lichen	2
	avens-herb-lichen	2
	herb-avens-moss-lichen	2
	sedge-willow	1
	avens-herbs	1
	avens-sedge	1
	sedge-moss-willow-avens	1
	herb-avens-lichen-moss	1
Plains	sedge-willow	2
	herb-lichen	1
	avens-herb-lichen	1
	avens-herb-willow	1
	herb-avens-moss-lichen	1
	sedge-herb-avens	1
	sedge-willow-avens-moss	1
Other	avens-herb-lichen	1
	herb-avens	1
	herb-avens-lichen	1
	sedge	1

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0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 3.5

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
VALLEY AND RIPARIAN VEGETATION IN THE RSA

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ELC Unit	Land Component	Site Description	Vegetation Abundance	Vegetation Productivity Value	Vegetation Type 1	Vegetation Type 2	Vegetation Type 3	Vegetation Type 4
1	uplands	poorly drained depressions, lowlands, drainage ways	sparse-discontinuous	5	herb-willow	avens-willow	sedge	sedge-avens-willow moss
2	uplands							
3	uplands	poorly drained depressions; low, gentle slopes	sparse-discontinuous	5	sedge-willow-avens-moss			
4	uplands	poorly drained depressions; low, gentle slopes	sparse-discontinuous	5	avens-willow-herb moss			
5	plains	poorly drained depressions, drainage ways, stream, lake and pond margins	sparse-discontinuous	5	sedge-willow-herb-moss	sedge	sedge-willows-avens-moss	
6	uplands	valley bottoms	sparse-discontinuous	5	sedge-willow-avens-moss			
7	uplands	poorly drained depressions	discontinuous-continuous	7	avens-sedge	sedge-willow		
8	uplands	valley bottoms	sparse-discontinuous	5	avens-herb-sedge			
9	plains & uplands	poorly drained depressions, lower slopes, streams, drainage ways, lake margins	discontinuous	6	sedge	sedge-moss	sedge-avens-willow-moss	
10	plains	sheltered areas, along streams and drainage ways	very sparse-sparse	3	herb-aven-willow			
11	plains	poorly drained depressions	discontinuous-continuous	7	sedge-moss			
12	plains	poorly drained depressions	continuous	8	sedge-moss			
13	uplands	poorly drained depressions, lower slopes, streams, drainage ways, lake margins	discontinuous	6	sedge	sedge-moss	sedge-avens-willow-moss	
14	uplands	poorly drained depressions, lower slopes, streams, drainage ways, lake margins	discontinuous-continuous	7	sedge	sedge-willow-avens-moss		
15	uplands	poorly drained depressions, lower slopes, streams, drainage ways, lake margins	sparse-discontinuous	5	herb-avens-lichen	herb-avens-willow-moss		
16	plains	poorly drained depressions, lower slopes, streams, drainage ways, lake margins	continuous	8	sedge-moss			
17	uplands	poorly drained depressions, lower slopes, streams, drainage ways, lake margins	discontinuous	6	sedge	sedge-willow-avens-moss		

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NOTES:

1. SHADING MEANS NO ENTRY.

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REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 3.6

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
UPLAND VEGETATION IN THE RSA

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ELC Unit	Land Component	Site Description	Vegetation Abundance	Vegetation Productivity Value	Vegetation Type 1	Vegetation Type 2	Vegetation Type 3
1	uplands	rolling to hilly	nearly barren-very sparse-sparse	2	herb-lichen	aven-herbs	
2	uplands	gently rolling to hilly to undulating	discontinuous-continuous	7	sedge-willow	avens-sedge	sedge-moss-willow-avens
3	uplands	low rounded hills	nearly barren-very sparse-sparse	2	avens-herb-lichen		
4	uplands	rolling, well-dissected plateau	nearly barren-very sparse-sparse	2	avens-herb-lichen		
5	plains						
6	uplands	rolling, well-dissected plateau and upland	nearly barren	1			
7	uplands	rolling to undulating inclined uplands	nearly barren-very sparse-sparse	2	herb-lichen		
8	uplands	rolling to hilly plateau and uplands	nearly barren	1			
9	plains & uplands	rolling to hilly	very sparse-sparse	3	herb-avens-moss-lichen		
10	plains						
11	plains						
12	plains						
13	uplands	undescribed	very sparse-sparse	3	herb-avens-moss-lichen		
14	uplands	undescribed	very sparse-sparse	3	herb-avens-lichen-moss		
15	uplands	hilly upland	(see Table 5)				
16	plains						
17	uplands	nearly level to undulating	sparse	4	avens-willow-lichen	herb-willow-lichen	

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NOTES:

1. SHADING MEANS NO ENTRY.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE

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TABLE 3.7

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
PLAINS VEGETATION IN THE RSA

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ELC Unit	Land Component	Site Description	Vegetation Abundance	Vegetation Productivity Value	Vegetation Type 1	Vegetation Type 2	Vegetation Type 3
1	uplands						
2	uplands						
3	uplands						
4	uplands						
5	plains	gently rolling to rolling to undulating, broad valley and slightly inclined plains	nearly barren-very sparse-sparse	2	herb-lichen	avens-herb-lichen	avens-herb-willow
6	uplands						
7	uplands						
8	uplands						
9	plains & uplands	gently rolling to rolling plain	very sparse-sparse	3	herb-avens-moss-lichen		
10	plains	gently rolling plain	nearly barren	1			
11	plains	hummocky to rolling plain/moderately drained mid-slope positions	sparse-discontinuous	5	sedge-willow		
12	plains	hummocky to rolling plain	discontinuous-continuous	7	sedge-herb-avens		
13	uplands						
14	uplands						
15	uplands						
16	plains	nearly level to undulating, gently inclined coastal plain	discontinuous	6	sedge-willow	sedge-willow-avens-moss	
17	uplands						

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.7

NOTES:

1. SHADING MEANS NO ENTRY.

0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
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TABLE 3.8

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
OTHER VEGETATION TYPES IN THE RSA

Print Dec/03/10 11:25:56

ELC Unit	Land Component	Site Description	Vegetation Abundance	Vegetation Productivity Value	Vegetation Type 1	Vegetation Type 2
1	uplands					
2	uplands	well-drained uplands	nearly barren-very sparse-sparse	2	avens-herb-lichen	
3	uplands					
4	uplands					
5	plains					
6	uplands					
7	uplands					
8	uplands	stabilized colluvial slopes	very sparse-sparse	3	herb-avens-lichen	
9	plains & uplands					
10	plains					
11	plains	bouldery hill-crests	very sparse-sparse	3		
12	plains	summit positions	sparse-discontinuous	5	sedge	herb-avens
13	uplands					
14	uplands					
15	uplands					
16	plains	crests of raised beaches	nearly barren	1		
17	uplands	crests of raised beaches	nearly barren	1		

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.1

NOTES:

1. SHADING MEANS NO ENTRY.

0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
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TABLE 3.9

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION
RELATIVE ABUNDANCE OF PLANT SPECIES/GUILDS IN THE VALLEYS AND RIPARIAN AREAS, PLAINS, AND UPLANDS WITHIN THE RSA

Print Nov/23/10 9:19:11

Plant Species/Guild	Valleys and Riparian Areas (mean %; n=29)	Plains (mean %; n=8)	Uplands (mean %; n=13)	F-value (ANOVA)	Probability Value
sedges	48.5	27.8	10.7	6.84	0.002
	only 48.5 and 10.7 are statistically different from each other (p<.051)				
avens	17.5	20.9	27.9	1.02	0.369
	none of these means are significantly different				
herbs	9.6	25.6	30.9	5.18	0.009
	only 9.6 and 30.9 are statistically different from each other (p<.051)				
willows	14.0	14.1	8.2	0.81	0.452
	none of these means are significantly different				
mosses	9.5	3.8	6.2	1.03	0.363
	none of these means are significantly different				
lichens	0.6	7.5	13.4	12.34	0.000
	only 0.6 and 13.4 are statistically different from each other (p<.051)				

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.9

NOTES:

1. DATA FROM THE LAND USE INFORMATION SERIES MAPS (DEPARTMENT OF THE ENVIRONMENT AND INDIAN AND NORTHERN AFFAIRS CANADA 1981).
2. RELATIVE ABUNDANCE RELATES TO VEGETATION COVER NOT ALL GROUND SURFACE COVER.

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TABLE 3.10

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION
CORRELATIONS BETWEEN ORDINATION (DCA) SAMPLE SCORES AND PHYSICAL HABITAT VARIABLES MEASURED IN THE FIELD

Print Nov/23/10 9:19:11

Physical Habitat Variable	DCA Axis 1 Correlation Coefficient (probability level)	DCA Axis 2 Correlation Coefficient (probability level)
Surficial Geology		
Rocks	**-0.235 (0.000)**	**0.190 (0.000)**
Gravel	**-0.115 (0.009)**	**0.364 (0.000)**
Bedrock	**-0.107 (0.015)**	-0.010 (0.812)
Sand	0.032 (0.472)	**0.203 (0.000)**
Water		
Moisture index	**0.591 (0.000)**	**-0.289 (0.000)**
Standing water	**0.393 (0.000)**	-0.080 (0.068)
Flowing water	**0.131 (0.003)**	-0.061 (0.168)
Aspect [2]	**0.114 (0.009)**	**0.259 (0.000)**
Slope	**-0.107 (0.015)**	-0.051 (0.251)
Elevation	0.059 (0.180)	**0.270 (0.000)**

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.9

NOTES:

1. VALUES IN BOLD ARE SIGNIFICANT AT PROBABILITY < .051.
2. USED GIS-GENERATED VALUES FOR SOLAR RADIATION AS A SURROGATE.

0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
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TABLE 3.11

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION
LIST OF PLANT SPECIES FOUND IN FIELD PLOTS THROUGHOUT THE RSA
RANKED BY MEAN ABUNDANCE

Print Nov/23/10 9:26:55

Scientific Name	Common Name	Mean Abundance (% cover)
Dryas integrifolia	mountain avens	9.9623
Cassiope tetragona	Arctic heather	9.0731
Vaccinium uliginosum	blueberry	4.9278
Racomitrium lanuginosum	racomitrium moss	4.6455
Salix arctica	Arctic willow	3.8892
Carex aquatilis	water sedge	3.5039
Salix richardsonii	Richardson's willow	2.8512
	rock lichen	2.5825
Salix reticulata	net-veined willow	2.5256
	biological crust	2.3581
Salix herbacea	least willow	1.8793
Centraria spp.	(lichen)	1.6635
Luzula confusa	northern wood rush	1.2892
Carex rupestris	curly sedge	1.2710
Hierochloe alpina	alpine holygrass	1.2340
Carex membranacea	fragile sedge	1.0670
	sphagnum moss	1.0507
Carex atrofusca	darkbrown sedge	1.0042
Oxyria digyna	mountain sorrel	0.9897
Carex scirpoidea	northern singlespike sedge	0.9589
Saxifraga oppositifolia	purple mountain saxifrage	0.8500
Ledum palustre decumbens	Labrador tea	0.7197
Calamagrostis purpurascens	purple reed bentgrass	0.6756
Oxytropis maydelliana	yellow crazyweed	0.6660
Poa arctica	Arctic bluegrass	0.6569
Pyrola grandiflora	large-flowered wintergreen	0.5640
Luzula nivalis	Arctic wood rush	0.4955
Eriophorum vaginatum	tussock cottongrass	0.4902
Eriophorum angustifolium		0.4673
Cerastium alpinum	mouse-eared chickweed	0.4507
Silene acaulis	moss campion	0.4285
Cladonia spp.		0.4266
Saxifraga tricuspidata	prickly saxifrage	0.4012
Carex nardina		0.3961
	map lichen	0.3591
Draba spp.		0.3547
	cushion moss	0.3342
Polygonum viviparum		0.3264
Epilobium latifolium	dwarf fireweed	0.3173
Carex misandra		0.3099
Thamnolia subuliformis		0.3030
Pedicularis capitata	capitate lousewort	0.2961
Rhododendron lapponicum	Lapland rosebay	0.2200
Saxifraga cernua	nodding saxifrage	0.2120
Stellaria spp.	chickweeds	0.2052
Empetrum nigrum	crowberry	0.1973
Saxifraga hirculus	yellow marsh saxifrage	0.1746
Astragalus alpinus	alpine milkvetch	0.1685
Oxytropis arctica	Arctic crazyweed	0.1591
Cladina spp.		0.1460
Alopecurus alpinus	foxtail	0.1396
Papaver radicatum		0.1281
Saxifraga caespitosa		0.1239
Carex rotundata		0.1202
Pedicularis sudetica	Sudetan lousewort	0.1199
Potentilla nivea	snow cinquefoil	0.1089
Oxytropis arctobia		0.1027
Melandrium apetalum	red bladder campion	0.0966
Eriophorum scheuchzerii		0.0955
Equisetum arvense	common horsetail	0.0929
Diapensia lapponica		0.0864
Leucanthemum integrifolium	chrysanthemum	0.0746
Saxifraga aizoides/aizoon	yellow/white mountain saxifrage	0.0616
Puccinellia spp.	goose grass	0.0606
Potentilla vahliana		0.0586
Saxifraga nivalis	spring saxifrage	0.0582
	antler lichen	0.0556
	fleabane spp.	0.0513

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TABLE 3.11

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION
LIST OF PLANT SPECIES FOUND IN FIELD PLOTS THROUGHOUT THE RSA
RANKED BY MEAN ABUNDANCE

Print Nov/23/10 9:26:55

Scientific Name	Common Name	Mean Abundance (% cover)
Pleuropogon sabinei	semaphore grass	0.0481
	sunburst lichen	0.0424
Arctagrostis latifolia		0.0416
Armeria maritima	thrift	0.0409
Senecio congestus	mastodon flower	0.0364
Ranunculus pygmaeus	pygmy buttercup	0.0362
Tofieldia coccinea	red false asphodel	0.0342
Ranunculus nivalis	snow buttercup	0.0325
Antennaria friesiana		0.0305
Chrysosplenium tetrandrum	golden saxifrage	0.0286
Carex capillaris		0.0278
	jewel lichen	0.0274
Saxifraga foliolosa		0.0264
Potentilla hyparctica		0.0259
Papaver cornwallisense		0.0253
Taraxacum spp.	dandelion	0.0229
Eutrema edwardsii		0.0222
Pedicularis hirsuta	hairy lousewort	0.0207
Pedicularis lanata	woolly lousewort	0.0195
Cystopteris fragilis	fragile fern	0.0178
Tofieldia pusilla	white false asphodel	0.0162
Cochlearia officinalis	scurvey grass	0.0152
Saxifraga hieracifolia		0.0146
Saxifraga rivularis	brooklet saxifrage	0.0143
	rock tripe	0.0104
	pixy lichen	0.0101
Minuartia spp.		0.0093
	rock-cress	0.0084
Melandrium affine	white bladder campion	0.0069
Draba alpina	alpine draba	0.0054
Cardamine bellidifolia	bitter cress	0.0052
Lesquerella arctica	Arctic bladderpod	0.0042
Eriophorum russeolum		0.0034
Carex bigelowii		0.0020
Dryopteris fragrans	fragrant shield fern	0.0019
Epilobium arcticum	Arctic willowherb	0.0017
Pedicularis arctica	Arctic lousewort	0.0013
Braya purpurascens		0.0008
Ranunculus hyperboreus		0.0008
Lycopodium selago	mountain club-moss	0.0008
Saxifraga tenuis		0.0005
Woodsia glabella	woodsia	0.0005
Campanula rotundifolia	round-leafed bluebell	0.0003
Draba glabella		0.0003
Eriophorum callitrix		0.0003
	blood lichen	0.0003
Mertensia maritima	seaside bluebells	0.0002
Ranunculus sulphureus	sulfur buttercup	0.0002

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.11

NOTES:

1. THE 30 MOST ABUNDANT SPECIES ARE SHADED IN GRAY.

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TABLE 3.12

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION
MOST ABUNDANT PLANT SPECIES AND SELECTED PLANT GUILDS THROUGHOUT THE RSA AND THEIR STATISTICAL RELATIONSHIP WITH SURFICIAL GEOLOGY

Print Nov/23/10 9:31:31

Plant Species/Guilds		ANOVA F-value (probability level)	Surficial Geology Groupings based on Differences in Mean Abundance of Plant Species/Guilds [1,2]
Scientific Name	**Common Name**		
Dryas integrifolia	**mountain avens**	**1.84 (0.059)**	TB vs R&AP
Cassiope tetragona	Arctic heather	1.64 (0.101)	TB vs GH
Vaccinium uliginosum	**blueberry**	**4.08 (0.000)**	TB&CA vs TV&R; R vs all but TV&AP
Racomitrium lanuginosum	racomitrium moss	1.59 (0.113)	TB vs GH
Salix arctica	Arctic willow	1.43 (0.173)	TM vs CA
Carex aquatilis	water sedge	1.40 (0.183)	TV vs L
Salix richardsonii	Richardson's willow	1.58 (0.118)	no differences
Salix reticulata	net-veined willow	1.37 (0.200)	no differences
Salix herbacea	least willow	0.83 (0.587)	no differences
Centraria spp.	(lichen)	0.83 (0.585)	no differences
Luzula confusa	northern wood rush	**1.78 (0.069)**	no differences
Carex rupestris	curly sedge	1.47 (0.154)	TB vs GH
Hierochloe alpina	alpine holygrass	1.35 (0.209)	no differences
Carex membranacea	fragile sedge	1.38 (0.196)	no differences
Sphagnum spp.	sphagnum moss	1.14 (0.331)	TV vs L
Carex atrofusca	**darkbrown sedge**	**1.91 (0.048)**	GT&R vs TB
Oxyria digyna	**mountain sorrel**	**1.68 (0.091)**	CA vs TV
Carex scirpoidea	**northern singlespike sedge**	**1.70 (0.086)**	TB,TV,GT,R,GH vs M
Saxifraga oppositifolia	**purple mountain saxifrage**	**3.01 (0.002)**	GT vs TB&M; M vs TV,GT,R,AP,GH
Ledum palustre	**Labrador tea**	**4.69 (0.000)**	M vs all others; R vs GH
Calamagrostis purpurascens	purple reedgrass	1.34 (0.213)	TM vs TV
Oxytropis maydelliana	yellow crazyweed	0.78 (0.638)	no differences
Poa arctica	Arctic bluegrass	1.20 (0.291)	no differences
Pyrola grandiflora	large-flowered wintergreen	0.94 (0.490)	no differences
Luzula nivalis	**Arctic wood rush**	**2.67 (0.005)**	TM&GT vs R; L vs TB,TM,TV,GT
Eriophorum vaginatum	tussock cottongrass	0.73 (0.678)	no differences
Guilds			
	cotton grasses and rushes	**2.00 (0.038)**	TV vs R,GH
	grasses and sedges	**1.81 (0.063)**	TM vs CA,TV,R
	herbs	1.10 (0.363)	no differences
	lichens, foliose & fruticose	**1.30 (0.231)**	GT vs TM
	mosses	**3.22 (0.001)**	TB vs GT,GH,L; L vs M,TM,CA,TV; R vs GH
Saxifrage spp.		0.45 (0.909)	no differences
	willows	**3.00 (0.002)**	TV vs R,GH; GT vs GH

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.12

NOTES:

1. SURFICIAL GEOLOGY TYPES INCLUDE: TB-TILL BLANKET, M-MARINE SEDIMENTS, TM-END MORAINE, CA-TALUS, TV-TILL VENEER, GT-PROGLACIAL OUTWASH, R-BEDROCK, AP-ALLUVIAL DEPOSITS, GH-ICE CONTACT STRATIFIED DRIFT, L-GLACIAL LAUCUSTRINE SEDIMENTS.

2. ALL SURFICIAL GEOLOGY TYPES NOT LISTED HAVE MEANS THAT ARE NOT SIGNIFICANTLY DIFFERENT FROM THE GROUPS LISTED.

3. SPECIES/GUILDS IN **BOLD** ARE STATISTICALLY SIGNIFICANT AT PROBABILITY LEVEL 0.100 OR LESS.

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TABLE 3.13

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION
RELATIONSHIPS BETWEEN THE 14 PREDICTOR PLANT SPECIES/GUILDS AND
HABITAT CONDITIONS OTHER THAN SURFICIAL GEOLOGY

Print Nov/23/10 9:32:45

Carex atrofusca **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	1.03	0.77	1.14	1.08	na	0.821
Solar Radiation	0.00	0.38	1.15	1.57	0.44	0.165
Elevation	0.76	1.15	1.53	0.75	na	0.492
Slope	1.07	1.02	0.13	0.27	na	0.451
	South	West	Flat	East	North	na
Aspect	1.14	0.79	1.21	0.69	0.01	0.589

Carex scirpoidia **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	1.63	0.60	0.83	0.55	na	0.059
Solar Radiation	0.00	0.80	1.06	0.97	0.85	0.762
Elevation	1.09	1.00	0.75	0.00	na	0.633
Slope	1.01	1.20	0.41	0.47	na	0.729
	South	West	Flat	East	North	na
Aspect	1.35	0.80	1.02	0.18	0.44	0.525

Cotton Grasses & Rushes **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	3.60	2.96	2.61	3.47	na	0.694
Solar Radiation	1.80	6.75	2.50	2.79	4.25	0.008
Elevation	3.34	2.43	1.48	7.53	na	0.009
Slope	2.99	3.06	3.41	2.14	na	0.955
	South	West	Flat	East	North	na
Aspect	1.76	3.89	2.95	4.26	2.99	0.278

Dryas integrifolia **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	9.91	9.74	11.63	9.73	na	0.542
Solar Radiation	5.21	7.08	10.26	12.22	8.48	0.061
Elevation	10.33	10.44	10.63	1.00	na	0.014
Slope	9.93	11.20	10.25	6.53	na	0.620
	South	West	Flat	East	North	na
Aspect	13.44	7.53	9.57	10.87	7.78	0.019

Grasses & Sedges (mean %cover)

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	14.13	13.18	14.84	14.26	na	0.878
Solar Radiation	9.79	15.14	13.89	15.02	9.94	0.415
Elevation	14.63	14.37	8.29	4.66	na	0.036
Slope	14.19	12.83	11.13	11.35	na	0.720
	South	West	Flat	East	North	na
Aspect	14.73	13.51	14.03	9.72	10.07	0.573

Ledum palustris **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	0.64	0.98	0.13	0.83	na	0.059
Solar Radiation	2.58	2.81	0.33	0.56	0.00	0.000
Elevation	1.40	0.06	0.00	0.00	na	0.000
Slope	0.60	0.68	2.38	0.00	na	0.016
	South	West	Flat	East	North	na
Aspect	0.35	0.80	0.36	2.28	1.67	0.002

Lichen (foliose and fruiticose) (mean %cover)

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	4.27	3.88	3.85	4.00	na	0.959
Solar Radiation	2.42	4.23	4.60	2.67	2.53	0.054
Elevation	4.02	4.26	2.16	2.57	na	0.365
Slope	4.48	1.92	2.30	2.93	na	0.019
	South	West	Flat	East	North	na
Aspect	4.17	3.15	4.78	3.82	4.14	0.648

Luzula confusa **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	1.74	0.88	1.04	1.76	na	0.256
Solar Radiation	1.13	2.51	0.95	1.59	2.08	0.131
Elevation	1.63	0.87	0.67	2.79	na	0.062
Slope	1.31	0.65	2.66	0.93	na	0.168
	South	West	Flat	East	North	na
Aspect	1.04	1.62	1.18	1.55	1.93	0.815

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TABLE 3.13

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION
RELATIONSHIPS BETWEEN THE 14 PREDICTOR PLANT SPECIES/GUILDS AND HABITAT CONDITIONS OTHER THAN SURFICIAL GEOLOGY

Print Nov/23/10 9:32:45

Luzula nivalis **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	0.61	0.56	0.44	0.17	na	0.667
Solar Radiation	0.38	0.13	0.39	0.25	1.78	0.000
Elevation	0.15	0.55	0.80	3.87	na	0.000
Slope	0.49	0.50	0.22	1.21	na	0.448
	South	West	Flat	East	North	na
Aspect	0.26	0.46	0.41	1.50	0.67	0.011

Moss (mean %cover)

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	14.62	10.53	12.18	17.04	na	0.098
Solar Radiation	11.77	20.06	13.50	9.40	11.10	0.039
Elevation	13.58	12.82	11.73	7.83	na	0.552
Slope	13.41	10.99	10.73	11.97	na	0.651
	South	West	Flat	East	North	na
Aspect	11.75	13.10	13.50	11.98	15.03	0.915

Oxyria digyna **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	1.72	0.41	1.05	0.61	na	0.029
Solar Radiation	0.58	0.42	0.82	1.02	3.30	0.002
Elevation	0.61	1.24	1.23	2.98	na	0.035
Slope	0.77	2.22	1.13	1.80	na	0.030
	South	West	Flat	East	North	na
Aspect	1.80	0.78	0.93	1.34	0.12	0.315

Saxifraga oppositifolia **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	0.86	0.78	0.77	1.40	na	0.456
Solar Radiation	0.42	0.10	0.98	0.44	1.69	0.001
Elevation	0.77	0.62	2.22	2.91	na	0.000
Slope	0.90	0.70	0.72	0.57	na	0.788
	South	West	Flat	East	North	na
Aspect	0.73	0.64	0.93	1.43	0.59	0.298

Vaccinium uliginosum **(mean %cover)**

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	2.95	8.94	3.44	4.33	na	0.000
Solar Radiation	15.83	14.68	3.29	4.25	3.24	0.000
Elevation	9.19	1.67	0.00	0.00	na	0.000
Slope	3.86	8.15	16.31	3.00	na	0.000
	South	West	Flat	East	North	na
Aspect	5.22	5.15	3.90	6.15	14.39	0.005

Willow (mean %cover)

	Class 1	Class 2	Class 3	Class 4	Class 5	ANOVA F-value
	low		medium		high	probability[1]
Moisture Index	11.63	8.94	11.91	11.87	na	0.292
Solar Radiation	4.55	19.52	10.84	10.19	10.30	0.003
Elevation	12.82	10.12	7.86	1.84	na	0.008
Slope	10.81	11.03	12.47	15.30	na	0.715
	South	West	Flat	East	North	na
Aspect	9.55	12.96	11.14	8.37	13.22	0.453

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.13

NOTES:

1. ONLY PROBABILITY VALUES <.101 ARE CONSIDERED SIGNIFICANT AND HIGHLIGHTED IN BLUE.

0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

Knight Piésold
CONSULTING

TABLE 3.14

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
QUANTITATIVE ECOLOGICAL LAND CLASSIFICATION
PAIRED T-TEST RESULTS, CORRELATION COEFFICIENTS, AND ACCURACY FOR PREDICTED ABUNDANCE FOR EACH PLANT SPECIES/GUILD USED IN THE GIS MODEL

Print Dec/03/10 11:25:56

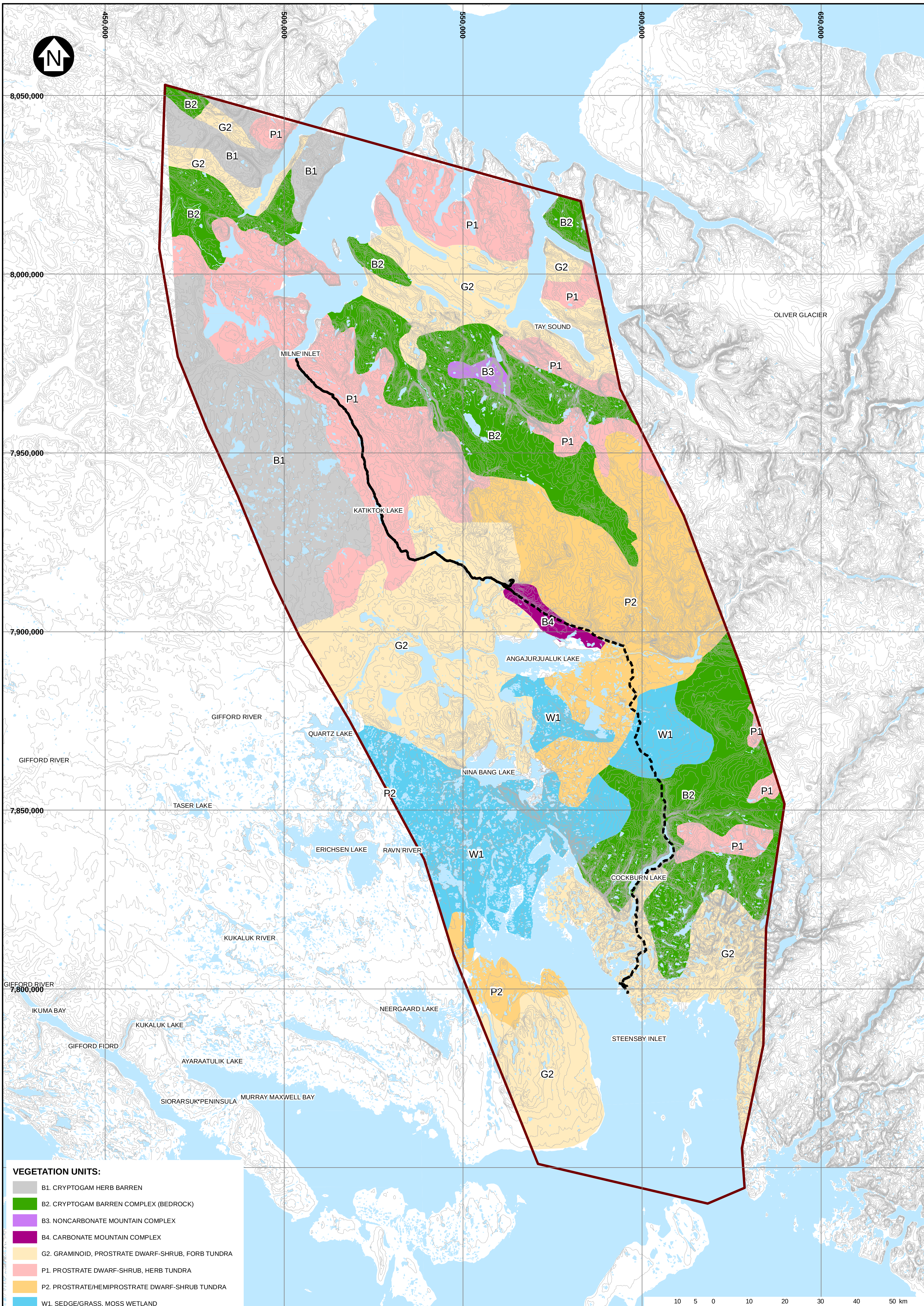
Species/Guild	Abundance (mean %cover)		T-value (probability)[1]	Correlation Coefficient (probability)	Mean Absolute Difference between Observed and Predicted Abundance	Accuracy of Predicted Abundance (% of observed range)
	Observed (field plots)	Predicted (GIS- generated)				
Carex atrofusca	0.99	0.98	0.10 (0.917)	0.170 (0.000)	1.6	5.4
Carex scirpoidia	0.99	0.99	-0.01 (0.992)	0.155 (0.000)	1.6	2.7
Cotton Grasses & Rushes	2.99	2.99	0.00 (0.999)	0.259 (0.000)	3.8	6.2
Dryas integrifolia	10.10	10.10	-0.00 (0.998)	0.247 (0.000)	9.2	12.3
Grasses & Sedges	13.95	13.98	-0.03 (0.976)	0.193 (0.000)	13.6	14.6
Ledum palustris	0.70	0.70	0.00 (1.000)	0.267 (0.000)	1.2	3.6
Lichen (foliose and fruiticose)	4.00	3.59	1.28 (0.200)	0.088 (0.037)	4.9	6.8
Luzula confusa	1.30	1.30	-0.01 (0.994)	0.155 (0.000)	2.0	4.4
Luzula nivalis	0.48	0.48	0.00 (0.999)	0.475 (0.000)	0.7	3.4
Moss	13.10	13.08	0.03 (0.979)	0.250 (0.000)	12.9	12.9
Oxyria digyna	0.99	0.84	0.88 (0.378)	0.172 (0.000)	1.5	2.9
Saxifraga oppositifolia	0.82	0.82	0.01 (0.995)	0.256 (0.000)	1.1	5.5
Vaccinium uliginosum	5.10	5.10	0.00 (1.000)	0.335 (0.000)	7.1	8.9
Willow	11.14	11.13	0.01 (0.989)	0.083 (0.050)	11.5	11.5

I:\1\02\00181\25\A\Report\Report 5, Rev. 0 - Ecological Land Classification\Tables\[Tables.xls]Table 3.1

NOTES:

1. T-VALUES GENERATED FROM RESULTS OF THE PAIRED T-TEST.

0	22NOV'10	ISSUED WITH REPORT NB102-181/25-5	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



LEGEND:

- STUDY AREA
- MILNE INLET TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- CONTOUR
- WATER/STREAM/DRAINAGE
- WATER

NOTES:

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2. CO-ORDINATE GRID IS IN METRES. DATUM: NAD83 PROJECTION: UTM ZONE 17
3. CONTOUR INTERVAL IS 20 METRES.
4. VEGETATION MAP: © ALASKA GEOBOTANY CENTER. ALL RIGHTS RESERVED.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	ASM	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

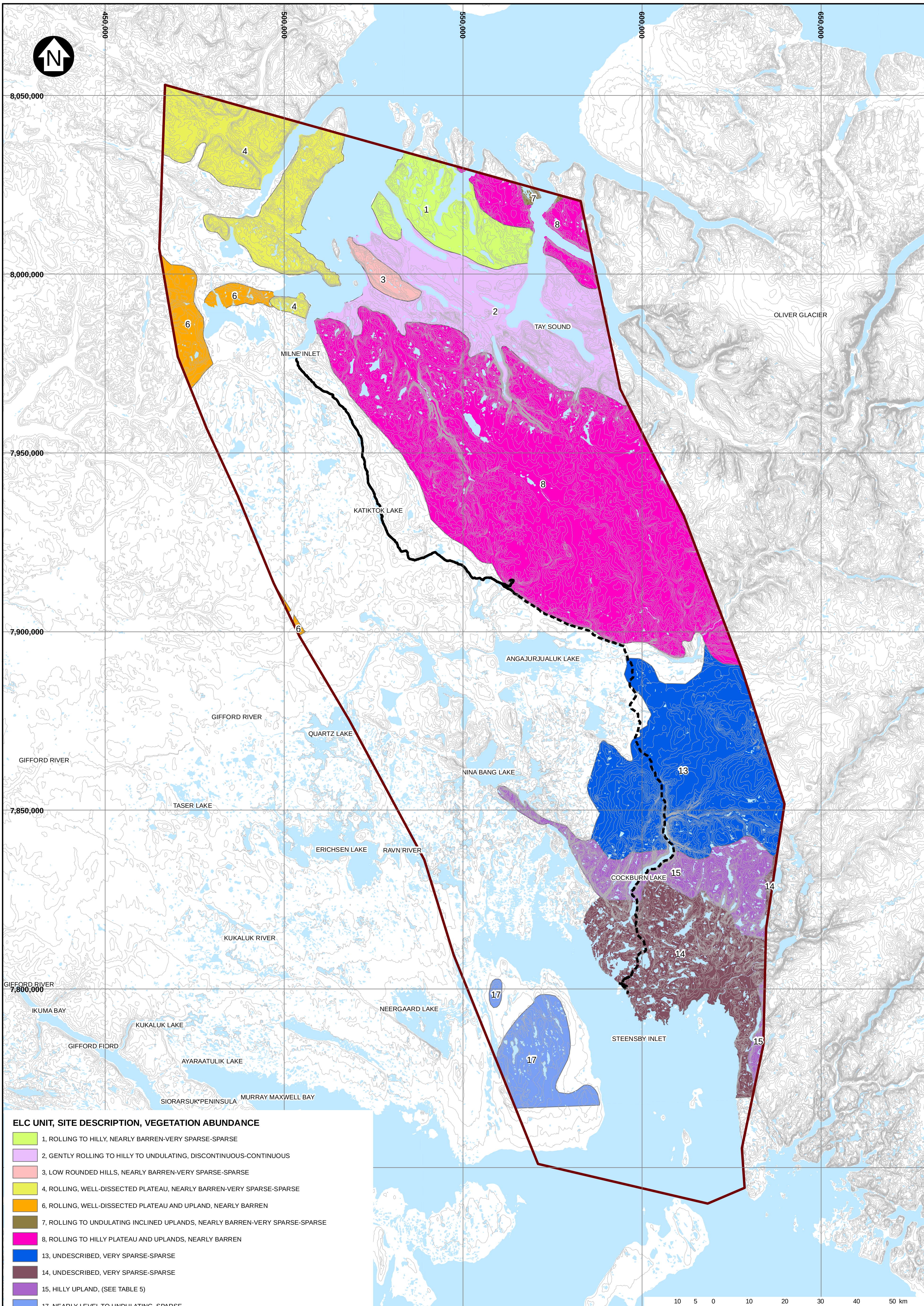
REGIONAL STUDY AREA: BOUNDARIES AND VEGETATION ZONES

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/25	5

FIGURE 2.1 REV 0

SAVED: I:\102\00181\25\A\GIS\ArcView\figures\B110_r0.mxd; Nov 23, 2010 9:44:45 AM amoore



LEGEND:

- STUDY AREA
- MILNE INLET TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- CONTOUR
- WATER/STREAM/DRAINAGE
- WATER

NOTES:

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3. CONTOUR INTERVAL IS 20 METRES.
4. VEGETATION MAP: © ALASKA GEOBOTANY CENTER. ALL RIGHTS RESERVED.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

UPLANDS IN THE RSA AS DEFINED BY THE DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION

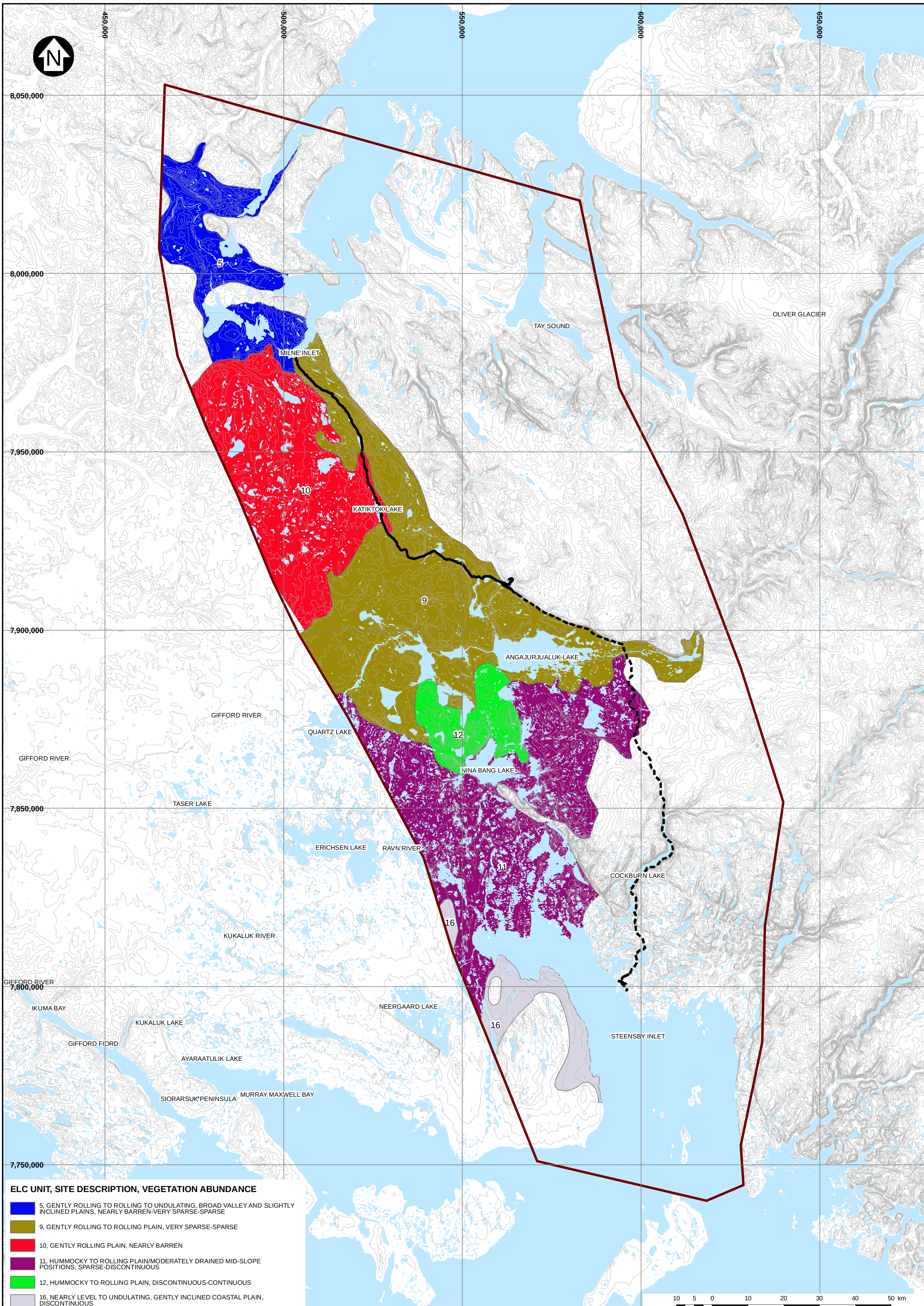
Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/25	5

FIGURE 3.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	ASM	RAC	KDE

SAVED: I:\102\00181\25\A\GIS\ArcView\figures\B111_r0.mxd; Nov 23, 2010 9:47:13 AM amoore



LEGEND:

- STUDY AREA
- MILNE INLET TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- CONTOUR
- WATER/STREAM/DRAINAGE
- WATER

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

PLAINS IN THE RSA AS DEFINED BY THE DESCRIPTIVE ECOLOGICAL LAND CLASSIFICATION

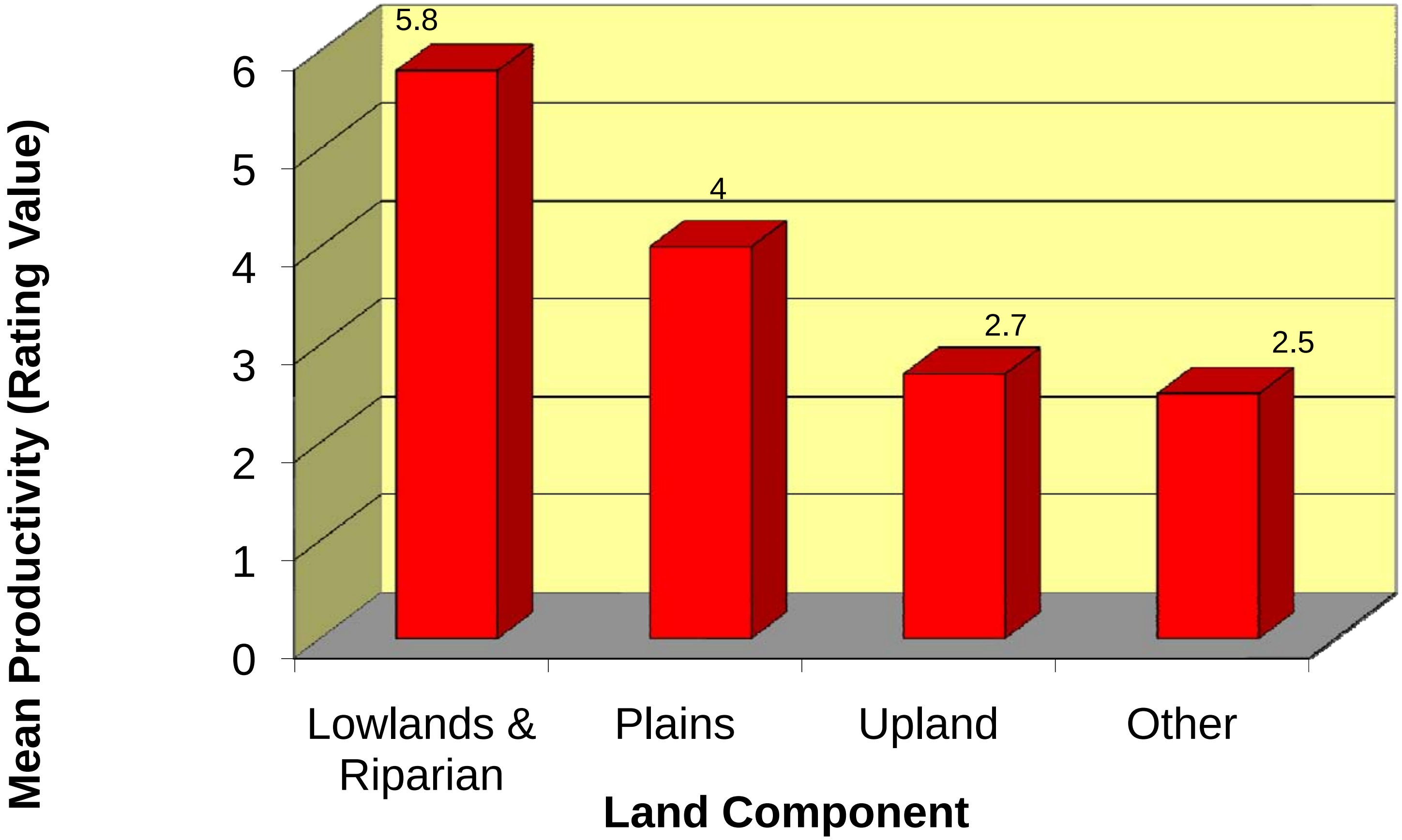
Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/25	5

FIGURE 3.2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	ASM	RAC	KDE

SAVED: I:\102\00181\25\A\GIS\ArcView\figures\B112_r0.mxd; Nov 23, 2010 9:48:44 AM amoore



BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

PRODUCTIVITY OF THE MAJOR LAND COMPONENTS IN THE RSA

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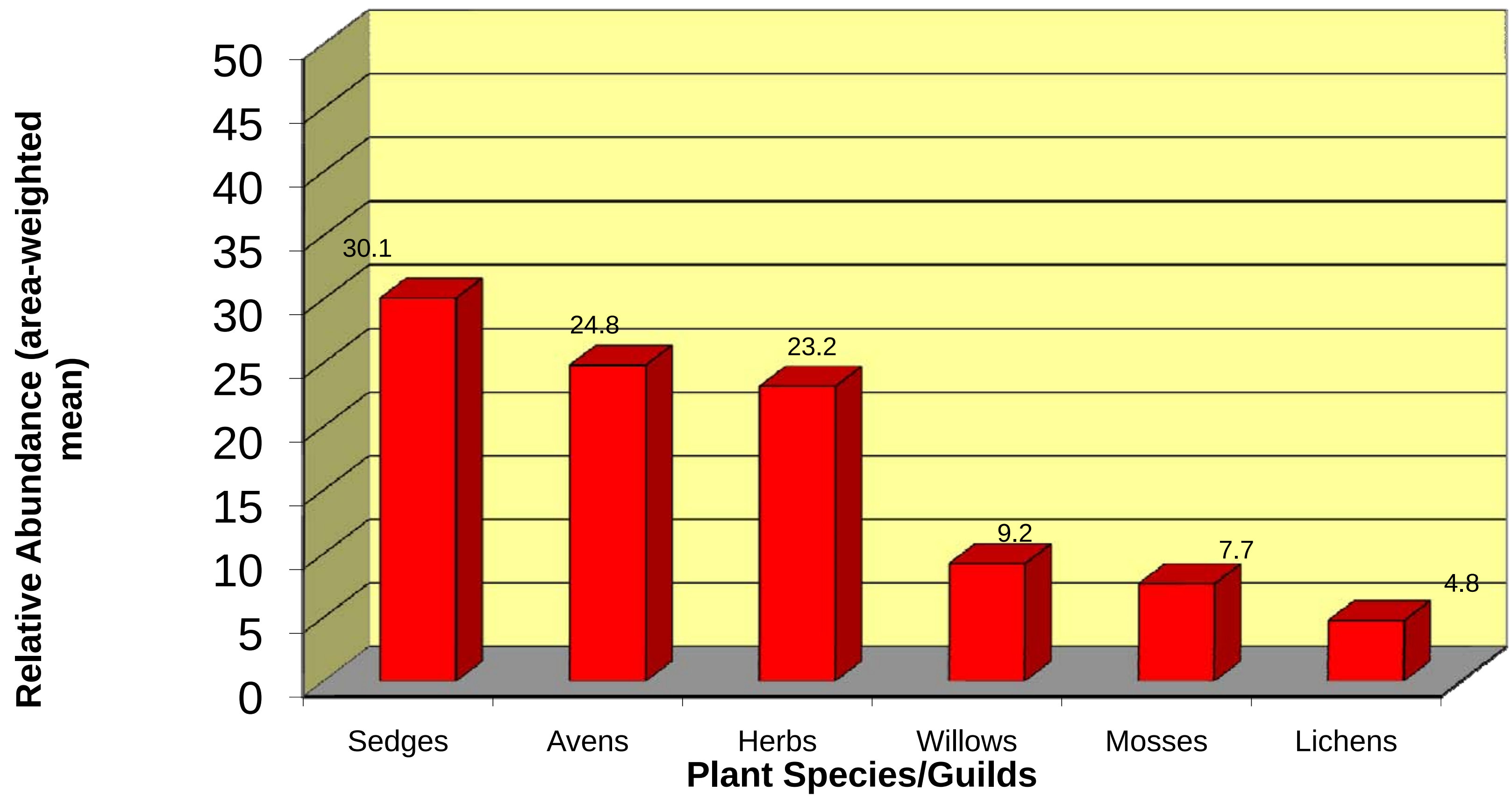
P/A NO.	REF. NO.
NB102-181/25	5

FIGURE 3.3 REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PQ	RAC	KDE



0	22NOV'10	ISSUED WITH REPORT	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

RELATIVE ABUNDANCE OF PLANT SPECIES/GUILDS THROUGHOUT THE ENTIRE RSA

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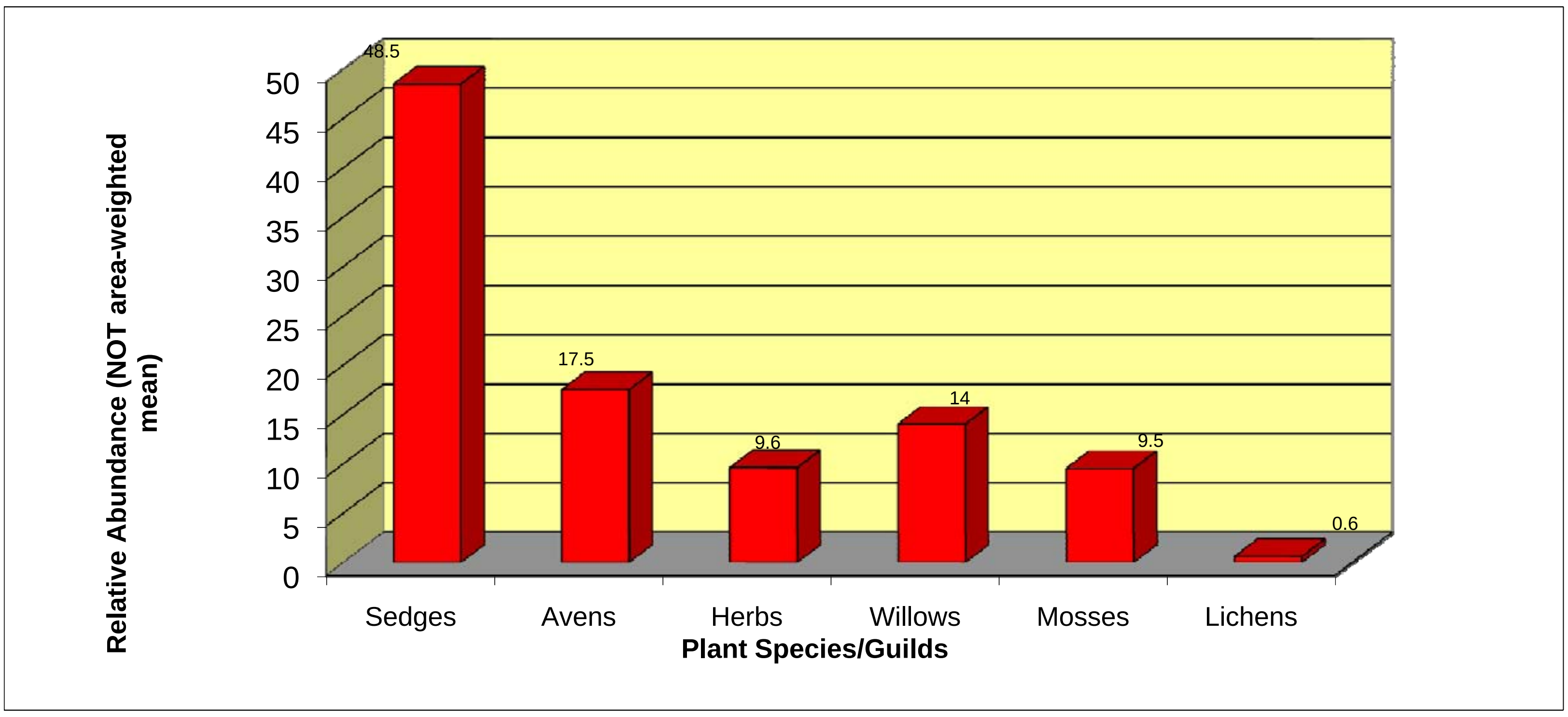
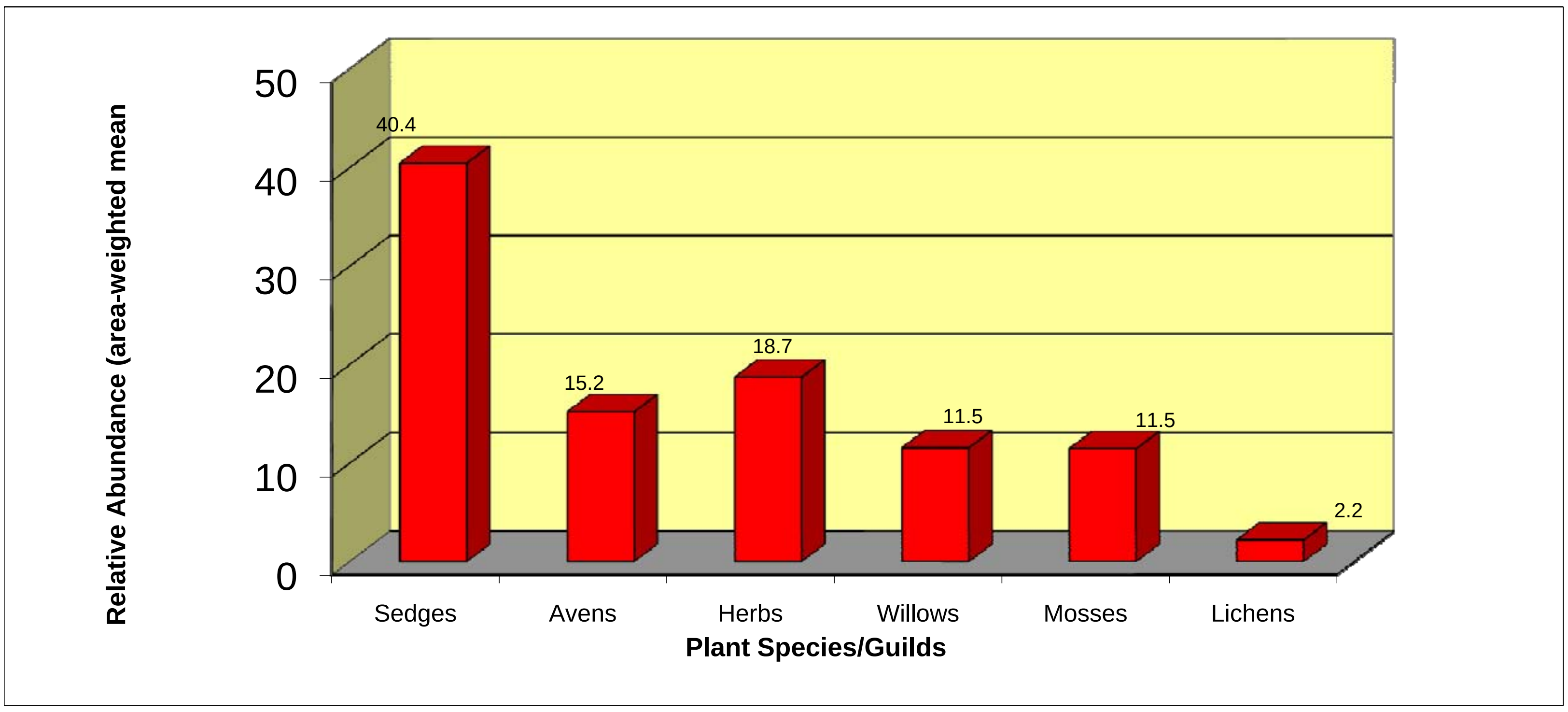
P/A NO. NB102-181/25

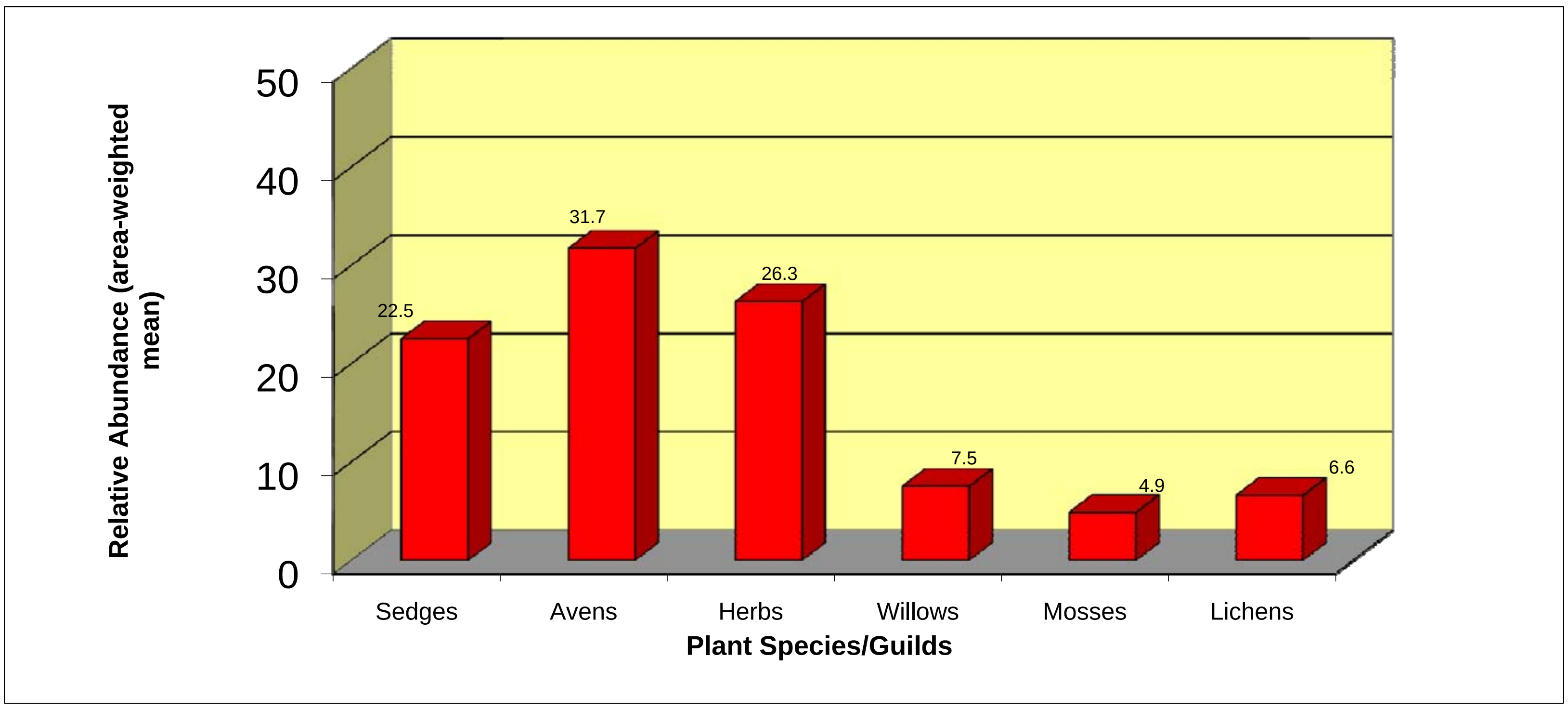
REF. NO. 5

FIGURE 3.4

REV 0







BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

RELATIVE ABUNDANCE OF PLANT SPECIES/GUILDS IN VALLEYS AND RIPARIAN AREAS, PLAINS, AND UPLANDS

Knight Piésold CONSULTING

P/A NO.	REF. NO.
NB102-181/25	5

FIGURE 3.5 REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
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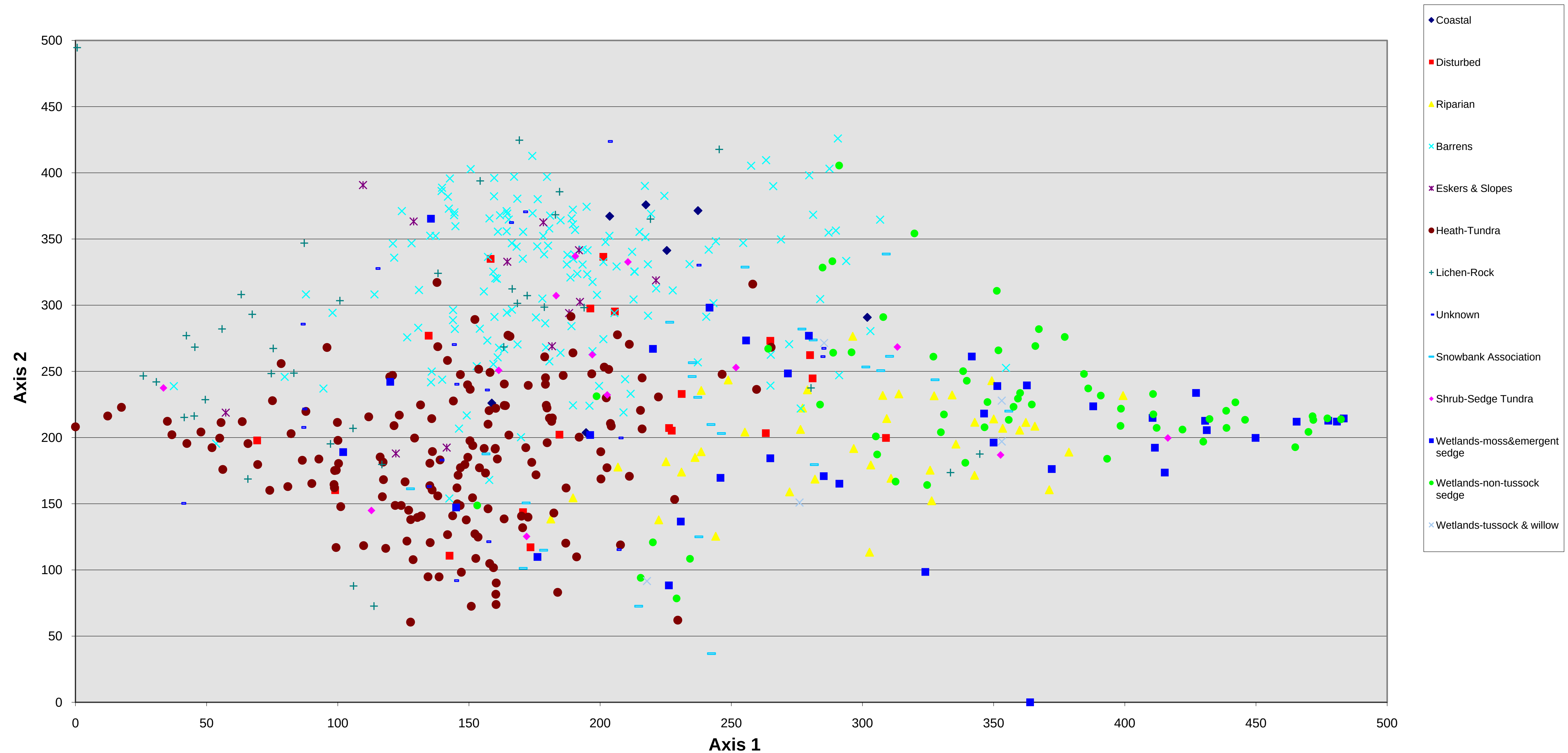


0	22NOV'10	ISSUED WITH REPORT	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

ORDINATION (DCA) OF THE 594 VEGETATION FIELD PLOTS THROUGHOUT THE ENTIRE RSA CLASSIFIED BY FIELD-BASED HABITAT TYPE

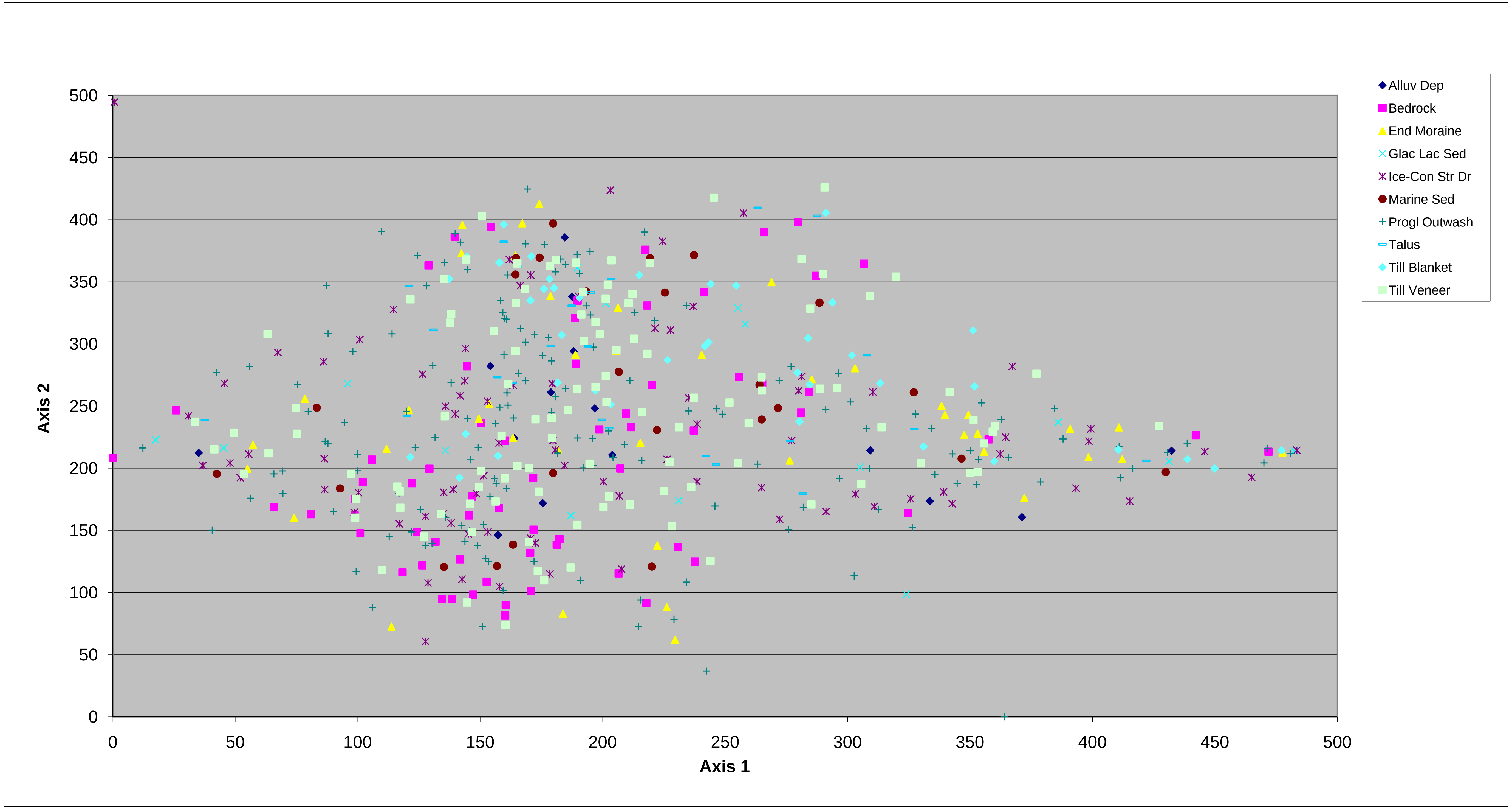
Knight Piésold CONSULTING

P/A NO. NB102-181/25

REF. NO. 5

FIGURE 3.6

REV 0



0	22NOV'10	ISSUED WITH REPORT	PQ	RAC	KDE
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

ORDINATION (DCA) OF THE 594 VEGETATION FIELD PLOTS THROUGHOUT THE ENTIRE RSA CLASSIFIED BY SURFICIAL GEOLOGY TYPE

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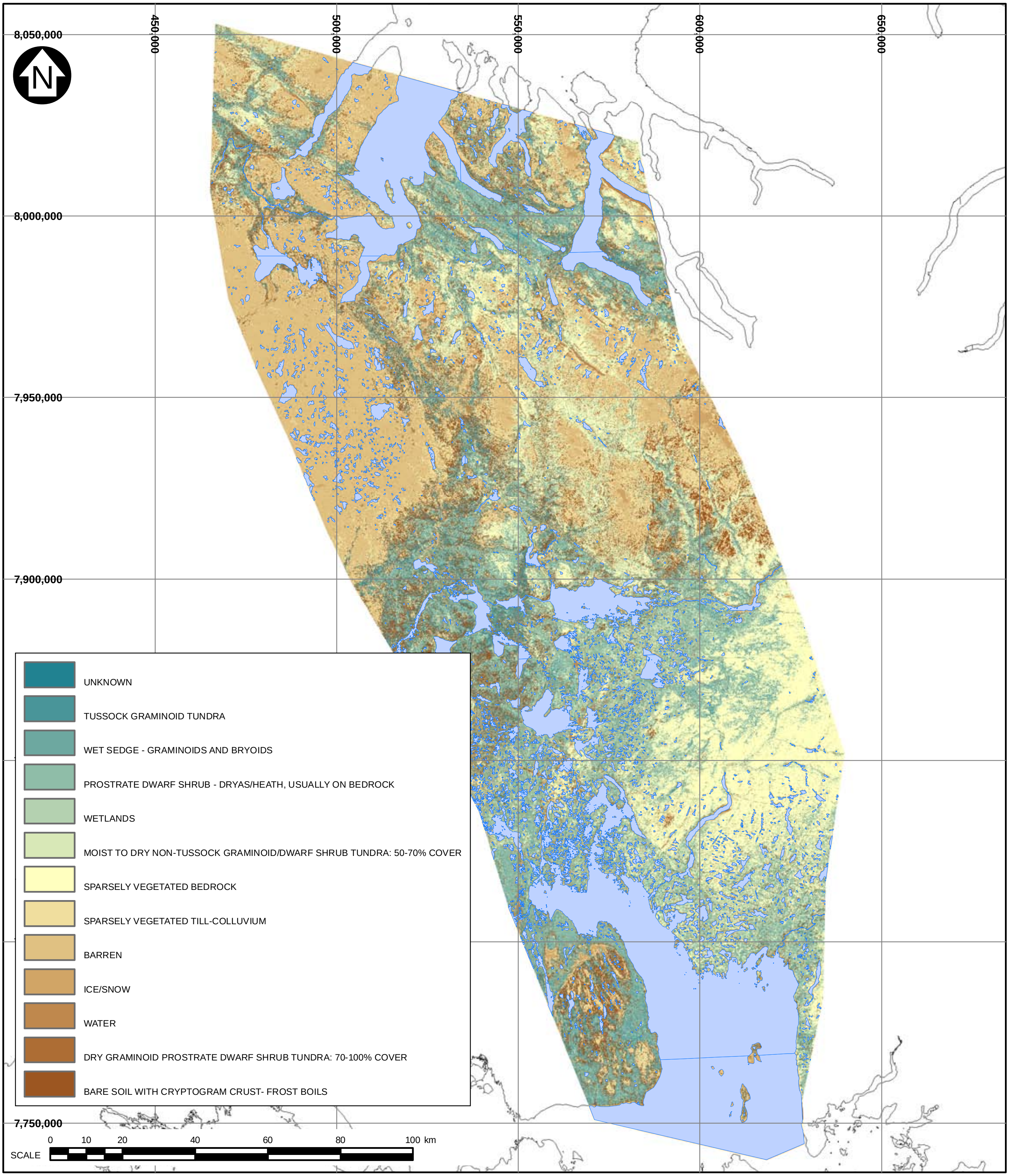
P/A NO. NB102-181/25 | REF. NO. 5

FIGURE 3.7 | REV 0



SAVED: C:\MaryRiverELC\VegetationCategories.mxd

LEGEND:

- WATER
- LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES. DATUM: NAD83 PROJECTION: UTM ZONE #17

.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MAP OF PLANT COMMUNITIES/ HABITAT TYPES IN THE RSA

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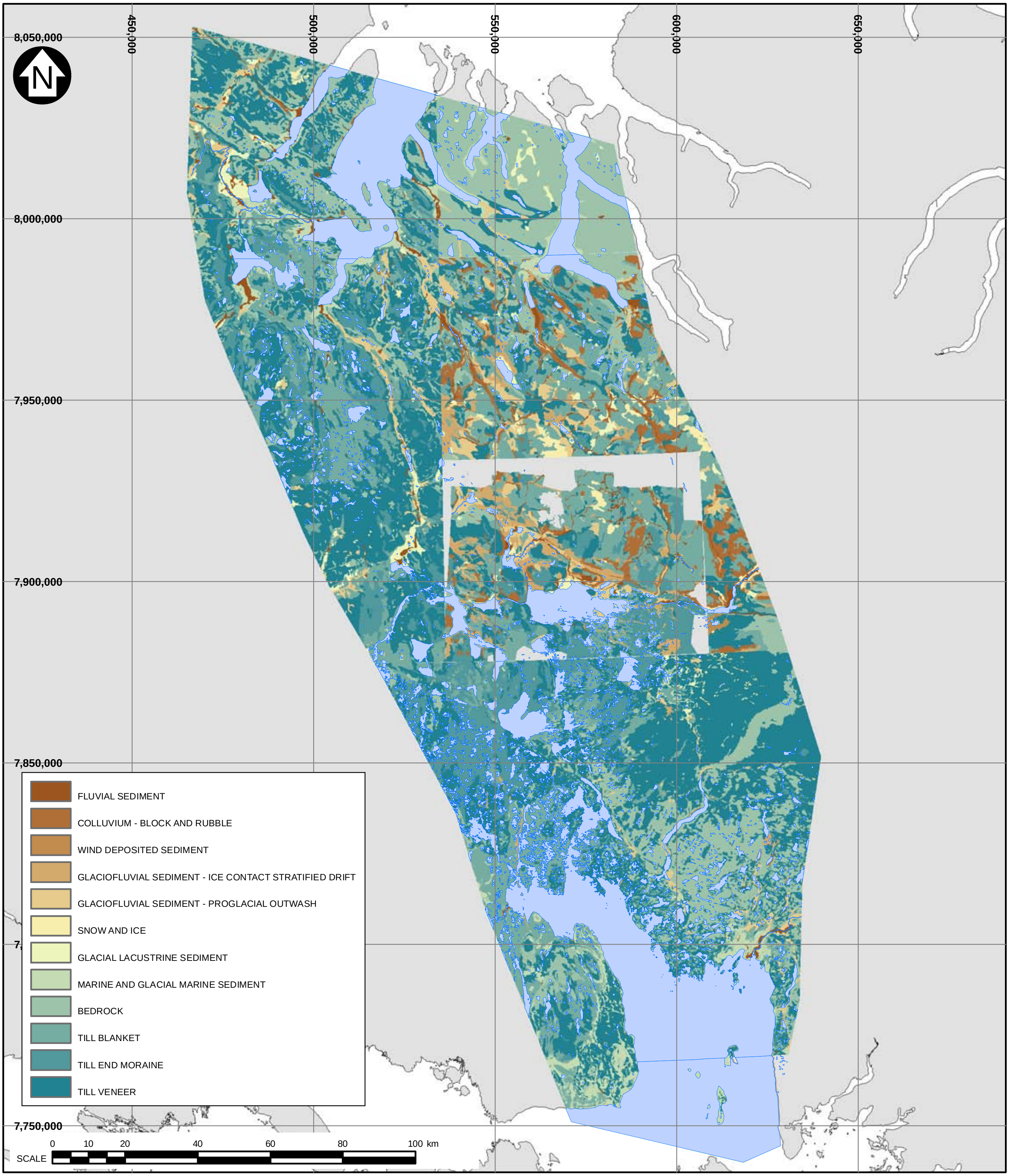
LGL LIMITED environmental research associates

P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.8

REV 0



LEGEND:

WATER

LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES. DATUM: NAD83 PROJECTION: UTM ZONE #17

.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MAP OF SURFICIAL GEOLOGY IN THE RSA

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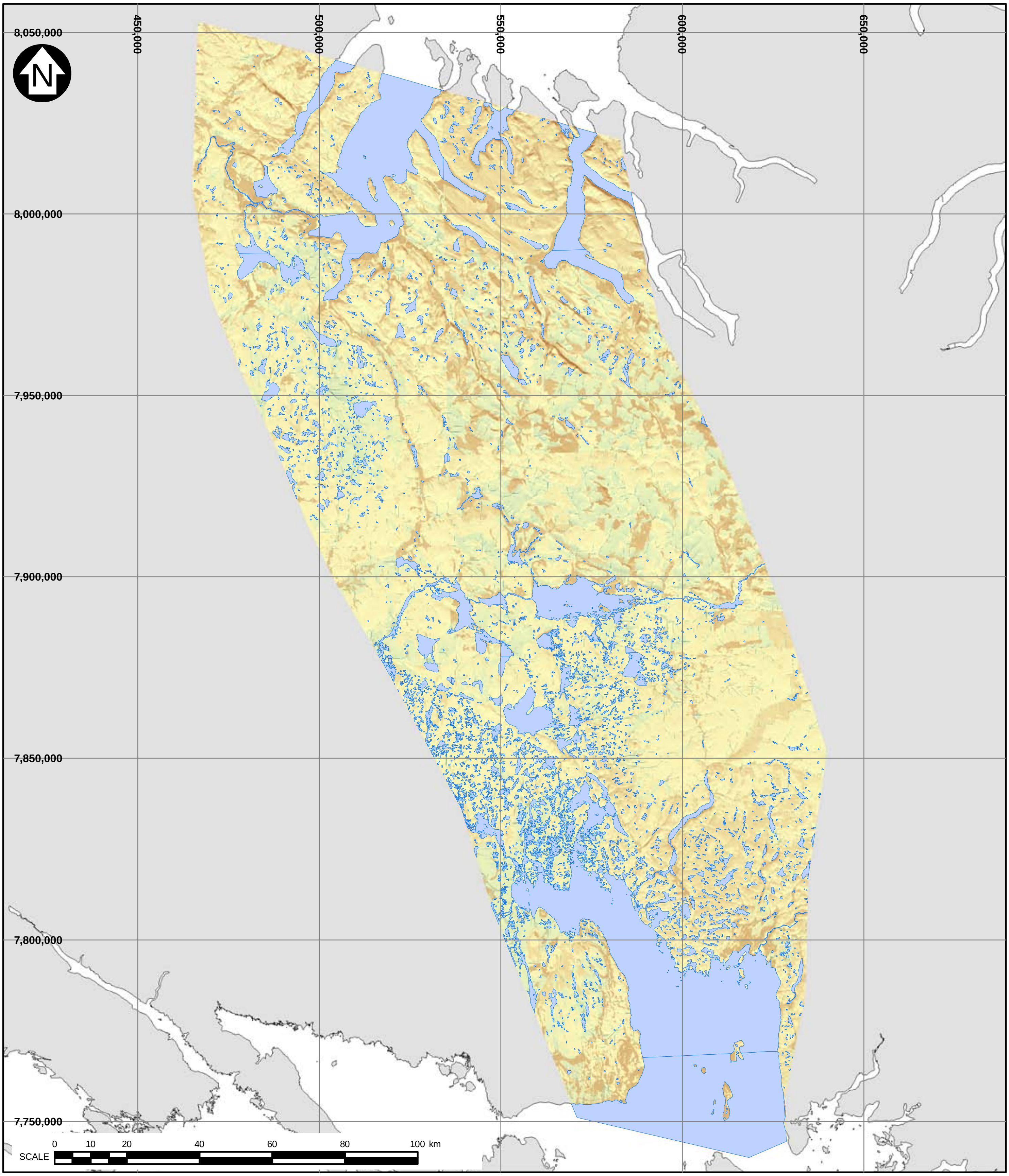
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.9

REV 0

SAVED: C:\MaryRiverELC\SurfaceGeology.mxd



LEGEND:

Value

HIGH : 90.990486

LOW : 8.015954

WATER

LAND

NOTES:

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   DATUM: NAD83
   PROJECTION: UTM ZONE #17

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MAP OF THE MOISTURE INDEX IN THE RSA

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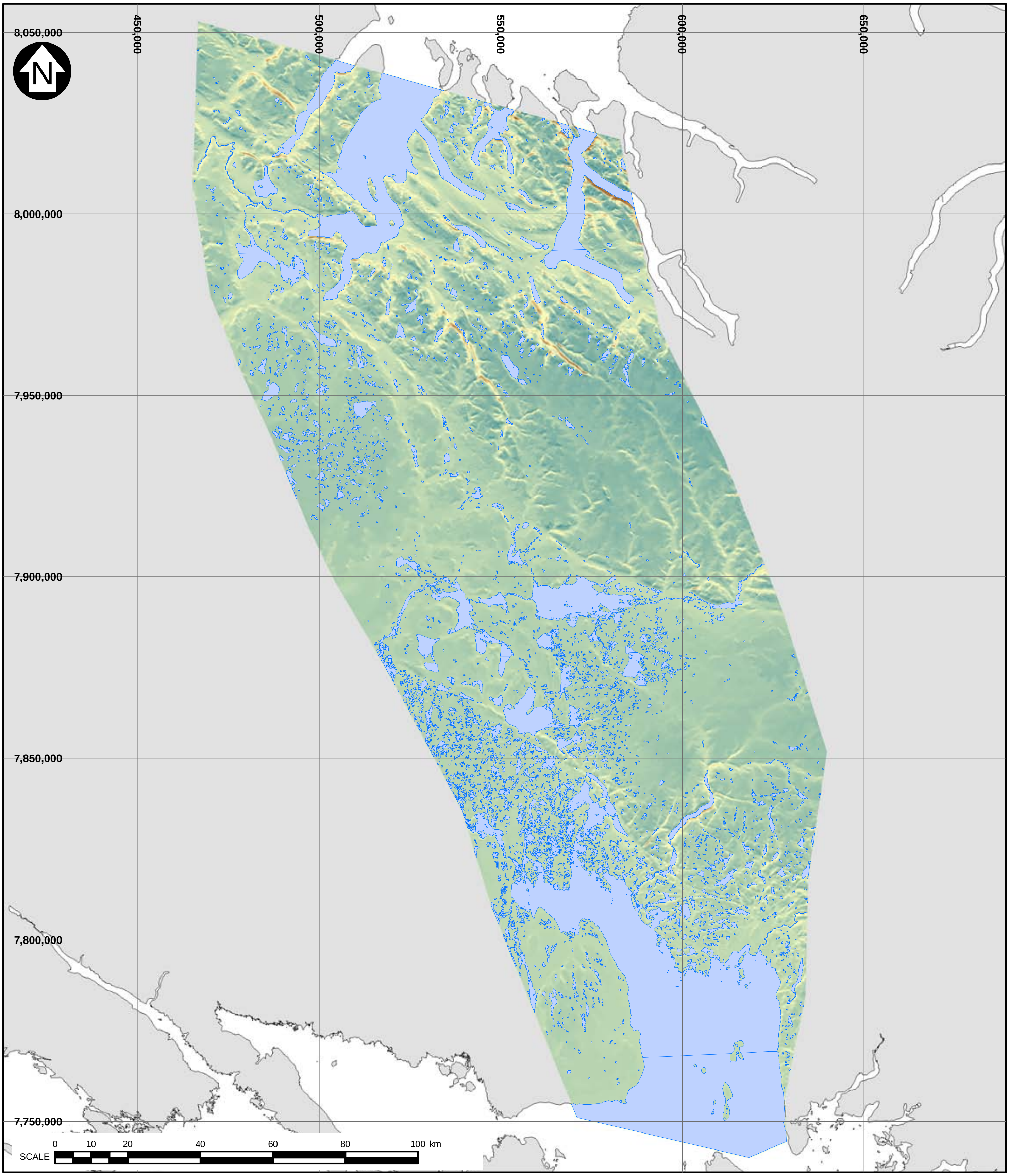
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.10

REV 0

SAVED: C:\MaryRiverELC\Moisture.mxd



LEGEND:

Value

HIGH : 276672.437500

LOW : 86117.929688

WATER

LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES.
   DATUM: NAD83
   PROJECTION: UTM ZONE #17

.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MAP OF SOLAR RADIATION IN THE RSA

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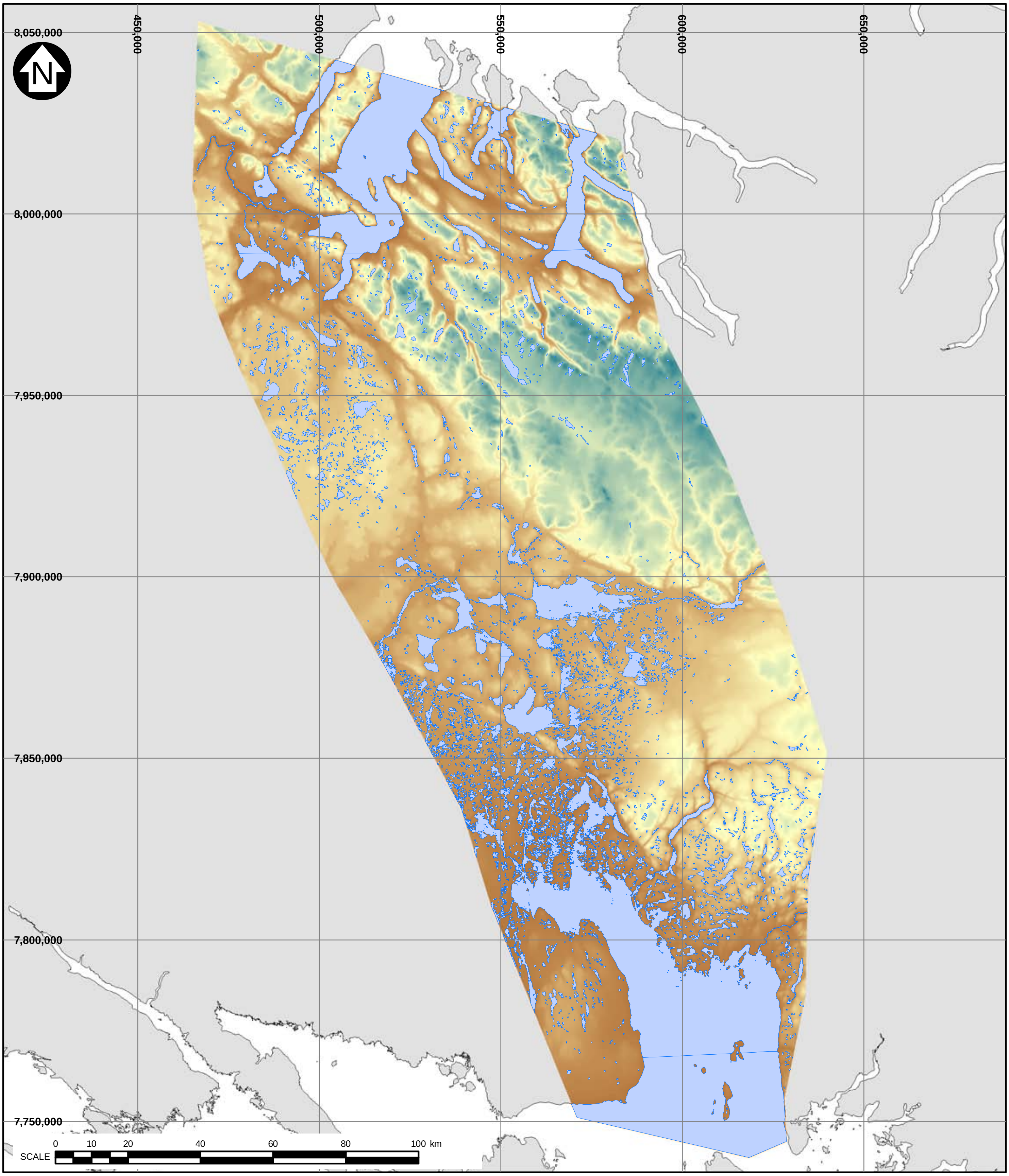
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.11

REV 0

SAVED: C:\MaryRiverELC\SolarRadiation.mxd



LEGEND:

Value

HIGH : 976.346436

LOW : 0

WATER

LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES.
   DATUM: NAD83
   PROJECTION: UTM ZONE #17

.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MAP OF ELEVATION IN THE RSA

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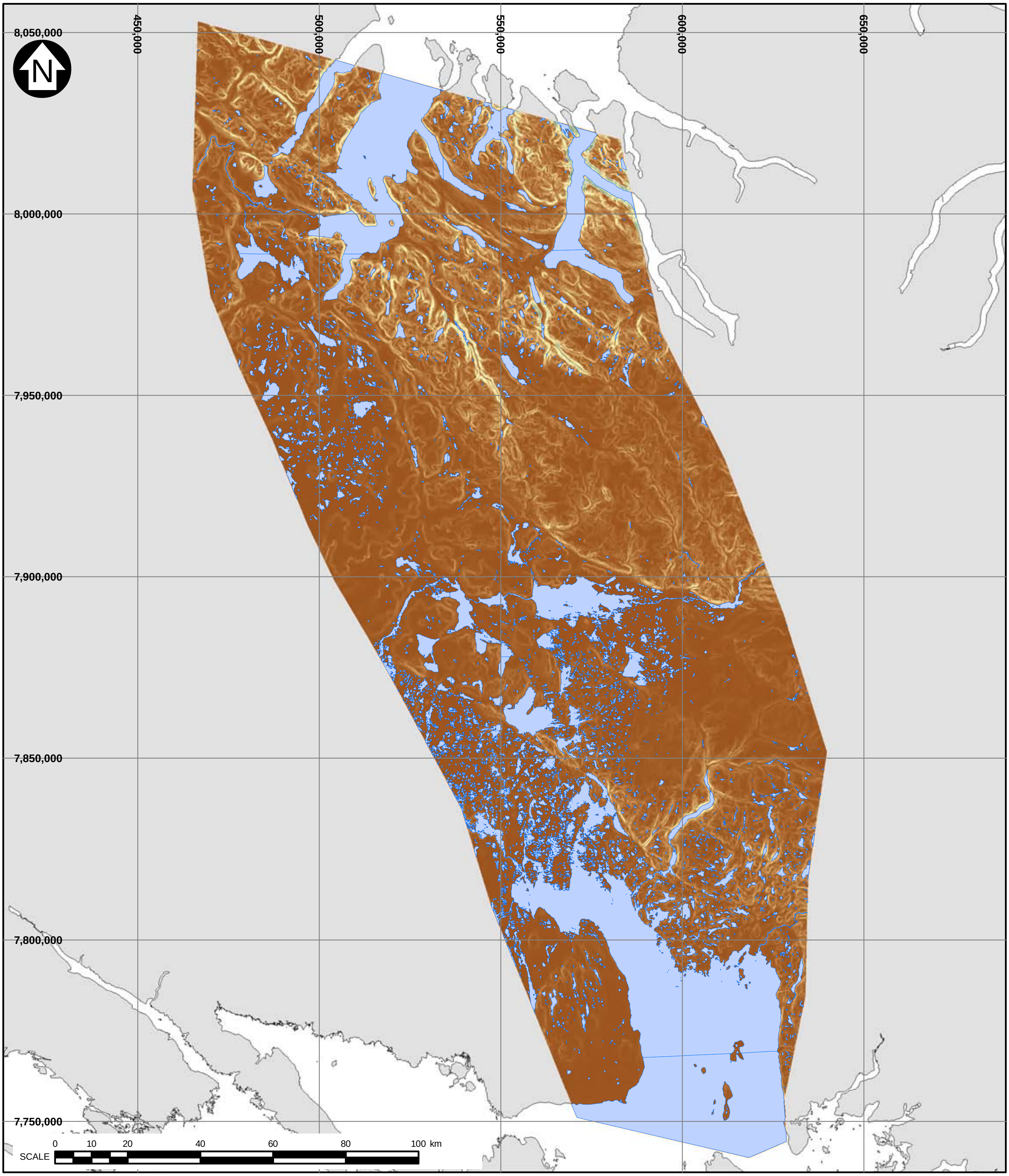
P/A NO.	REF NO.
NB102-181/25	5

FIGURE 3.12 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

SAVED: C:\MaryRiverELC\Elevation.mxd



SAVED: C:\MaryRiverELC\Slope.mxd

LEGEND:

Value

HIGH : 56.248741

LOW : 0.000002

WATER

LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES. DATUM: NAD83 PROJECTION: UTM ZONE #17

.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MAP OF SLOPE IN THE RSA

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P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.13

REV 0

LEGEND:

Value

HIGH : 359.999969

LOW : 0.000000

WATER

LAND

NOTES:

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.

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

MAP OF ASPECT IN THE RSA

Knight Piésold CONSULTING

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

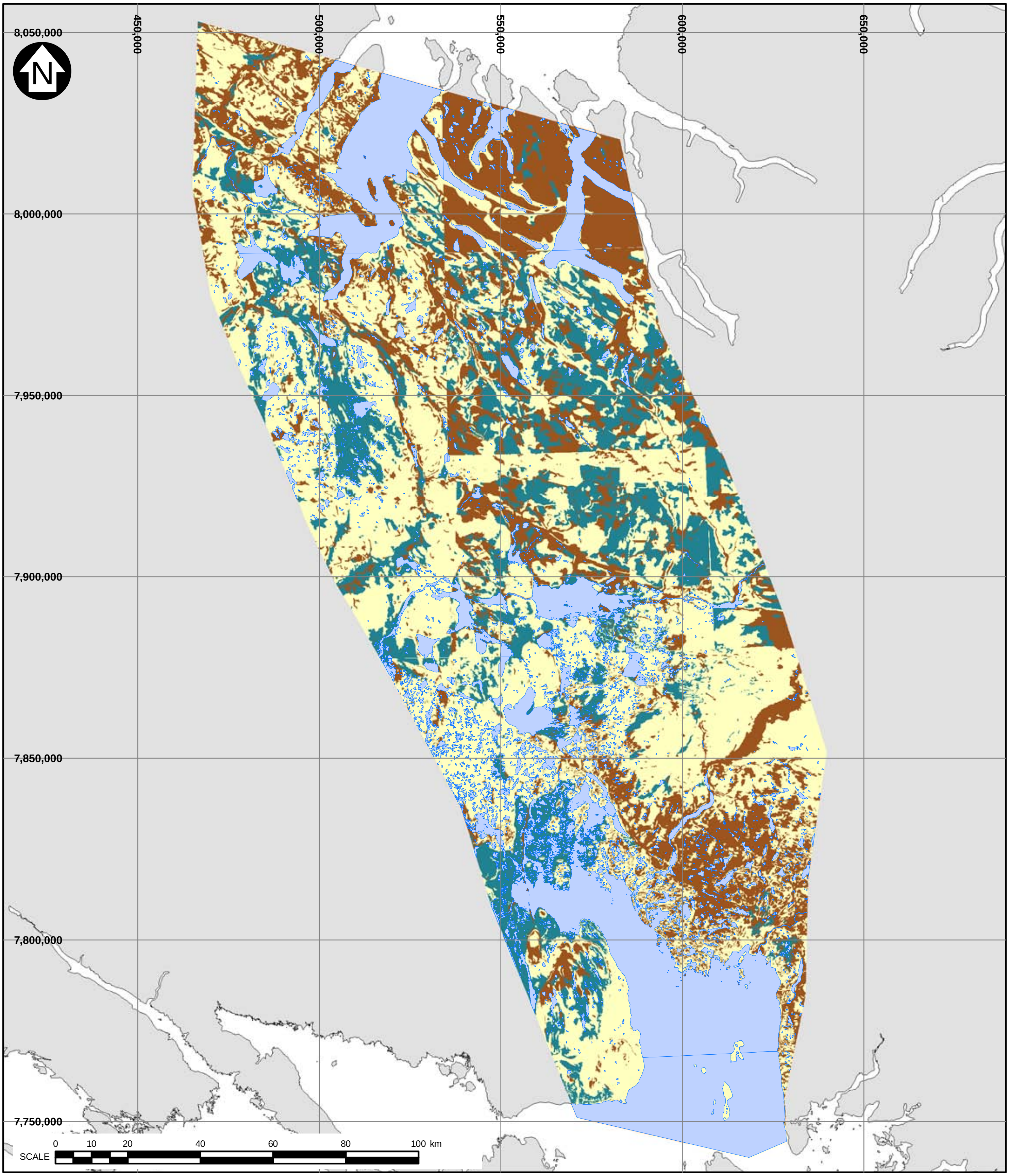
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.14

REV 0

SAVED: C:\MaryRiverELC\Aspect.mxd



SAVED: C:\MaryRiverELC\CarexAtrofusca Cover.mxd

LEGEND:

Value

HIGH : 2

LOW : 0

WATER

LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES.
   DATUM: NAD83
   PROJECTION: UTM ZONE #17

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

ABUNDANCE (MEAN % COVER) OF *Carex atrofusca* IN THE RSA

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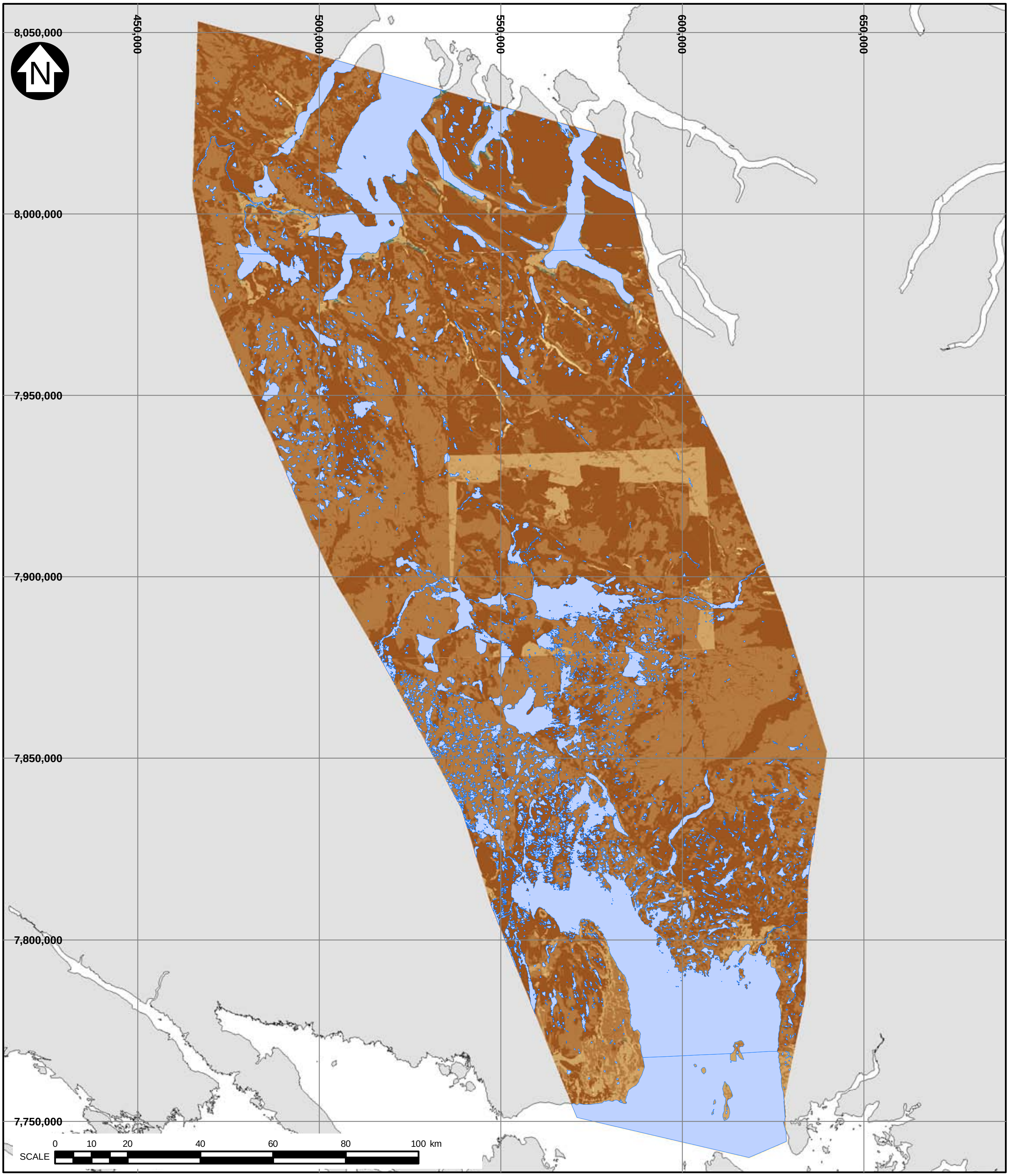
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.15

REV 0



SAVED: C:\MaryRiverELC\CarexScirpoidea Cover.mxd

LEGEND:

Value

HIGH : 8

LOW : 0

WATER

LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES.
DATUM: NAD83
PROJECTION: UTM ZONE #17

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

ABUNDANCE (MEAN % COVER) OF *Carex scirpoidea* IN THE RSA

Knight Piésold CONSULTING

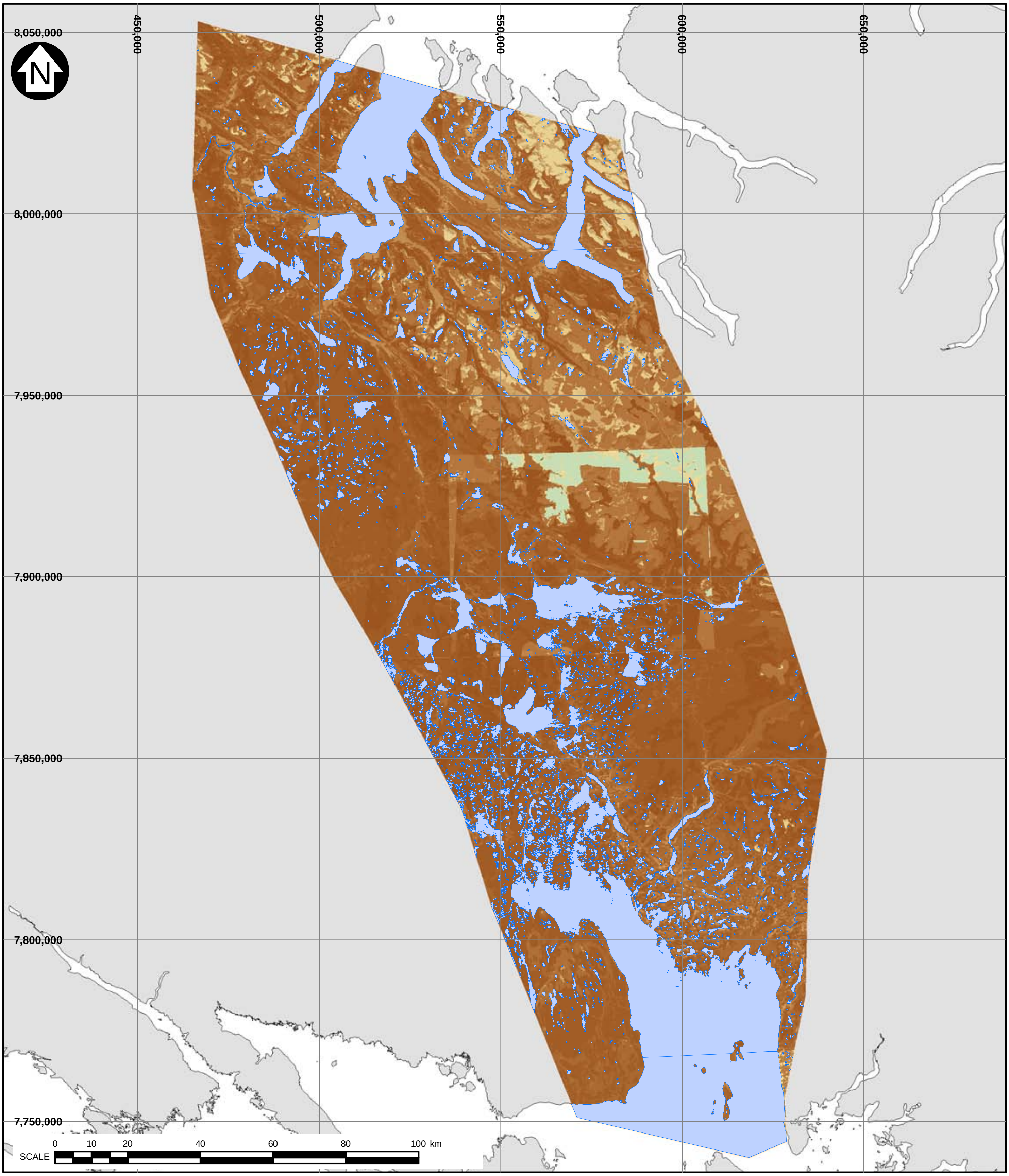
LGL LIMITED environmental research associates

P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.16

REV 0



LEGEND:

Value

HIGH : 42

LOW : 0

WATER

LAND

NOTES:

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2. CO-ORDINATE GRID IS IN METRES.
   DATUM: NAD83
   PROJECTION: UTM ZONE #17

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

ABUNDANCE (MEAN % COVER) OF COTTON GRASSES AND RUSHES IN THE RSA

Knight Piésold CONSULTING

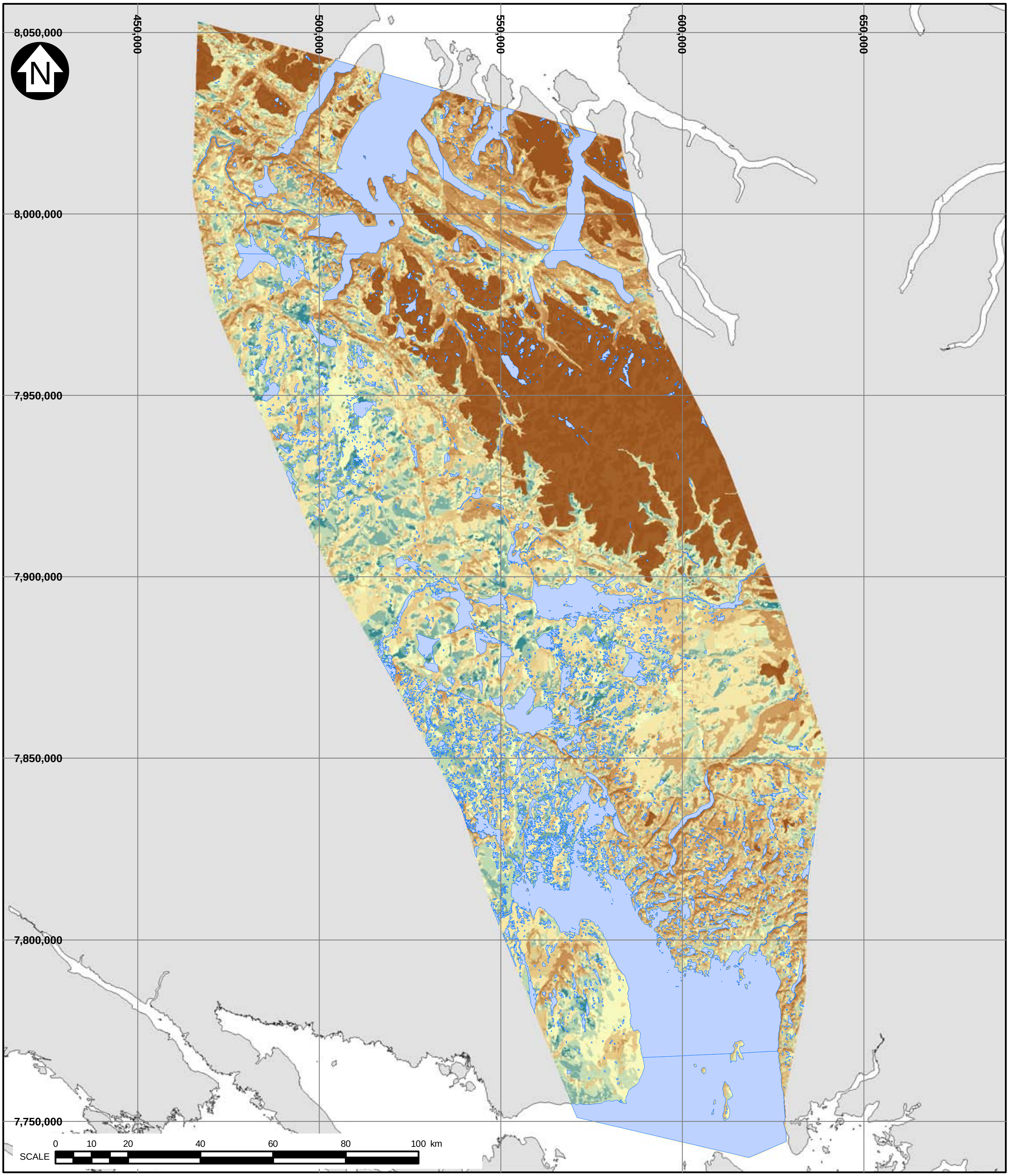
LGL LIMITED environmental research associates

P/A NO.	REF NO.
NB102-181/25	5

FIGURE 3.17 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

SAVED: C:\MaryRiverELC\CottonGrassesRushes Cover.mxd



SAVED: C:\MaryRiverELC\DryasIntegrifolia Cover.mxd

LEGEND:

Value

HIGH : 25

LOW : 0

WATER

LAND

NOTES:

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   DATUM: NAD83
   PROJECTION: UTM ZONE #17

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

ABUNDANCE (MEAN % COVER) OF *Dryas integrifolia* IN THE RSA

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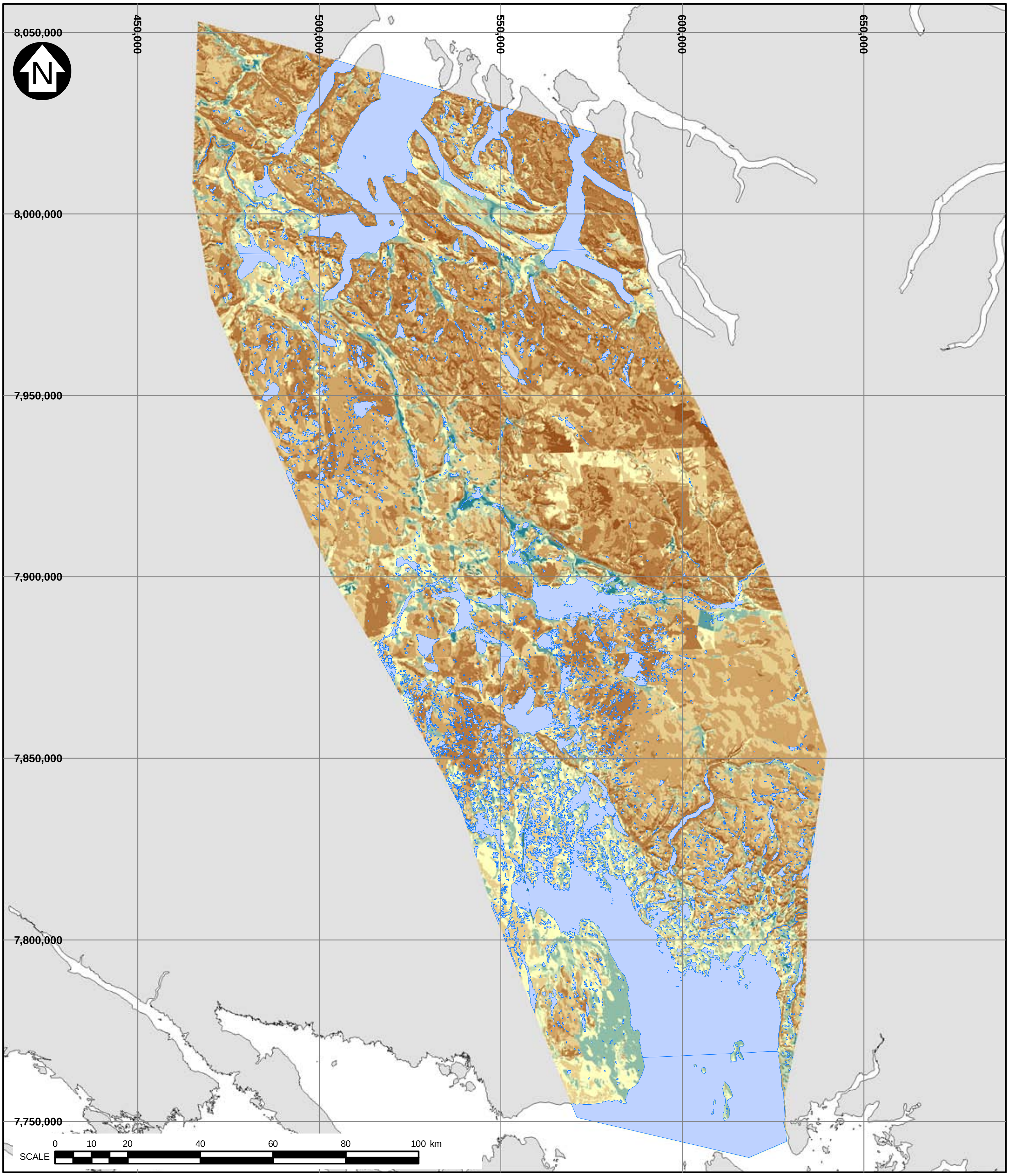
LGL LIMITED environmental research associates

P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.18

REV 0



SAVED: C:\MaryRiverELC\FolioseFruiticoseLichens Cover.mxd

LEGEND:

Value

HIGH : 8

LOW : 0

WATER

LAND

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

ABUNDANCE (MEAN % COVER) OF FOLIOSE AND FRUITICOSE LICHENS IN THE RSA

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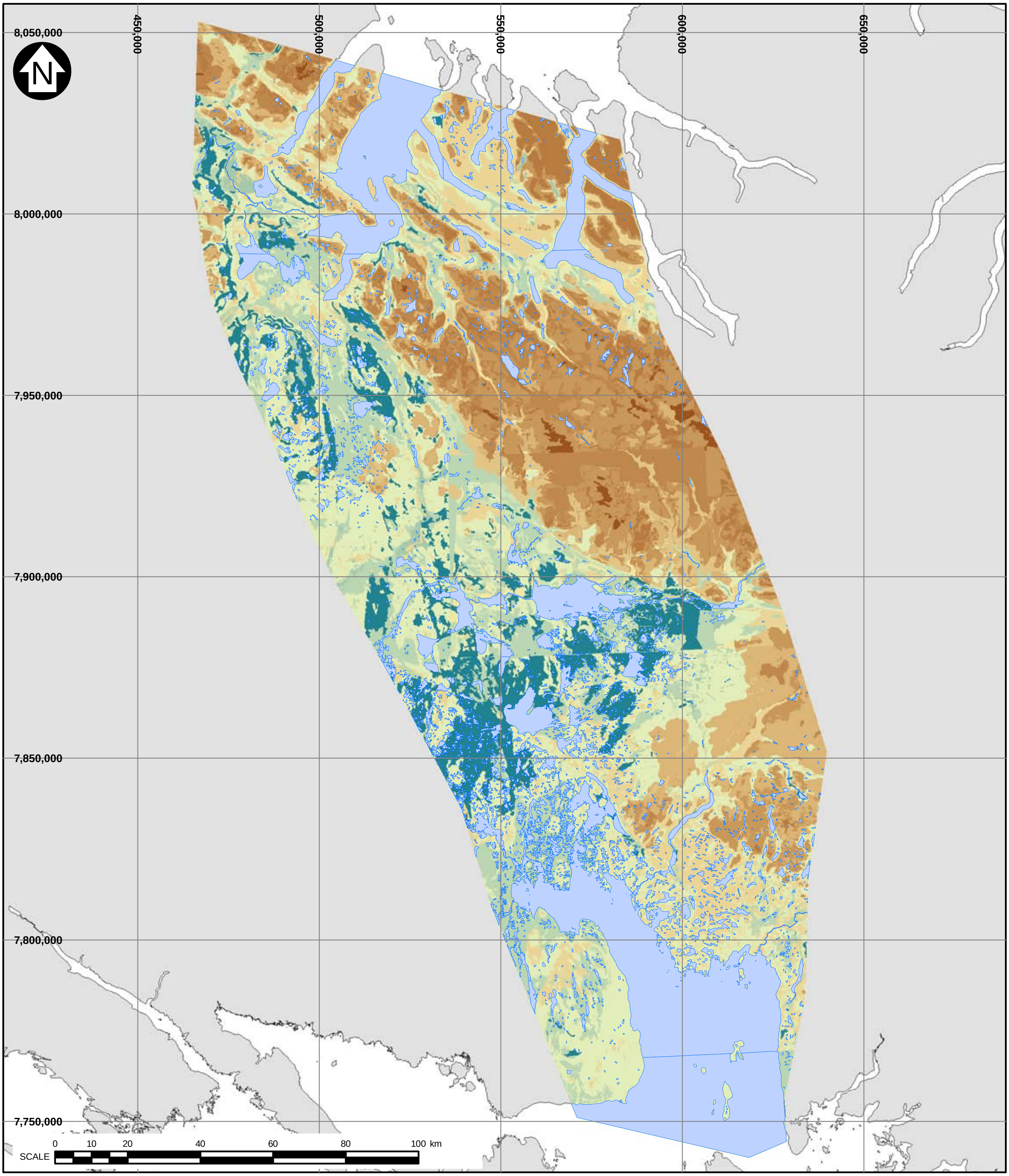
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.19

REV 0



SAVED: C:\MaryRiverELC\GrassesSedges Cover.mxd

LEGEND:

Value

HIGH : 23

LOW : 0

WATER

LAND

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

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MARY RIVER PROJECT

ABUNDANCE (MEAN % COVER) OF GRASSES AND SEDGES IN THE RSA

Knight Piésold CONSULTING

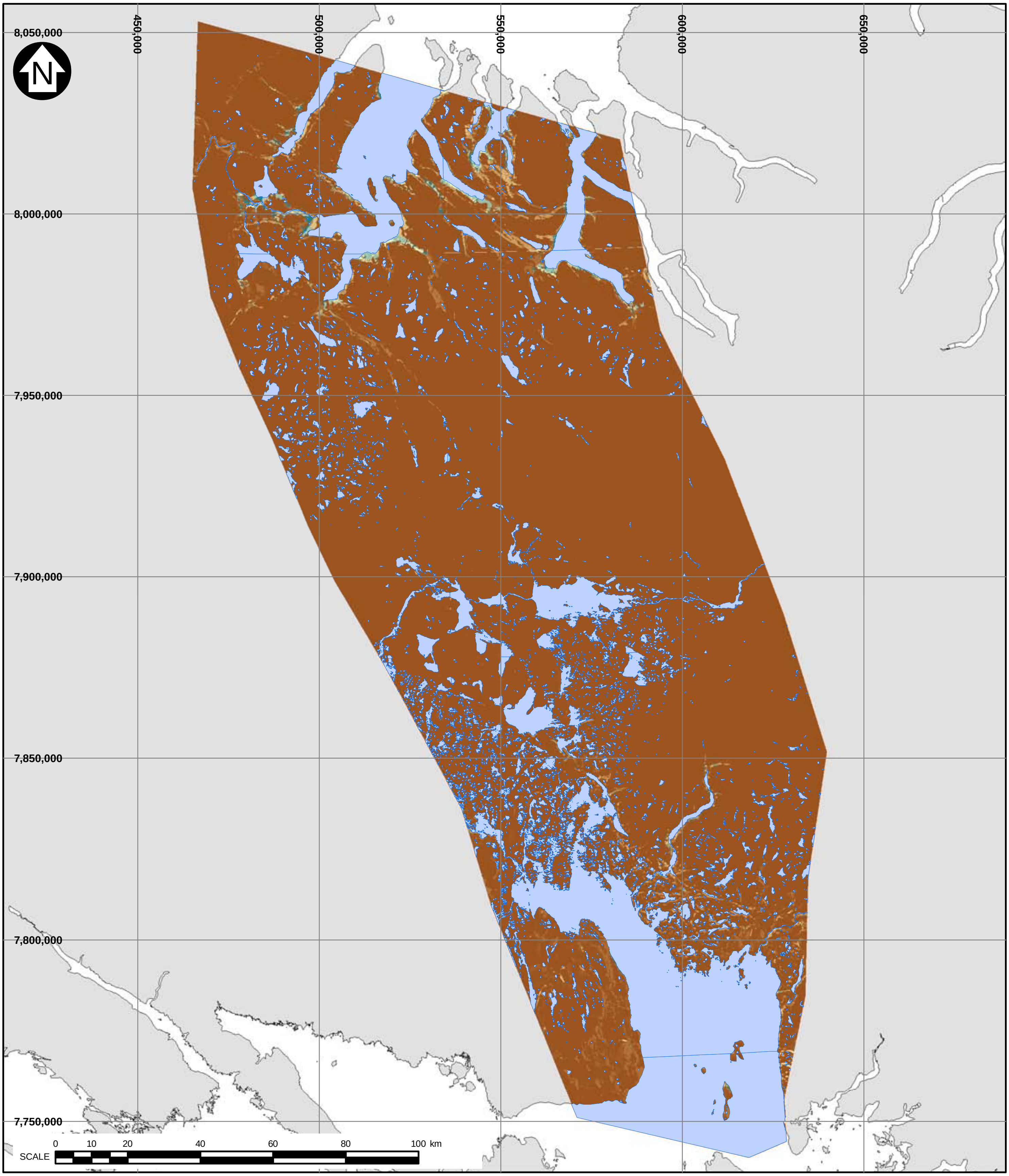
LGL LIMITED environmental research associates

P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.20

REV 0



SAVED: C:\MaryRiverELC\LedumPalustris Cover.mxd

LEGEND:

Value

HIGH : 30

LOW : 0

WATER

LAND

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ABUNDANCE (MEAN % COVER OF *Ledum palustris* (LABRADOR TEA) IN THE RSA

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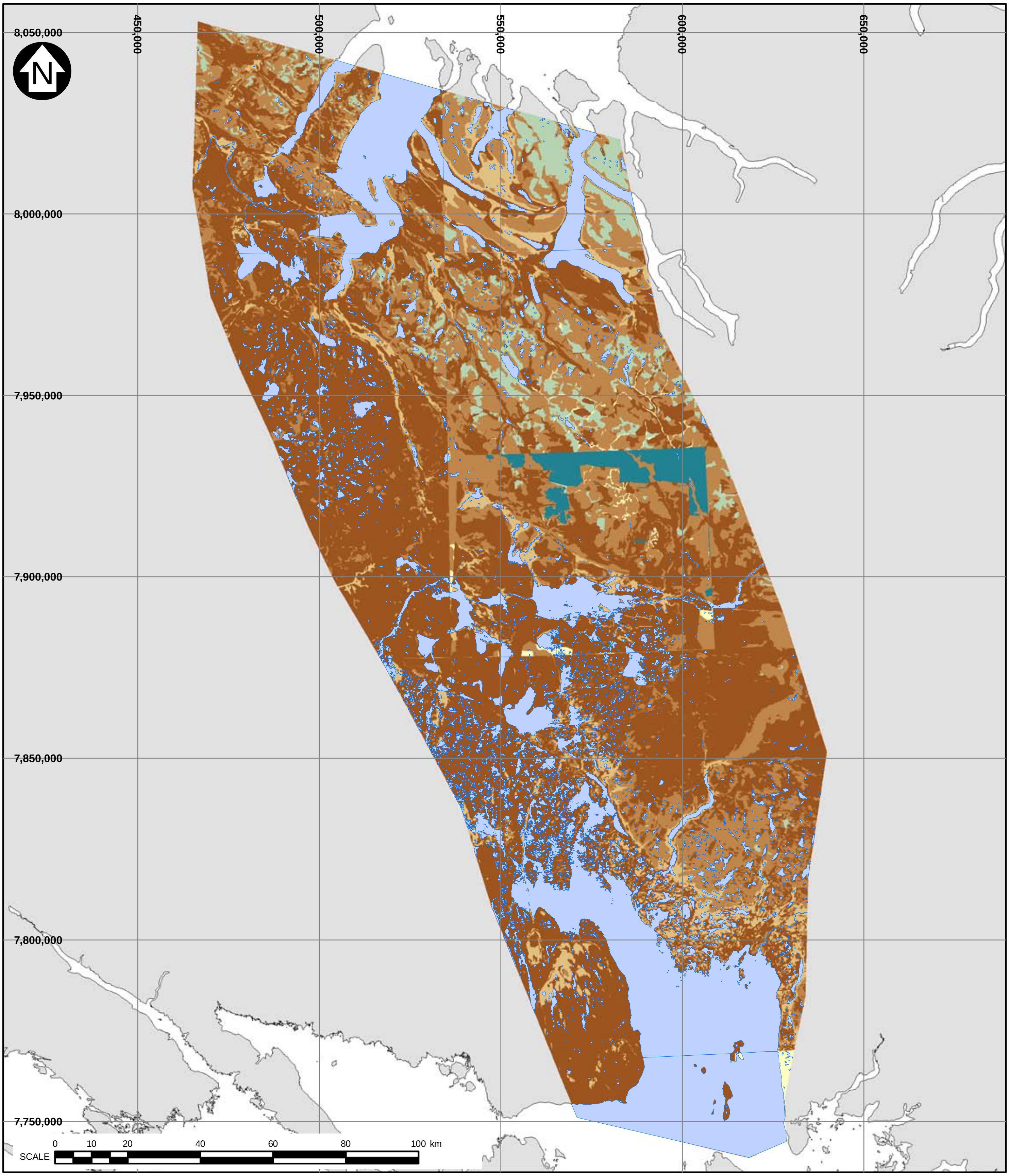
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.21

REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE



LEGEND:

Value

HIGH : 6

LOW : 0

WATER

LAND

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   PROJECTION: UTM ZONE #17

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

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ABUNDANCE (MEAN % COVER) OF *Luzula confusa* IN THE RSA

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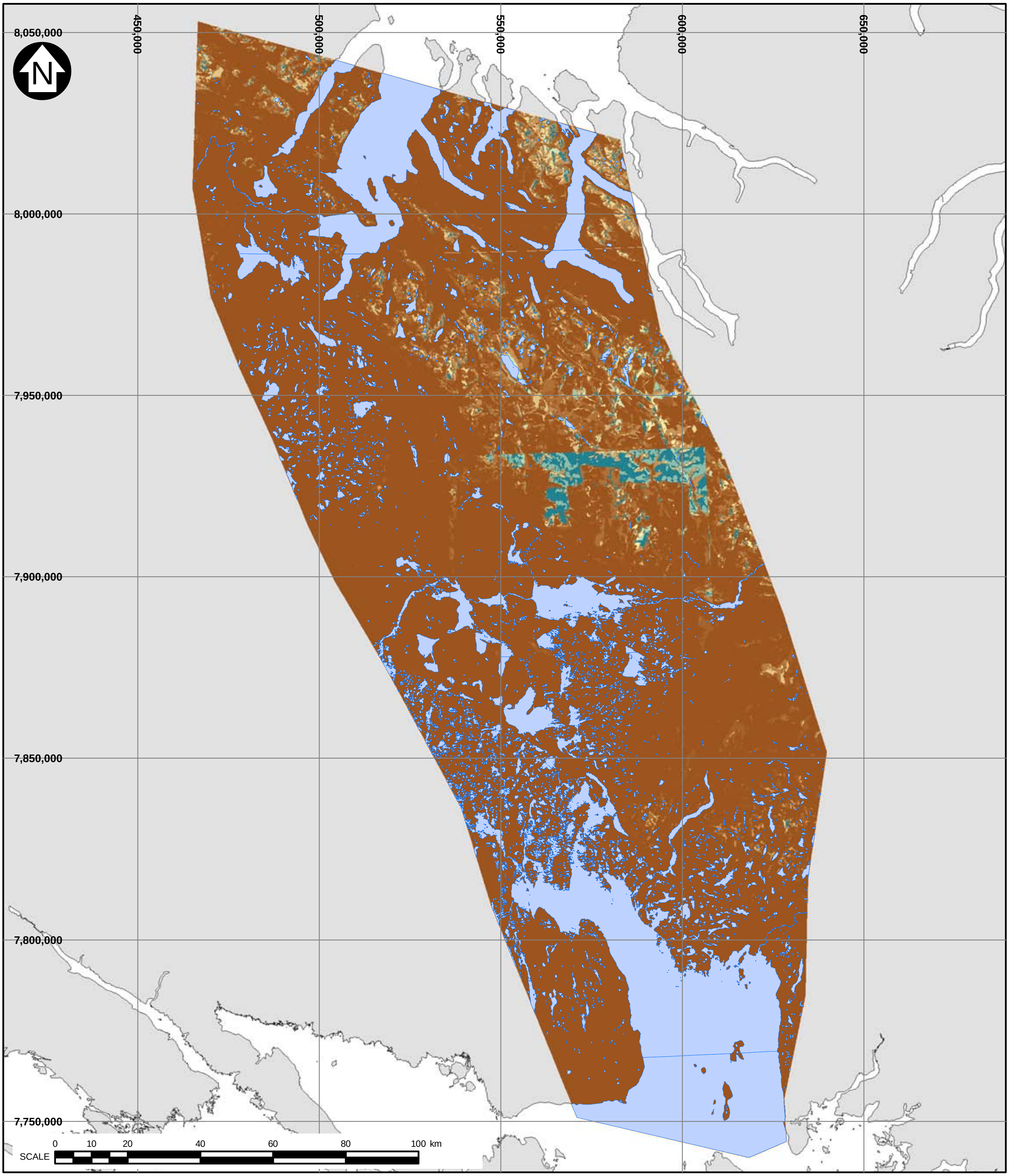
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.22

REV 0

SAVED: C:\MaryRiverELC\LuzulaConfusa Cover.mxd



LEGEND:

Value

HIGH : 20

LOW : 0

WATER

LAND

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ABUNDANCE (MEAN % COVER) OF *Luzula nivalis* IN THE RSA

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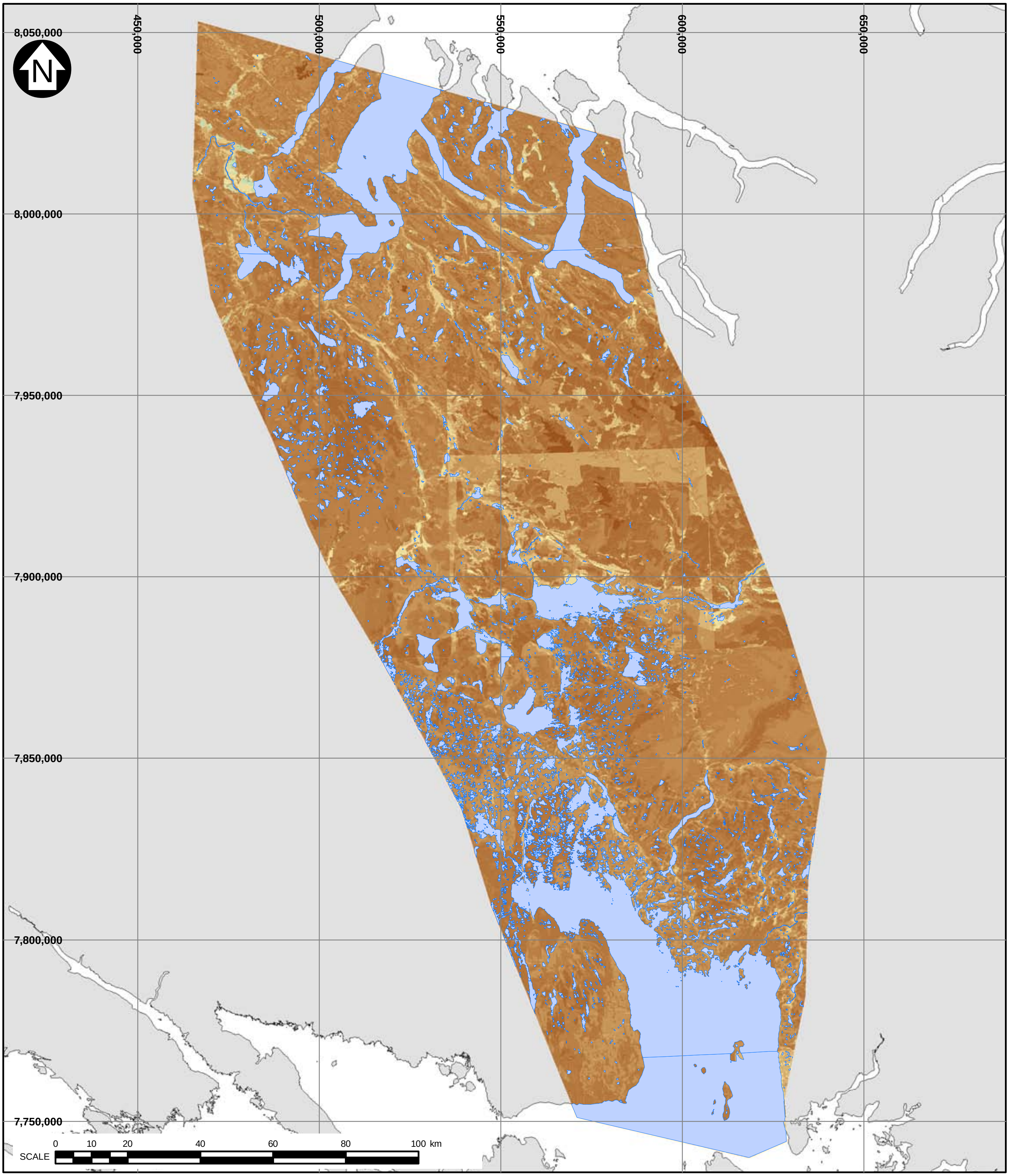
P/A NO.	REF NO.
NB102-181/25	5

FIGURE 3.23 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

SAVED: C:\MaryRiverELC\LuzulaNivalis Cover.mxd



SAVED: C:\MaryRiverELC\Mosses Cover.mxd

LEGEND:

Value

HIGH : 56

LOW : 0

WATER

LAND

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

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ABUNDANCE (MEAN % COVER) OF MOSSES IN THE RSA

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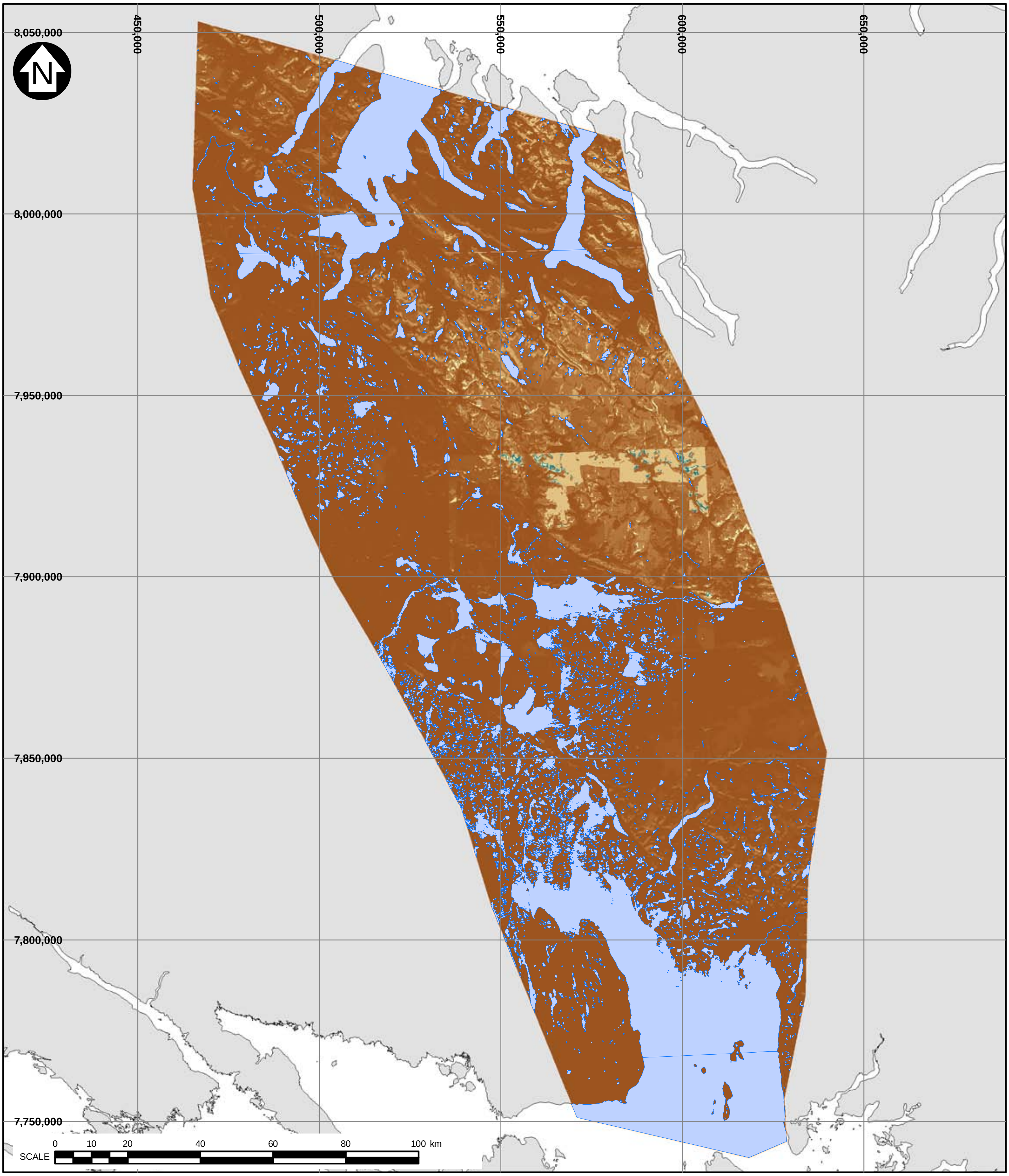
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.24

REV 0



LEGEND:

Value

HIGH : 50

LOW : 0

WATER

LAND

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ABUNDANCE (MEAN % COVER) OF *Oxyria digyna* IN THE RSA

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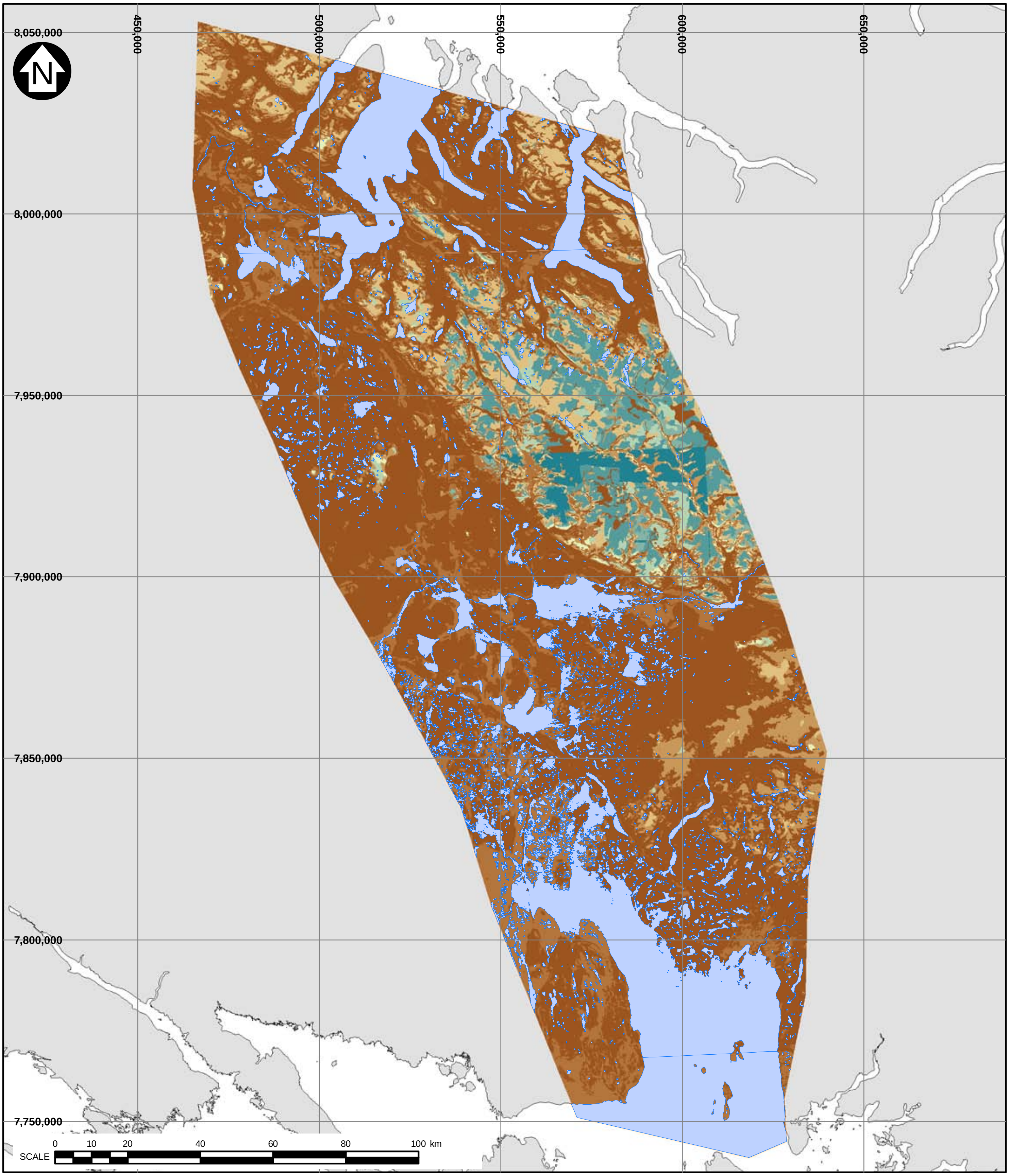
P/A NO.	REF NO.
NB102-181/25	5

FIGURE 3.25 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

SAVED: C:\MaryRiverELC\OxyriaDigyna Cover.mxd



LEGEND:

Value

HIGH : 9

LOW : 0

WATER

LAND

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

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ABUNDANCE (MEAN % COVER) OF *Saxifraga oppositifolia* IN THE RSA

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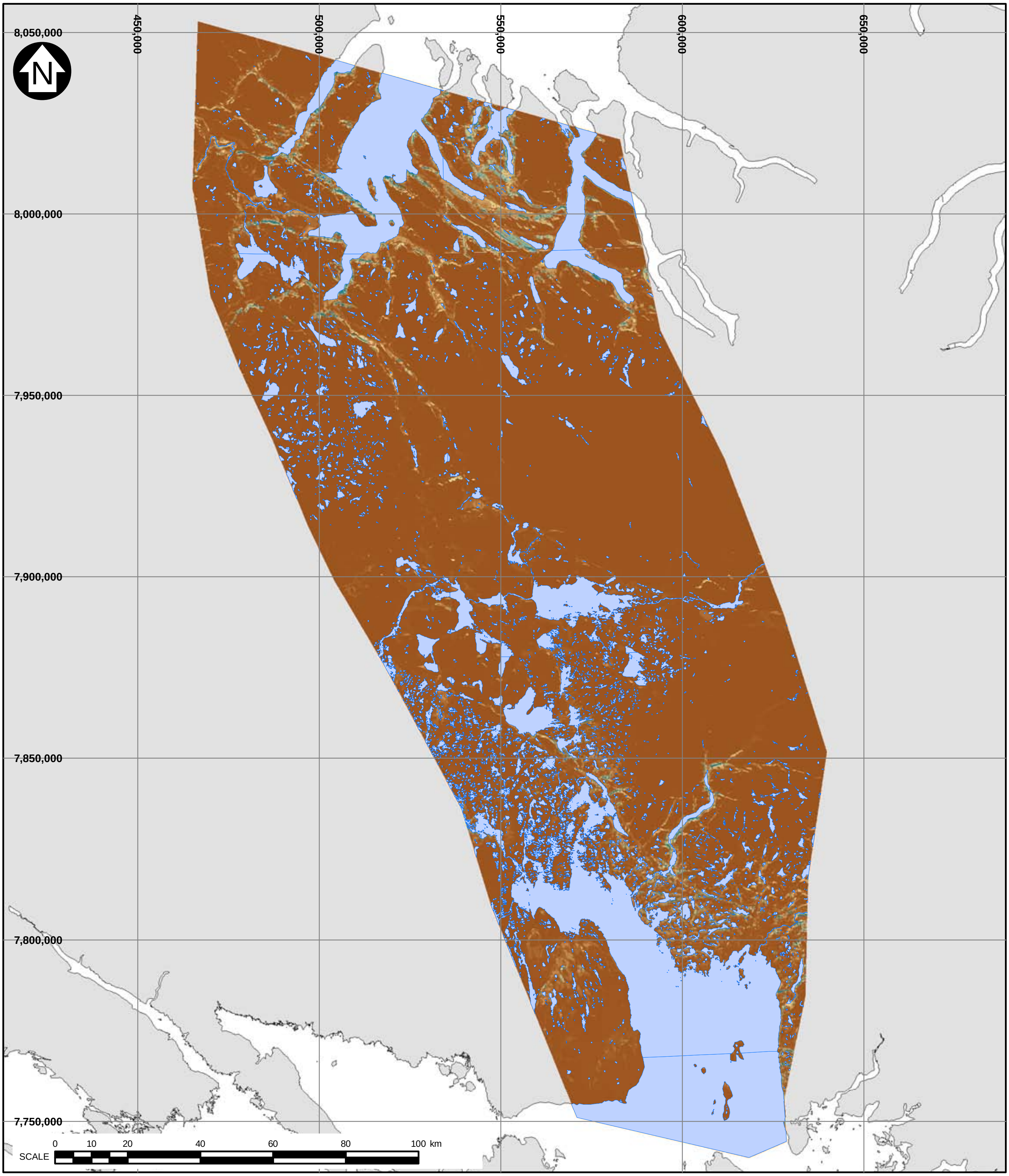
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.26

REV 0

SAVED:C:\MaryRiverELC\SaxifragaOppositifolia Cover.mxd



LEGEND:

Value

HIGH : 80

LOW: 0

WATER

LAND

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ABUNDANCE (MEAN % COVER) OF *Vaccinium uliginosum* IN THE RSA

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

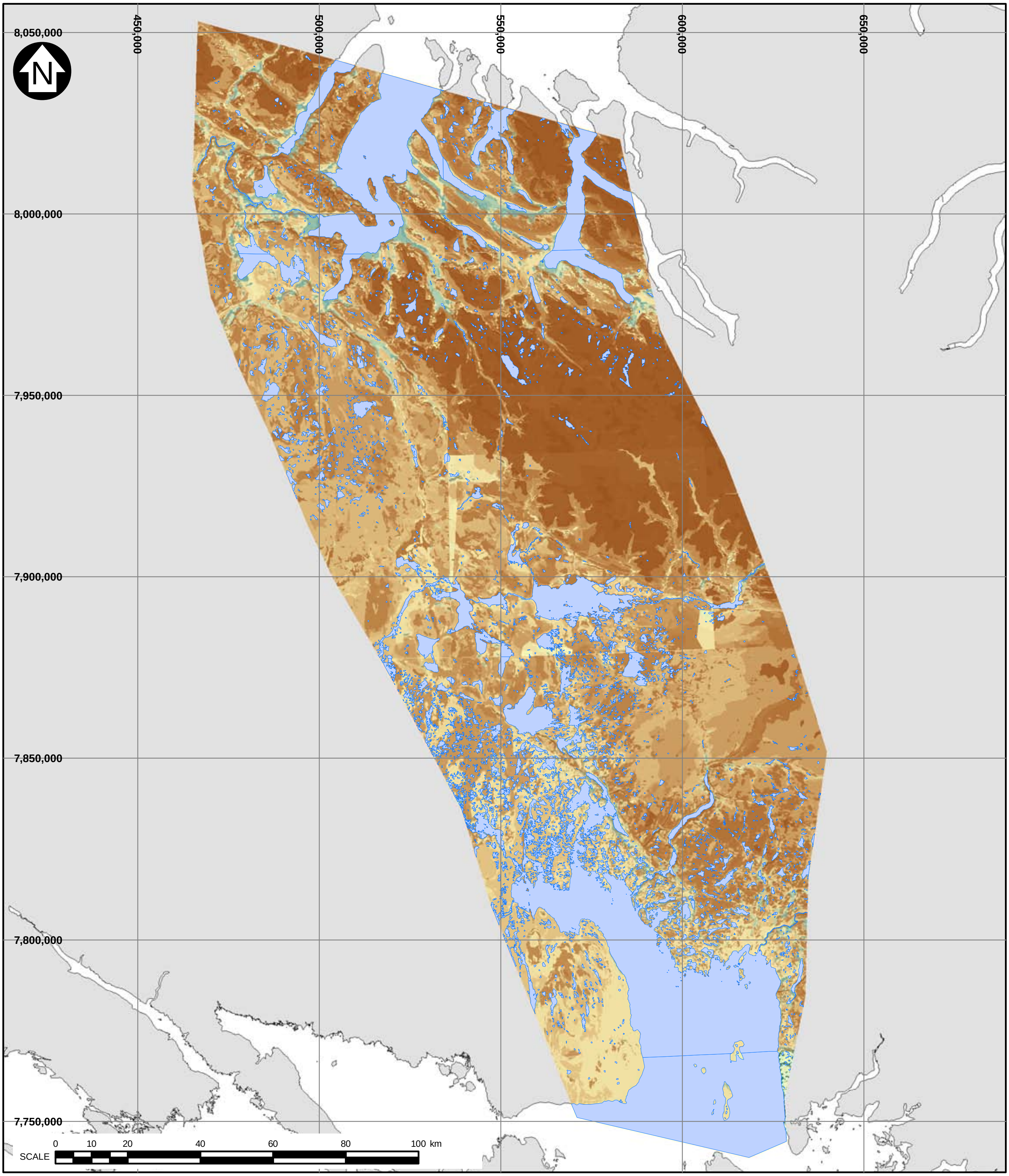
P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.27

REV 0

SAVED: C:\MaryRiverELC\VacciniumUliginosum Cover.mxd



SAVED: C:\MaryRiverELC\SalixSp Cover.mxd

LEGEND:

Value

HIGH : 38

LOW : 0

WATER

LAND

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	22NOV'10	ISSUED WITH REPORT	PAQ	REE	RAC	KDE

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ABUNDANCE (MEAN % COVER) OF WILLOWS IN THE RSA

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P/A NO. NB102-181/25

REF NO. 5

FIGURE 3.28

REV 0

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APPENDIX A

ANNOTATED BIBLIOGRAPHY

(Pages A-1 to A-205)

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APPENDIX A

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

ECOLOGICAL LAND CLASSIFICATION
ANNOTATED BIBLIOGRAPHY AND LIBRARY COLLECTION

TABLE OF CONTENTS

PAGE

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SECTION 1.0 - INTRODUCTION

This annotated bibliography represents the results of collecting literature for the development and application of the ecological land classification for the Mary River Project. This included the following topics: Arctic ecology and wildlife habitat, remote sensing and vegetation mapping, ecological indicators, environmental impact assessment, conservation, and resource development. Electronic copies of these publications are available for use at the Knight Piésold Ltd. office in North Bay, Ontario.

SECTION 2.0 - ARCTIC ECOLOGY & WILDLIFE HABITAT

2.1 GENERAL

Blackburn, T. M. and K. J. Gaston. 2006. There's more to macroecology that meets the eye. ***Global Ecology and Biogeography*** 15:537-540.

Abstract taken directly from text
Macroecology sits at the junction of, and can contribute to, the fields of ecology, biogeography, palaeontology and macroevolution, using a broad range of approaches to tackle a diverse set of questions. Here, we argue that there is more to macroecology than mapping, and that while they are potentially useful, maps are insufficient to assess macroecological pattern and process. The true nature of pattern can only be assessed, and competing hypotheses about process can only be disentangled, by adopting a statistical approach, and it is this that has been key to the development of macroecology as a respected and rigorous scientific discipline.

Bliss, L. C., G. M. Courtin, D. L. Pattie, R. R. Riewe, D. W. A. Whitfield and P. Widden. 1973. Arctic Tundra Ecosystems. ***Annual Review of Ecology and Systematics*** 4:359-399.

Abstract not available [excerpts directly from text]
The purpose of this paper is to review the knowledge on how heat-limited terrestrial systems function. It also looks at the effects humans have on terrestrial systems including plants. Arctic systems have characteristics of fragile systems, and there are a number of environmental concerns in this area. This paper also discusses the effects of human, predator and prey densities on the success of certain populations. Static energy and carbon flow analysis, as well as primary production models, can effectively model population trends and mechanisms. There has been a rapid progression in modelling used as an investigative and synthetic tool, and more progress can be expected in modelling as it is use more in planning and research.

Chapin III, F. S. and C. H. Korner. 1995. Patterns, Causes, Changes, and Consequences of Biodiversity in Arctic and Alpine Ecosystems. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 313-320.

Abstract not available [excerpts directly from text]
The land area covered by arctic and alpine vegetation is roughly 11 million km^2 or 8% (5% arctic, 3% alpine) of the terrestrial surface of the globe. Climatic changes since the Pleistocene altered the geographic distribution of arctic ecosystems and caused vertical migration of alpine vegetation belts. However, each species typically showed a unique pattern of migration in response to climatic change because of individualistic responses to the environment. Consequently, past communities often had quite different species composition than those of today. Patterns of diversity differ between arctic and alpine ecosystems. Alpine areas have higher species richness than arctic ecosystems, and have high ecological diversity at the landscape level due to the greater vertical relief in these areas. Biodiversity in arctic and alpine ecosystems is currently threatened most strongly by diffuse impacts of human activity. CO^2-induced climatic warming is causing upward migration of alpine species with the possible loss of

some alpine ecosystems from low-altitude summits. Moreover, biogeochemical pools and fluxes are the ecosystem traits and processes that are least sensitive to changes in biodiversity. Only major changes in the abundance of functional groups can strongly alter the biogeochemical processes. This is quite different from organism interactions like herbivory and pollination that are very sensitive.

Dunbar, M. J. 1973. Stability and Fragility in Arctic Ecosystems. ***Arctic*** 26:178-185.

Abstract taken directly from text

1) Two definitions of ecological stability are in use, and it is essential to keep them separate and explicitly stated. "Type-1 stability" is the condition of non-oscillation, or nearly non-oscillation and steady state found in certain tropical situations, the result of continued evolution toward greater economy of energy and involving high information content and low production/ biomass ratio. This type of stability is highly vulnerable to serious perturbation, to which it cannot adapt. Such systems may thus be called "fragile" and they are found in the tropics and perhaps in certain parts of high latitude systems, such as lakes, subarctic forests and perhaps the tundra vegetation itself. "Type-2 stability" is the condition of ability to absorb serious perturbation and return to a stable state, usually the *status quo ante.* This involves system oscillation, smaller information content, higher production/biomass ratios, and lesser economy of energy use. This type is found in mid and high latitudes, in which the physical environment itself oscillates considerably.

2) In tundra environments, extreme ecosystem simplicity in the animal communities leads to extreme oscillation, and it is suggested that such oscillations can be tolerated only if the geographic scale is large, which it is in the Arctic.

3) "Thermokarst", or damage to tundra terrain by damage to, or removal of, the active layer, is a serious hazard which is well understood and can be easily avoided. It is upon this that the "fragile Arctic" reputation is founded.

4) Oil in arctic sea water constitutes a serious hazard, probably more serious than in warmer waters.

Hines, J. E., M. A. Fournier, S. Moore, K. H. Seidel, M. Sutherland and L. J. Wilkinson. 1988. ***A Natural Resource Survey of Auyuittuq National Park Reserve Baffin Island***. Contract Report Number 4, Department of Renewable Resources, Government of the Northwest Territories, Yellowknife, NWT. 382 pp.

Abstract not available [excerpt directly from text]

The objective of this report is to summarize information about the natural resources of Auyuittuq National Park Reserve, Baffin Island, for use in park planning. This park is part of the Davis Region of the Canadian Shield. Two major subdivisions of the Davis Region occur in the park: (1) the Davis Highlands characterized by deep, nearly vertical-walled fiords, steep terrain, ice-covered plateaus, and mountain peaks that are separated by glaciers; and (2) the Baffin Upland which is lower in elevation, consisting of plateaus and hills that are frequently dissected by deep valleys. As for the climate of Auyuittuq National Park Reserve, it is extremely harsh, complex, and variable. The long, cold winters are characterized by short days, light precipitation, and strong winds. Summers are short with moderate temperatures and long days. The area has low amounts of precipitation (largely in the form of snow) and low rates of evaporation. Streams are generally straight in form and have narrow channels. A few larger streams carrying glacial melt waters have heavy sediment loads and braided channel patterns. Freshwater lakes cover 2% of the park, and are mainly small lakes. The soils of the area are poorly developed, nutrient poor, and acidic.

Hines, J. E. and S. Moore. 1987. ***Progress Report on the Basic Resource Inventory, Auyuittuq National Park Reserve, 1986-87***. Habitat Management Section, Wildlife Management Division, Department of Renewable Resources, Yellowknife, Northwest Territories. 50 pp.

Abstract not available [excerpts directly from text]

The purpose of the Basic Resource Inventory was to gather and summarize information on Auyuittuq National Park Reserve. The objectives which Environment Canada provided to those involved in creating this inventory were to provide detailed biophysical maps of the park, to review the existing literature and information on the natural environment of Auyuittuq, and to integrate this information and these maps in an overview of the physical features and wildlife of Auyuiituq. During the completion of this overview, a field program was set up to gain more information on the area. Seven "ecosections" were selected based on the presence of vegetation and their local diversity. Information on plant communities and wildlife habitat areas was gained using basic classification systems. Terrain Analysis and Mapping Services Ltd. was hired to conduct the biophysical mapping of the park.

Koleff, P. and K. J. Gaston. 2002. The relationships between local and regional species richness and spatial turnover. ***Global Ecology & Biogeography*** 11:363-375.

Abstract taken directly from text

Aim: To determine the empirical relationships between species richness and spatial turnover in species composition across spatial scales. These have remained little explored despite the fact that such relationships are fundamental to understanding spatial diversity patterns.

Location: South-east Scotland.

Methods: Defining local species richness simply as the total number of species at a finer resolution than regional species richness and spatial turnover as turnover in species identity between any two or more areas, we determined the empirical relationships between all three, and the influence of spatial scale upon them, using data on breeding bird distributions. We estimated spatial turnover using a measure independent of species richness gradients, a fundamental feature which has been neglected in theoretical studies. Results Local species richness and spatial turnover exhibited a negative relationship, which became stronger as larger neighbourhood sizes were considered in estimating the latter. Spatial turnover and regional species richness did not show any significant relationship, suggesting that spatial species replacement occurs independently of the size of the regional species pool. Local and regional species richness only showed the expected positive relationship when the size of the local scale was relatively large in relation to the regional scale.

Conclusions: Explanations for the relationships between spatial turnover and local and regional species richness can be found in the spatial patterns of species commonality, gain and loss between areas.

Krebs, C. J., K. Danell, A. Angerbjorn, J. Agrell, D. Berteaux, K. A. Brathen, O. Danell, S. Erlinge, V. Fedorov, K. Fredga, J. Hjalten, G. Hogstedt, I. S. Jonsdottir, A. J. Kenney, N. Kjellen, T. Nordin, H. Roininen, M. Svensson, M. Tannerfeldt and C. Wiklund. 2003. Terrestrial trophic dynamics in the Canadian Arctic. ***Canadian Journal of Zoology*** 81:827-843.

Abstract taken directly from text

The Swedish Tundra Northwest Expedition of 1999 visited 17 sites throughout the Canadian Arctic. At 12 sites that were intensively sampled we estimated the standing crop of plants and the densities of herbivores and predators with an array of trapping, visual surveys, and faecal-pellet transects. We developed a trophic-balance model using ECOPATH to integrate these observations and determine the fate of primary and secondary production in these tundra ecosystems, which spanned an 8-fold range of standing crop of plants. We estimated that about 13% of net primary production was consumed by herbivores, while over 70% of small-herbivore production was estimated to flow to predators. Only 9% of large-herbivore production was consumed by predators. Organization of Canadian Arctic ecosystems appears to be more top-down than bottom-up. Net primary production does not seem to be herbivore-limited at any site. This is the first attempt to integrate trophic dynamics over the entire Canadian Arctic.

Mueller, G., G. Broll, and C. Tarnocai. 1999. Biological Activity as Influenced by Microtopography in a Cryosolic Soil, Baffin Island, Canada. ***Permafrost and Periglacial Processes*** 10:279-288.

Abstract taken directly from text

Biological activity and cellulose decomposition in the topsoil of an east-west oriented slope in the Canadian Arctic were studied in the summers of 1995 and 1996. Two microsites, small mounds and the adjacent troughs, characterize the surface of the study site on a slope. This microtopography results from erosion in the past when the area was not vegetated, and recent frost action. The aim of the study was to describe differences in the decomposition processes and the contributing factors in relation to the microtopography. Biological activity in the soil was measured by the feeding activity of the soil organisms. In both years of the study feeding activity by bait-lamina test and cellulose decomposition by nylon-mesh-bag assessment were higher in the troughs than in the mounds. The C/N ratios and acidity were similar in the zone showing the highest biological activity at both sites, but soil temperatures and water content were different. Soil moisture was found to be the main factor affecting feeding activity and cellulose decomposition at both microsites.

Pitelka, F. A. 1969. Ecological Studies on the Alaskan Arctic Slope. ***Arctic*** 22:333-340.

Abstract not available [excerpts directly from text]
This paper discusses how the Naval Arctic Research Laboratory has done an excellent job of gaining ecological knowledge of the Arctic. The University of Alaska, the Arctic Health Research Laboratory of the U.S. Public Health Service, the U.S. Geological Survey and the Atomic Energy Commission have also had moved ecology forward in the Alaskan Arctic. Reasons for conducting ecology in the Arctic are given, and it is stressed that future general fauna and flora studies are decreasingly justifiable. Instead, it is suggested that studies should focus on the interests and needs of ecologists and physiologists, and should follow more problem-oriented approaches.

Polunin, N. 1951. The Real Arctic: Suggestions for its Delimitation, Subdivision and Characterization. ***Journal of Ecology*** 39:308-315.

Abstract not available [excerpts directly from text]
Although in the biological sciences satisfactory definition is often difficult or even impossible, that is no excuse for not attempting to be precise. A bad blot in the literature is the persistent vagueness surrounding the use of the term 'arctic', whether it be employed in the adjectival form (in which case it is not now customary to capitalize the initial letter) or as a substantive implying a region, viz., the Arctic. It is common for an author to term a plant (or its range) arctic when it reaches an area which according to his conception (or mere copying) constitutes part of the Arctic; but what this last is, where it begins or ends, evidently varies greatly in different authors' minds. Unfortunately such single criteria as the Arctic Circle, which in theory governs the presence or absence of 'midnight sun', are practically useless for our purpose and indeed are apt to be seriously misleading. Nor is the common conception of the Arctic as a 'cold desert' particularly helpful. In the restricted sense to which it seems desirable to limit the term, the Arctic is thus the region lying to the north-poleward of an imaginary but by no means meaningless line. Its character is too impossibly complex and infinitely variable from place to place to define scientifically, at least in our present state of ignorance: but in general it may be said to be treeless, with the winters largely dark and cold and the mean temperature of the warmest month plus one-tenth of the mean of the coldest month over a cycle of years not more than 9" C., with high wind chill and less than 50 days between spring and fall frosts, with the subsoil in most places permanently frozen and frost-heaving and allied phenomena important, with an annual precipitation normally below 500 mm. (19.8 in.) and largely in the form of snow which drifts and is packed tightly by the wind, with the soils generally moist in summer but the air of low absolute humidity, and with sheltered salt as well as fresh water frozen over for much of the winter. But still there are some exceptions of areas which fail to comply in one or two respects but from general consideration seem for the time being best included within the arctic region.

Sutherland, M., K. H. Seidel and J.E. Hines. 1988. ***Auyuittuq National Park Reserve: An Annotated Bibliography***. Manuscript Report 22, Department of Renewable Resources, Government of the Northwest Territories, Yellowknife, NWT. 198 pp.

Abstract taken directly from text
A total of 605 references concerning the natural resources of Auyuittuq National Park Reserve are presented in this annotated bibliography. References are organized alphabetically by author and indexed

by fourteen keywords. The bibliography should be a useful references for anyone interested in the local flora, fauna, or natural environment (aquatic, terrestrial, and atmospheric), both present-day and historic.

Walker, D. A, H. E. Epstein, W. A. Gould, A. M. Kelley, A. N. Kade, J. A. Knudson, W. B. Krantz, G. Michaelson, R. A. Peterson, C.L. Ping, M. K. Raynolds, V. E. Romanovsky and Y. Shur. 2004. Frost-Boil Ecosystems: Complex Interactions between Landforms, Soils, Vegetation and Climate. ***Permafrost and Periglacial Processes*** 15:171-188.

Abstract taken directly from text
Frost boils in northern Alaska vary from large, 2–3-m diameter, barren non-sorted circles to completely vegetated hummocks. Summer warmth increases southwards from the coast. Average thaw-layer thickness shows the opposite trend. Frost heave shows no trend along the climate gradient but is affected by soil texture. Heave is greatest on frost boils with fine-grained sediments. Biomass increases from 183 gm^{-2} at the coast to 813 gm^{-2} in the Arctic Foothills. An aggrading permafrost table is evident in most of the frost-boil soil profiles, indicating that, over time, accumulation of plant biomass leads to reduced thaw-layer thickness. A conceptual model suggests how vegetation affects the morphology of patterned ground forms. In the coldest parts of the High Arctic well-developed frost boils do not form and there is little vegetation on frost boils or the inter-boil areas. In the warmest parts of the Low Arctic, vegetation is usually sufficient to stabilize the frost boil soils. Frost boils play an important role in Arctic ecosystems functions, including the flux of trace gases to the atmosphere, flux of water and nutrients to streams, and the recycling of important nutrients to wildlife populations.

Wolfe, A.P. 1996. Wisconsinan Refugial Landscapes, Eastern Baffin Island, Northwest Territories. ***Canadian Geographer*** 40:81-87.

Abstract taken directly from text
Geomorphologists, geologists, and ecologists alike have long been interested in the occurrence of regions that escaped Wisconsinian glaciation, whether partially or wholly. This is because such areas offer rare (in the Canadian context) glimpses of landscapes having evolved over significantly longer time frames than those deglaciated following the late Wisconsinian. The study of such areas has implications for long-term rates of weathering and denudation, pleniglacial biological refugia and the loci of subsequent species expansions, and research in Quaternary paleoecology and paleoclimatology. On Cumberland Peninsula, eastern Baffin Island, despite a complex glacial history that juxtaposes the influences of cirque glaciation, local ice caps, and the Baffin sector of the Laurentide Ice Sheet, certain areas nonetheless appear to have escaped glacial modification throughout the last glacial cycle. An example near the hamlet of Pangnirtung (66o 16’N, 65o 45’W) serves to illustrate the development of these ancient landscapes.

2.2 AQUATIC

Kling, G. W. 1995. Land-Water Interactions: The Influence of Terrestrial Diversity on Aquatic Ecosystems. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 297-310.

Abstract not available [excerpts directly from text]
Due to little research, the interaction between ecological diversity on land and in water was the topic of this journal. A number of biotic and abiotic factors in a terrestrial ecosystem affect the functioning of a water body nearby. This would include the input of water, nutrients, and organic matter. The success of aquatic organisms may be dependent on some on these factors, so research into these inputs is very useful. Water flow, vegetation and soil uptake and release, and landscape heterogeneity, are thought to play key roles in transporting materials from land into surface waters. Material flux increases with water flow, while vegetation and soil effects decrease due to reduced interaction time in soils. Highest water flows may increase vegetation and soil effects. Representing the correlations between water flow,

vegetation and soil effects in land-water interactions curves is essential for further research in this area, and may shed light on what factors control material fluxes into water bodies the most. Further research should also look into developing models that will predict the movement of materials from land to water in a number of varying conditions.

Rawson, D. S. 1953. Limnology in the North American Arctic and Subarctic. ***Arctic*** 6:198-204.

Abstract not available [excerpts directly from text]
The study of inland waters, limnology, is important in the Arctic considering the thousands of lakes there. Despite many lakes and rivers holding arctic char or other wildlife, research in this field has fallen behind studies into arctic resources. This article investigates the variety of potential studies that could be conducted in the Arctic, and gives a brief history of past limnological studies in this area. There is the potential to discover quite a bit about a broad array of Arctic species. The itinerary could be quite flexible since the whole area is practically unknown from the limnological point of view. This kind of work could provide invaluable data as to depths, temperatures, chemical, physical, and biological conditions, and the distributions of aquatic organisms.

Smol, J. P. 2005. Tracking Long-Term Environmental Changes in Arctic Lakes and Ponds: A Paleolimnological Perspective. ***Arctic*** 58:227-229.

Abstract not available [excerpts directly from text]
Due to the Arctic being particularly sensitive to changes in the environment, examining this area for past environmental conditions may better allow current climatic changes to be predicted (in terms of both timing and magnitude). Paleolimnology examines the history of lakes and ponds using proxy data contained in sediment profiles. Diatoms and other indicators preserved in lake sediments can allow scientists to predict long-term environmental trends. Researchers at PAL and PEARL look at climate change using paleolimnological data from the Arctic, and can also use this data to look at the accumulation of contaminants in the Arctic and the movement of fish populations. Although climate change is the major research focus of PEARL, they also look at the human impact on water bodies. Their work extends throughout the circumpolar region, and they are one of the few groups who conduct monitoring the Arctic.

2.3 SOILS AND CLIMATE

Bockheim, J. G. 1979. Properties and Relative Age of Soils of Southwestern Cumberland Peninsula, Baffin Island, N.W.T., Canada. ***Arctic and Alpine Research*** 11:289-306.

Abstract taken directly from text
On southwestern Cumberland Peninsula, Baffin Island, Minimal Podzol (*Pergelic Cryopsamments*), Arctic Brown (*P. Cryorthents*), and Tundra (*P. Cryaquepts*) soils occur along moist fiords and Polar Desert (*P. Cryorthents*) soils occur in the more xeric uplands. Polar Desert soils have undergone acid leaching but maintain some features of Polar Desert soils in the high arctic, above ca. 75"N latitude. Most of the soils are extremely to strongly acid and contain low amounts of organic matter, exchangeable bases, extractable phosphorus, and clay. Arctic Brown and Minimal Podzol soils contain the greatest amount of water-soluble salts. The order of abundance of cations in water extracts is Ca> Mg> Na >K> H, and thus are typical of well-drained soils of semiarid regions. Dominant textures are gravelly or cobbly sand and loamy sand. Silt increases markedly with soil depth, possibly due to vertical frost sorting. Kaolinite is prevalent in the clay fraction of Polar Desert soils; mica is most abundant in the other soils. Poor profile development, frost sorting, variable snow cover, and differences in vegetation and microclimate over short distances have affected soil properties, thereby limiting the use of soils in estimating relative age of moraines. Soil properties most related to age are depth of oxidation, maximum percent free iron, color of the surface mineral horizon, and kaolinite/mica ratio in the clay-size fraction.

Brown, O., J. R. Harris, D. Utting and E. C. Little. 2007. ***Remote predictive mapping of surficial materials on northern Baffin Island: developing and testing techniques using Landsat TM and digital elevation data***. Current Research 2007-B1, Geological Survey of Canada. 12pp.

Abstract taken directly from text
Considering the vastness of Nunavut, the paucity of regional-scale surficial geology maps for the territory, the significant expense of working in a remote region, and the increasing availability of affordable, remotely sensed data, it is timely to develop and test remote predictive mapping techniques for producing surficial geology maps. The goals of this remote predictive mapping project is to produce a surficial materials map, which will be used to expedite subsequent ground-based mapping and sampling. This paper describes techniques used to produce a surficial materials map for an area in northern Baffin Island using remote predictive mapping techniques with Landsat TM and digital elevation data. The predictive maps produced in advance of the field work (i.e. “ground truthing”) were found to be approximately 50% accurate. To improve remote predictive mapping accuracy to at least 80%, high-resolution imagery may need to be included in the remote predictive mapping protocol.

Crowe, R. B. 1976. ***A Climatic Classification of the Northwest Territories for Recreation and Tourism***. Project Report 25, Meteorological Applications Branch, Atmospheric Environment, Environment Canada, Toronto, ON. 232 pp.

Abstract
1) Temperature usually decreases at a rate of ~3 degrees F with every 1000 ft. elevation increase
2) Precipitation also usually increases with elevation.
3) The lee side of a mountain barrier has much less precipitation and more sunshine than does the windward side.
4) Winds on the leeward side of a mountain range are relatively warm, dry, and often strong – the “foehr” or “Chinook effect”.
5) The more rugged the terrain, the more variable are the winds.
6) Coastal and lake shoreline locations usually have stronger winds than inland areas.
7) The strongest winds are located in coastal valleys with inland sections covered by large ice sheets.
8) Low elevations usually cool off more rapidly at night than higher elevation areas.

Everett, K. R. and R. J. Parkinson. 1977. Soil and Landform Associations, Prudhoe Bay Area, Alaska. ***Arctic and Alpine Research*** 9:1-19.

Abstract taken directly from text
Seven soils belonging to four soil orders are described from the Prudhoe Bay area, Alaska. The soils and their associated landforms, macro- and micro-, have been strongly conditioned by the progression of events related to the thaw-lake cycle. Pergelic Cryoborolls (Mollisols) occur on pingos and some high center polygons. Their thick mollic epipedons were produced, for the most part, in organic materials reworked in the bed of the lake from which the pingo originated. Less well drained Mollisols, Pergelic Cryaquolls, are found on slopes marginal to drainages, some interfluves and high center polygons, and occasionally on the rims of well-developed low center polygons. Histic Pergelic Cryaquepts (Inceptisols) and Pergelic Crvohemists and Crvofibrists (Histosols) are commonly associated with drained lake basins and low center polygon terrain. The Histosols may be the products of long stable conditions which permitted the development of thick peaty deposits or their organic material may represent the products of present vegetation laid down on old reworked organic materials of the former lake. Pergelic Cryaquepts are common in areas lacking reworked organic materials in relatively recently drained lake basins and on some floodplains. Elevation of areas of reworked organic materials to better drained positions by the processes of thermokarst and thermal erosion or by uplift of polygon rims due to expansion of their underlying ice wedges results in oxidation of the mineral rich organic materials and in many cases the production of a mollic epipedon. Sand dunes and low river terraces are sites of Entisols- Pergelic Cryopsamments and Pergelic Cryorthents, respectively.

Seidel, K. H. 1987. ***The Climate of Auyuittuq National Park Reserve: A Review***. Habitat Management Section, Wildlife Management Division, Department of Renewable Resources, Yellowknife, Northwest Territories. 48 pp.

<u>*Abstract taken directly from text*</u>

The climate of Auyuittuq National Park Reserve is extremely harsh, complex, and variable. The long, cold winters are characterized by short days, light precipitation, and strong winds. Summers are short with moderate temperatures and long days. The climate is influenced by a number of regional and local controlling factors. The high latitude location of Auyuittuq, major air masses, and pressure systems govern weather patterns on a regional scale. Cyclonic (low pressure) activity affecting regional and local weather occurs year-round, but is most frequent in summer. Storms bring significantly great amounts of precipitation in late summer and fall than at any other time of the year. Peak precipitation occurs in October as snowfall. Local weather patterns are affected by the ruggedness of the mountains which often scatter storm systems and frequently cause cloud formation and precipitation. Vast areas of snow and ice cause temperature inversions, and extensive areas of open water moderate temperatures along coastal areas. Winds passing through narrow valleys, mountain passes, and fiords are subject to a channelling and intensifying effect. The wind channelling effect of fiords, and winder disturbances associated with inversions often restrict access to the Park by sea and air.

Tedrow, J. C. F. and J. E. Cantlon. 1958. Concepts of Soil Formation and Classification in Arctic Regions. ***Arctic*** 11:166-179.

<u>*Abstract taken directly from text*</u>

The soils of arctic Alaska can be arranged in a drainage catena in the same manner as those of other climatic regions. Mature or zonal soils (arctic brown) may be said to form only under adequate internal drainage. Tundra soils would thus not be considered mature or zonal, instead they would be intrazonal (hydromorphic). The arctic brown and related soils with brown surface horizons, tundra soils, and bog with permafrost are northern extensions or counterparts of podzol, humic glei, and bog soils, respectively. Plant communities have been successfully correlated with soils on well-drained sites and on areas of shallow soils. Correlation between soils and vegetation on the tundra and bog soils, however, poses major problems. Non-correspondence of soil profile with current site conditions is widespread because of the lag in development processes. Vegetation reflects the changes somewhat earlier. If relative wetness of the site is considered together with the profile morphology a workable relationship between soils and plant communities generally exists; and if the nature of the cryopedologic features is mapped independently, suitable soil maps may be prepared. Appreciation is expressed to R. B. Alderfer, F. E. Bear, F. H. Bormann, L. A. Douglas, J. V. Drew, J. J. Koranda, and R. E. Shanks, for important field discussions and critical examination of the manuscript. The earlier phases of our arctic investigations were supported by Boston University, Physical Research Laboratory. These studies were aided by a contract between ONR, Department of the Navy, and the Arctic Institute of North America. Reproduction in whole or in part is permitted for any purpose of the United States government.

2.4 <u>PLANTS</u>

Anderson, D. G. and L. C. Bliss. 1998. Association of Plant Distribution Patterns and Microenvironments on Patterned Ground in a Polar Desert, Devon Island, NWT, Canada. ***Arctic and Alpine Research*** 30:97-107.

<u>*Abstract taken directly from text*</u>

In this study, we quantify the distribution patterns of vascular plant species among microsites (stony border, transition, and center) of sorted stone nets and stripes. We also monitored edaphic factors (frost heave, temperature, moisture, and texture) at three intensive sites to identify controls on plant distribution. Adult plants were more abundant in the transition microsite (73 and 77%) with its cryptogamic crust than random distribution would predict (transition cover 17 and 14%) at the noncrusted stone nets and stone stripes, respectively. Adult plants were frost heaved (10 and 32%) from the bare-soil center

microsites at both sites. Nearly all of the few seedlings were in the transition microsite. At the crusted stone net, three species were randomly distributed; five species were over-represented in the two border microsites and two species were underrepresented there. No plants were frost heaved at this site and seedlings were abundant. There were 7.3 plants per lineal meter at the crusted net and only 3.0 and 2.3 plants per lineal meter at the non-crusted stone stripes and stone nets respectively. Of the environmental factors measured, soil heave (measured as soil settlement) appears most influential. Surface soils (0-1 cm) dry between summer rains and this may inhibit seedling establishment some summers. Soils at depth (5-10 cm) remain near saturation. Soil temperatures differed little between microsites as did soil texture.

Bay, C. 1997. Floristical and Ecological Characterization of the Polar Desert Zone of Greenland. ***Journal of Vegetation Science*** 8:685-696.

Abstract taken directly from text
Species composition and biomass of four plant communities were investigated in two coastal polar desert areas in eastern North Greenland, bordering the North East Water Polynya - an ice-free sea area kept open by upwelling – and compared with inland areas in North Greenland. Herb barren, the poorest type, has a species richness of 6 species/m^2, a cover of 0.7 %, and an above-ground biomass of 0.6 g/m^2 (vascular plants). The richest type, *Saxifraga oppositifolia* snowbed, has 10 species/m^2, 5.0 % cover, and 11.2 g/m^2 biomass. A floristic and vegetation boundary exists a few kilometres from the coast. The coastal areas bordering the North East Water Polynya had an impoverished flora and vegetation compared to areas near the ice-covered sea, possibly caused by very low summer temperatures and high frequency of clouds. A new delimitation of the polar deserts of Greenland is proposed on the basis of the number of vascular plant species, the occurrence of species with a specific inland distribution in North Greenland and the dominating life forms. At present the polar desert zone includes only areas within a zone up to ca. 15 km from the outer coast of high arctic Greenland - north of ca. 80" N. Large areas formerly classified as polar deserts in eastern North Greenland, as well as in Washington Land in western North Greenland, are excluded. New floristic data confirm that Greenland is correctly included in the Canadian province of the arctic polar deserts, whereas there is no reason for subdividing the polar deserts of the Canadian province.

Billings, W. D. 1973. Arctic and Alpine Vegetations: Similarities, Differences, and Susceptibility to Disturbance. ***BioScience*** 23:697-704.

Abstract not available [excerpts directly from text]
The short summer growing season of the Arctic and the low temperatures in this area result in smaller, short-stemmed perennial herbaceous plants, prostrate shrubs, lichens, and mosses. Desiccation and ice-abrasion can kill tissues extending above the snowpack in the Arctic, so trees are usually not found. The treeless landscape and low-lying vegetation is generally called tundra. Tundra can also be found in Equatorial regions and in mid-latitude regions, but differences do exist. A number of differences exist in plant communities growing at different latitudinal or altitudinal gradients. When referring to latitudinal gradients, the terms High Arctic, Low Arctic, Alpine, and Equatorial Alpine are used. There are also mesotopographic gradients, which are a series of smaller topographic gradients from ridge tops to wet meadows and bogs. These gradients are superimposed upon the latitudinal environmental gradient, and also upon the various altitudinal gradients. Furthermore, tundra areas have a more favourable balance of atmospheric and soil water than Polar deserts, so the abundance of grasses and mosses is generally greater. Other factors, like the local mesotopographic gradients, glacial history, proximity to water bodies, floristic migrations and evolution, animal effects and disturbance by humans causer there to be a mosaic of vegetation at any arctic or alpine location. Some plants species that are found in the United States are also found in the Arctic, and are often specialized for the particular environment they are in. These plants may be genetically different in the form of ecotypes. Tests conducted on the plant *Oxyria digyna*, or alpine sorrel, found that it consists of two main ecotypes (alpine and arctic) which different in many morphological and physiological ways. The alpine ecotypes had larger leaves with lower chlorophyll content and were larger plants. They also reach peak photosynthesis at higher temperatures and higher

light intensities than the Arctic ecotype. Another topic which was looked at was the susceptibility to disturbance of arctic and alpine environments. The two environments are compared, and both can be considered “fragile.”

Billings, W. D. 1987. Constraints to Plant Growth, Reproduction, and Establishment in Arctic Environments. ***Arctic and Alpine Research*** 19:357-365.

Abstract taken directly from text

Plant metabolism, growth, and reproduction in the Arctic are controlled by the interactions of physical environment and the genetic structure of an old, relatively small, winter-adapted flora. Gradients of both are described with particular reference to decreasing floristic richness toward the cold summer climates of high latitudes. Photosynthesis is restricted to the C_3 mode. Plant growth is constrained primarily by low air and soil temperatures, shallow depth of thaw, nutrient deficiencies, and at higher latitudes and elevations by drought stress. Arctic plants have one trait differentiating them from all others: the ability to metabolize and grow at temperatures only slightly above freezing.

Billings, W. D. 1997. Arctic Phytogeography. In: ***Disturbance and Recovery in Arctic Lands***, ed. by R. M. M. Crawford, Kluwer Academic Publishers, Netherlands. pp. 25-45.

Abstract not available [excerpts directly from text]

As the climates warms over the next few decades, it is unknown how the vegetation and flora may change in the Arctic. Only 1,000 of the approximately 250,000 know species of vascular plants on Earth occur in the Arctic. Floristic richness has a positive correlation with annual temperature in a region. A number of plant features also correspond to yearly temperature. For example, maximum net photosynthesis rates were higher in arctic populations that in alpine populations, and the difference could be increased by cold acclimation. In the plant *Oxyria digyna*, tests have shown that it is under genetic control and that “acclimation ecotypes” exist. The most plastic phenotypes in regard to acclimation occur in alpine ecotypes. Despite much research and modelling efforts, it is hard to predict global warming. A community will likely respond individualistically to climate change or to increases in ultraviolet-B radiation. There is the danger that the melting of warming permafrost will lead to sever thermokarst erosion and the loss of vegetation that holds tundra ecosystems together. This may lead to sparsely vegetated areas where the original vegetation has died out but where more southerly species have not yet arrived.

Bliss, L. C. 1962. Adaptations of Arctic and Alpine Plants to Environmental Conditions. ***Arctic*** 15:117-144.

Abstract not available [excerpts directly from text]

In his “Circumpolar Arctic Flora” Polunin (1959) recognizes 66 families, 230 genera, and 892 species of the division Tracheophyta. According to Love (1959), probably two-thirds of the arctic species are endemic. There is a striking reduction in number of species with increasing latitude that results from an increasing severity of the environment and a reduction of land area and available soil. Woody plants decrease rapidly going northward in the Canadian Arctic Archipelago. Organic matter decomposition rates were found to be regulated more by soil temperature than soil moisture in Alaska, and annual rates of decomposition are of the same order of magnitude as rates of organic matter production per year. Light intensity, community succession, and temperatures in the Arctic are also discussed. Tundra plants seem amazingly efficient with regard to energy conversion, and this can be attributed to utilization of a large portion of the growing season for growth and development, the use of considerable carbohydrate reserves of the previous year, and the higher caloric values of the species. Tundra plants are quite well adapted to the environments in which they grow and reproduce.

Bliss, L. C. and J. Svoboda. 1984. Plant communities and plant production in the western Queen Elizabeth Islands. ***Holarctic Ecology*** 7:325-344.

Abstract taken directly from text
A study of soils, plant communities, and net annual plant production was conducted with 41 stands at 3 sites on 3 arctic islands. Twelve additional sites were studied in less detail on Ellef Ringnes, King Christian and Melville islands and on four other islands. Through polar ordination five groupings were recognized. *Alopecurus* and *Puccinellia* barrens on sand to silty soils and on silty soils, high in sodium salts respectively. Species richness averaged 2.6 ± 2.0 and total plant cover 6.8 ± 2.7%. The *Phippsia* barrens occur on sheet eroded surfaces and in gulleys with deep winter snow. Species richness was 9.8 ± 5.0 and total plant cover 14.8 ± 9.6%. The graminoid steppes on sandy soils averaged 7.6 ± 2.4 species and total plant cover 40.0 ± 2.8%. Eight stands were dominated by moss-graminoids, mostly on loam soils. Species richness was 24.9 ±3.4 and total plant cover 77.7 ± 16.1%. Plant production was 8.0 g m-2 in a *Puccinellia* barren and 9.4 g m-2 in a *Luzula confusa* graminoid steppe. Net annual production ranged from 18.8 to 58.7 in 6 other stands. The 13 stands within the cryptogam-herb community complex occur on sandy loam to clay-loam soils. Species richness averaged 26.3 ± 6.2 and total plant cover 61.2 ± 24.7%. Mosses and lichens play a significant role in the establishment and maintenance of communities with a greater species richness and plant production of vascular plant species. The ability of mosses to hold moisture and the presence of limited blue-green algae that fix nitrogen appear essential to the maintenance of greater species richness, plant cover and plant production compared with the barren polar deserts that are often nearby.

Bliss, L. C., J. Svoboda and D. I. Bliss. 1984. Polar deserts, their plant cover and plant production in the Canadian High Arctic. ***Holarctic Ecology*** 7:305-324.

Abstract taken directly from text
A total of 41 stands was sampled for species composition and 29 of these stands for plant standing crop and net annual production at 7 sites on 6 arctic islands. Fourteen additional sites on U) islands were studied in less detail. Through polar ordination, three groupings were recognized: polar barrens with an average species richness of 6, a phytomass of 24gm^{-2}, and a net annual production of 0.8 g m^{-2}. Comparable data for the cushion plant and snowflush communities were 9, 120, 3 and 13 species, 4(K) g m^{-2}, phytomass and 41 g m^{-2} net production respectively. Cryptogams are minor except within showflush communities. The soils show no horizon development, arc alkaline, and are very tow in organic matter, nitrogen, and phosphorus. It is believed that the combination of limited soil moisture in mid-summer and very low nutrient levels are the primary reason for such low plant cover and plant production in these predominantly polar barren landscapes. Geologic substrate with an abundance of frost-shattered rock and topographic position are factors that control the limited availability of water.

Broll, G., C. Tarnocai and G. Mueller. 1999. Interactions between Vegetation, Nutrients and Moisture in Soils in the Pangnirtung Pass Area, Baffin Island, Canada. ***Permafrost and Periglacial Processes*** 10:265-277.

Abstract taken directly from text
Dry and moist Cryosols were compared on Baffin Island in the Canadian High Arctic considering vegetation, nutrient status and soil organic matter. Carbon and nitrogen contents and the C/N ratio were higher on the moist soils. Almost no differences were found, however, in the plant-available phosphorus and potassium. Cryoturbation plays an important role in nutrient cycling in moist soils since it not only translocates organic materials downwards, but also moves weathered mineral materials upwards and laterally. It is predicted that, in permafrost areas in Canada,climate warming will affect soil organic matter and the nutrient status of these moist soils, whereas the non-cryoturbated dry soils will be less affected.
Dry and moist Cryosols were compared on Baffin Island in the Canadian High Arctic considering vegetation, nutrient status and soil organic matter. Carbon and nitrogen contents and the C/N ratio were higher on the moist soils. Almost no differences were found, however, in the plant-available phosphorus and potassium. Cryoturbation plays an important role in nutrient cycling in moist soils since it not only translocates organic materials downwards, but also moves weathered mineral materials upwards and laterally. It is predicted that, in permafrost areas in Canada, climate warming will affect soil organic matter and the nutrient status of these moist soils, whereas the non-cryoturbated dry soils will be less affected.

Callaghan, T. V. and S. Jonasson. 1995. Implications for Changes in Arctic Plant Biodiversity from Environmental Manipulation Experiments. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 151-166.

Abstract not available [excerpts directly from text]

It is difficult to predict the effects climate change will have on arctic ecosystems. Longer-term trends in biodiversity based on environmental manipulations and changes will undoubtedly have an impact on arctic plants, and it is important to look at two concepts. First off, comparisons along an environmental severity gradient are used to test the generality of results from any one site in the context of the wider Arctic and to acknowledge that responses to the same change in climate should differ between different arctic ecosystems. Secondly, it is thought that individual species will respond differently to environmental change in different parts of their altitudinal/latitudinal geographical ranges and that they might be particularly responsive to climate change at their boundaries. There are a number of reasons why genotypic diversity may occur. Even if positive population growth is seen, if plants proliferate by vegetative meristems rather than recruitment from sexual reproduction, a loss of diversity will result. Changing competitive interactions can also result in a decline of genetic diversity among a population. Competitive interactions leading to changes in biodiversity can be generated by changes in soil nutrient availability, temperature, atmospheric CO_2, and UV-B. If soils change from environmental manipulation, there are implications for plant nutrition. Many vegetation types in the arctic are strongly correlated with moisture regimes. It is also possible for increasing carbon dioxide to reduce the nitrogen content of leaves relative to carbon, and could reduce leaf litter and those species that decompose leaf litter. Relatively few environmental changes, apart from extremes of soil moisture, are likely to affect biodiversity by directly killing plants.

Chapin III, F. S., S. E. Hobbie, M. S. Bret-Harte and G. Bonan. 1995. Causes and Consequences of Plant Functional Diversity in Arctic Ecosystems. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 225-237.

Abstract not available [excerpts directly from text]

There are many questions that must be asked when trying to understand or predicting how Arctic ecosystems will respond to global change. Two important questions pertaining to climate change are: 1) What kinds of species will respond most strongly to global changes in climate and land use?; and 2) what are the consequences of changes in species composition for ecosystem function? Plant functional groups are a simple framework to describe the physiognomic and physiological diversity present in natural ecosystems. Functional groups defined by plant size and RGR allow predictions of the effects of climate, soil resources, and animals on major functional groups of plants. Conversely, functional groups of plants which differ in size and RGR have predictably different effects on a wide range of ecosystem processes, including biogeochemical cycling, trace-gas fluxes, herbivory, pollination, plant-microbial interactions, and disturbance. Biogeochemical cycling, trace-gas flux, and disturbance rate are less sensitive to the identity of species within a functional group than are species interactions such as herbivory, pollination, and plant-microbial interactions. Genetic and species diversity are critical to providing insurance against major changes in ecosystem functioning, if global changes causes extinction of populations and species.

Crawford, R. M. M. 1997. Natural Disturbance in High Arctic Vegetation. In: ***Disturbance and Recovery in Arctic Lands***, ed. by R. M. M. Crawford, Kluwer Academic Publishers, Netherlands. pp. 47-62.

Abstract not available [excerpts directly from text]

Many habitats in the Arctic are physically fragile. The diminutive stature of the vegetation, the low number of species and lack of continuous plant cover, leaves a landscape that is prone to movement and physical disturbance by wind, water, ice and gravity. In the high Arctic, soil disturbance from constant physical movement and erosion creates the impression of a region occupied tenuously by fragile communities that could be irreversibly destroyed by any additional perturbation that might arise from climatic variation and human interference. In Arctic coastal habitats, ecotypes can evolve based on drainage, as some plants are covered in snow for up to 12 months of the year, while others are in drought-prone areas. Arctic flowering plants are often able to respond quite well to disturbance in the environment, and can even benefit from physical fragility and uncertainty of their environment. The cyclical nature of disturbance and stress at high latitudes maintains a high degree of polymorphism in Arctic plant populations. Such balanced polymorphisms not only confer immediate increased species fitness by increasing ecological tolerance, but also enhance long-term fitness which will pre-adapt many arctic species to long-term climatic oscillations.

Dansereau, P. 1954. Studies on Central Baffin Vegetation I. Bray Island. ***Plant Ecology*** 5-6:329-339.

Abstract not available [excerpts directly from text]
Bray Island was studied from May to September 1950 by a member of the BAIRF Expedition to Central Baffin Island. The goal of the many observations taken was to provide as clear and complete picture of the vegetation of this area as possible. Bray Island is about 6 miles off the west coast of Baffin Island, in Foxe Basin. Bray Island consists of a very low-lying network of Paleozoic limestone schists and gravel which extends over 22 by 17 miles. The tide is a fairly strong one and with wind, the salt spray could reach any part of the island. The island has marsh areas, gravel areas, sandy areas and salt marshes. Some plants that are abound and are of considerable ecological prominence on the mainland are conspicuously absent here, such as *Cassiope tetragona*, *Luzula confusa*, *Empetrum nigrum*, *Oxyria digyna* and *Salix herbaea*. Most of the species present here are very widespread in both the High and the Low Arctic and also occur in alpine situations: *Equisetum variegatum*, *Cerastium alpinum*, *Lychnis apetala*, *Papaver radicatum*, *Saxifraga caespitosa*, *Saxifraga cernua*, *Saxifraga hiculus*, *Saxifraga oppositifolia*, *Saxifraga tricuspidata*, *Stellaria laeta*, *Alopecurus alpinus*, *Carex atrofusca*, *Eriophorum scheuchzeri* and *Draba alpina*.

Dansereau, P. and E. E. Steiner. 1956. Studies in Potentillae of High Latitudes and Altitudes. II. Central Baffin Island Populations. ***Bulletin of the Torrey Botanical Club*** 83:113-135.

Abstract not available [excerpts directly from text]
In Central Baffin Island, five taxa of the genus *Potentilla* are reported: *pulchella* R. Br., *hyparctica* Malte, *vahliana* Lehm., *nivea* L. and *rubricaulis* Lehm. The characteristics of these plants are summarized in this paper. This includes morphological characteristics and measurements.

Edlund, S. A. 1992. ***Vegetation of Cornwalls and Adjacent Islands Northwest Territories: Relationships Between Vegetation and Surficial Materials***. Geological Survey of Canada, Ottawa, ON. 24 pp.

Abstract taken directly from text
Vegetation occurs on only 20% of Cornwallis and adjacent islands. This general lack of vegetation is due to 1) the high alkalinity of and lack of plant nutrients in the carbonates and evaporates from which the predominant soils are derived and 2) possible active cryoturbation. Where vegetation does occur, it is restricted to weakly to moderately alkaline materials, either on impure materials or carbonates that have supplementary materials added, such as marine deposits and marine reworked materials and till. The vegetation reflects the alkaline nature of the substrate, for calciphilous species such as *Saxifraga oppositifolia* and *Dryas integrifolia* are major vascular plant components of most plant communities. The densest vegetation is concentrated in lowland areas, valley bottoms, and on lower slopes where there is adequate or abundant moisture throughout most of the growing season and where some surface leaching and organic incorporation into soils occur. Nineteen plant communities are grouped by their composition, dominant growth form, and apparent growing season lengths into three bioclimatic zones within the High Arctic region. This is a high number for such a sparsely vegetated area and reflects the variety of microhabitats. Zone 3 has more than 60 vascular plant species and is dominated b prostrate shrubs and sedges. Zone 2 has 35 to 60 vascular plant species and is dominated

by herbs such as *Saxifraga oppositifolia*, *Luzula nivalis*, and *Alopecurus alpinus*, while sedges and prostrate shrubs have a minor role. Zone 1 has less than 35 vascular plant species and is dominated by herbs; sedges and dwarf shrubs are absent. This zonation also occurs locally in telescoped form down slope from late lying snowbeds, where the duration of the growth period is directly proportional to the length of time the unfrozen ground is exposed from beneath the gradually retreating snowbank.

Evans, B. M., D. A. Walker, C. S. Benson, E. A. Nordstrand and G. W. Petersen. 1989. Spatial Interrelationships between Terrain, Snow Distribution and Vegetation Patterns at an Arctic Foothills Site in Alaska. ***Holarctic Ecology*** 12:270-278.

<u>*Abstract taken directly from text*</u>
A multidisciplinary approach combining field surveys, aerial photographic techniques, digital terrain modelling, and GIS technology was used to analyze spatial interrelationships at a study site in the northern foothills of the Brooks Range. The sensitivity of snow drifting to topography at the site is pronounced. The drift patterns indicate winter winds are predominantly from the south with a major secondary component from the southwest. These southwest winds are likely in conjunction with storm events. The deepest snow beds are found on the steeper, north-facing slopes. Snow also has an effect on vegetation that is evident at the scale of mapping (1:6000). Communities dominated by *Cassiope tetragona* are associated with deeper snow regimes, and may be useful indicators of deeper snow regimes even at much smaller scales because of their unique spectral signatures. The analyses conducted to date demonstrate the power of the GIs for analyzing terrain-geobotanical interrelationships, which will increase as we add new layers for other variables, and are able to correlate these with satellite data.

Forbes, B. C. 1994. The Importance of Bryophytes in the Classification of Human-Disturbed High Arctic Vegetation. ***Journal of Vegetation Science*** 5:877-884.

<u>*Abstract taken directly from text*</u>
Evidence is presented from a variety of tundra cover types under human disturbance at three sites in the Canadian High Arctic to indicate that higher plants may be insufficient to differentiate among the apparently distinct geobotanical signatures of discrete surface disturbances. Unlike in the Low Arctic, woody growth forms are often minimal or lacking on heavily disturbed ground and several prominent species of ruderal herbs and especially graminoids occur on a wide variety of substrates. Therefore, cryptogams, particularly bryophytes, are important indicator taxa. Presence-absence data on bryophytes from minerotrophic and oligotrophic soils, combined with vascular cover-abundance data, enhanced detection of patch-level floristic gradients within and among disjunct coastal lowlands. However, the pool of ruderal bryophytes is limited, and ultimately factors such as frequency and abundance should be considered.

Forbes, B. C. 1996. Plant Communities of Archaeological Sites, Abandoned Dwellings, and Trampled Tundra in the Eastern Canadian Arctic: A Multivariate Analysis. ***Arctic*** 49:141-154.

<u>*Abstract taken directly from text*</u>
Arctic terrestrial ecosystems subjected to anthropogenic disturbance return to their original state only slowly, if at all. Investigations of abandoned settlements on three islands in the eastern Canadian Arctic Archipelago have detected striking similarities among contemporary and ancient human settlements with regard to their effects on tundra vegetation and soils. Ordination procedures using 240 quadrats showed the plant assemblages of Thule (ca. 800 B.P.) winter dwellings on northern Devon and southern Cornwallis Islands to be floristically similar to pedestrian-trampled meadows on northeast Baffin Island last used ca. 1969. Comparisons from the literature made with other North American sites in the Low Arctic reveal similar findings. The implication is that the depauperate flora of the Arctic has a limited number of species able to respond to disturbance, and that anthropogenically disturbed patches may be extremely persistent.

Gould, W. A. and M. D. Walker. 1999. Plant Communities and Landscape Diversity along a Canadian Arctic River. ***Journal of Vegetation Science*** 10:537-548.

<u>*Abstract taken directly from text*</u>

We analysed the structure and diversity of the vegetation along an Arctic river to determine the relationship between species richness and plant community structure. We examined whether variation in species richness along the corridor is structured as (1) an increase in the number of communities due to increasing landscape heterogeneity, (2) an increase in the floristic distinctiveness (β-diversity) of communities, or (3) an increase in within-community richness (α-diversity) as species-poor communities are replaced by species-rich communities. We described 24 community types and analysed the relationship between site vascular species richness (γ-diversity) and β-diversity, α-diversity, site environmental heterogeneity, and the number of distinct plant communities. We also measured diversity patterns of vascular, bryophyte, and lichen species within communities and examined their relationship to community-level estimates of environmental factors. We found that an increase in site species richness correlated with an increase in the number of communities (r^2= 0.323, P=0.0173) and β-diversity (r^2=0.388, P=0.0075), rather than an increase in the α-diversity of individual communities. Moisture and pH controlled most of the differences in composition between communities. Measures of species richness and correlations with moisture and pH within communities differed among vascular. bryophyte. and lichen species. Bryophyte richness was positively correlated with moisture (r^2 = 0.862, P =0.00 10) and lichen richness was negatively correlated with moisture (r^2 =0.809, P =0.003 1). Vascular plants had a peak in richness at pH 6.5 (r^2 = 0.213.P < 0.0001). We conclude that site variation in vascular richness in this region is controlled by landscape heterogeneity, and structured as variation in the number and distinctiveness of recognizable plant communities.

Hale Jr., M. E. 1954. Lichens from Baffin Island. ***American Midland Naturalist*** 51:232-264.

<u>*Abstract not available [excerpts directly from text]*</u>

In the summer of 1950, the author took part in an expedition of the Arctic Institute of North America to Baffin Island, which was the first scientific expedition of its kind to study intensively in the Canadian Eastern Arctic for an entire season. The centre of activity was around Clyde Inlet, and studies looking at lichen flora were carried out. Lichenological research on Baffin Island has provided us with a workable knowledge of the macrolichen flora. The nature of bedrock has a considerable influence on the lichen flora. Most of the stations underlain by acidic rocks have a relatively rich lichen flora. Although Baffin Island does not lie at a high altitude, the general atmospheric and oceanic circulation makes it much cooler than other land masses at the same latitude. The majority of lichens occurring on this land mass are common to all arctic lands and circumpolar in distribution. This includes 230 or 90 percent of the 257 species in the present list. These 257 species are 97 more species than previous expeditions identified.

Hanson, H. C. 1953. Vegetation Types in Northwestern Alaska and Comparisons with Communities in other Arctic Regions. ***Ecology*** 34:111-140.

<u>*Abstract not available [excerpts directly from text]*</u>

In making surveys for reindeer winter lichen range in north western Alaska, a classification of the major kinds of vegetation was needed to show relationships between the distribution and abundance of lichens and the major types which could be readily distinguished on the ground or from the air. Previous classifications of arctic vegetation, such as those used by Polunin have been based upon topographic location, physiognomy, and major constituent species. Raup summarized many of the difficulties in the delimitation of arctic plant communities and in the determination of successional relationships. Scandinavians, such as Du Rietz, Nordhagen, and others have used topographic location, physiognomy, and major constituent species for delimiting the chief geographic communities, and they have also used data from sociological analyses for precise classifications to include orders, alliances, associations, and sociations. They also have included descriptions of habitats and successional relationships. A large amount of work is needed to develop a classification applicable to the entire Arctic zone. As a result of study during the summers of 1949, 1950, and 1951, a preliminary classification of the vegetation of north western Alaska is presented. It contains 6 major physiognomic classes and 22 types. A characterization is given of each type, including the species composition, some of the environmental conditions, and aerial recognition characteristics. Eight new phytosociological analyses of different communities are presented, and the types occupying the largest land areas are the cottongrass-sedge-dwarf shrub-heath complex, sedge marshes, alpine *Dryas*, dwarf shrub, willow shrub, birch shrub, and white-spruce-shrubs.

Henry, G. H. R. 1998. Environmental influences on the structure of sedge meadows in the Canadian High Arctic. ***Plant Ecology*** 134:119-129.

<u>*Abstract taken directly from text*</u>
Wet sedge-dominated communities (sedge meadows) were sampled in five lowland oases in the Queen Elizabeth Islands of the Canadian High Arctic to assess species-environment relationships. The sites spanned 4^{o} of latitude, and varied in lithology and intensity of grazing by muskoxen (*Ovibosmoschatus*). A suite of 8 vascular species were common in all meadow stands, with an additional 4 - 6 species found in most stands. The position of these species in dominance-diversity curves was not significantly different between grazed and ungrazed meadows however, the grazed sites appeared to follow a log-normal distribution, while the ungrazed sites were more geometric. Redundancy analysis indicated that grazing intensity is important in determining structure in arctic sedge meadows, largely through increasing the cover of bryophytes and the availability of nitrogen. Greatest species richness was found in the more southerly sites which were moderately grazed and had diversity in microtopography.

Hines, J. E. and S. Moore. 1988. ***The Vegetation and Flora of Auyuittuq National Park Reserve, Baffin Island***. File Report No. 74, Department of Renewable Resources, Government of the Northwest Territories, Yellowknife, NWT. 93 pp.

<u>*Abstract taken directly from text*</u>
The purposes of this investigation were to describe the flora and major types of plant communities present in Auyuittuq National Park Reserve, Baffin Island, and to evaluate factors influencing the distribution of the local vegetation. Six major types of plant communities were recognized based on detailed descriptions of physical environment, flora, and ground cover of shrubs, herbs, bryophytes, and lichens at 100 sites. Three highly interrelated variables (elevation, soil moisture, and texture of surficial deposits) seemed to be important in determining the distribution and abundance of plant communities. Continuous vegetation developed mainly at low elevations on mesic to wet, fine-textured deposits.

Hodkinson, I. D., S. J. Coulson and N. R. Webb. 2003. Community assembly along proglacial chronosequences in the high Arctic: vegetation and soil development in north-west Svalbard. ***Journal of Ecology*** 91:651-663.

<u>*Abstract taken directly from text*</u>
1) Community assembly is described for two contrasting high Arctic chronosequences representing glacial regression of up to 2000 years on Svalbard. The chronosequences included a nutrient-poor glacier foreland (Midtre Lovénbre) and a series of nutrient enriched islands (Lovén Islands) progressively released from below a tidewater glacier.
2) Soil development and community assembly paralleled proglacial sequences elsewhere but time scales were extended and mature vegetation types comprised species-poor prostrate communities.
3 Initial colonization by Cyanobacteria stabilized soil surfaces and raised nutrient status. Cyanobacteria formed the dominant ground cover (up to 34%) for 60 years, after when they declined.
4) Vascular plants established slowly and represented minor components of ground cover for the first 100 years. Earliest colonizers were often species with ectomycorrhizal associations, followed by mid-successional species that tended to disappear as ground cover increased. Some species present in the mature vegetation at the oldest sites, established only after 60+ years.
5) Species richness of vascular plants increased for *c.* 100 years, beyond when only occasional species were added. Bryophytes became increasingly dominant with time.

6) Soil development on the Midtre Lovénbre and Lovén Island chronosequences was similar after 100 years. Differences subsequently developed, with organic horizon depth, percentage organic matter and water content on the older Lovén islands significantly greater than at equivalent Midtre Lovénbre sites. This was associated with increased bryophyte cover but lower vascular plant species richness. One explanation is a slightly more favourable microclimate, coupled with nutrient input from nesting birds.
7) Communities progressively recruit from a limited pool of effectively dispersed species, each with particular ecological requirements that determine their point of entry into the community. A measure of determinism by default is suggested in the way communities assembled.
8) Under climate warming, in the absence of nutrient enrichment, community development will accelerate but will be constrained by nutrient limitations and a restricted species pool. Where nutrients are less limiting, acceleration towards a moss-dominated community is expected, with a lower species richness of vascular plants.

Jacobs, J. D., A. N. Headley, L. A. Maus, W. N. Mode and E. L. Simms. 1997. Climate and Vegetation of the Interior Lowlands of Southern Baffin Island: Long-term Stability at the Low Arctic Limit. ***Arctic*** 50:167-177.

Abstract taken directly from text
The interior of southern Baffin Island between 64°N and 68°N latitude is a mainly lowland area over 50 000 km^2 in extent, containing two large lakes (Amadjuak and Nettilling) and numerous smaller lakes and ponds. This area is important as summer range for caribou and a variety of birds, and there is evidence for a human presence as early as 3000 B.P. Field studies between 1984 and 1988 and the operation of climatic autostations from 1987 to 1995 revealed a warm summer climate and cold winters. There is a locally rich and diverse vegetation, including *Betula glandulosa* and other species that are indicative of the low arctic bioclimatic zone and mark the present northern limit of that zone in the eastern Canadian Arctic. Air photos and Landsat imagery were used to map vegetation beyond the field areas, leading to an estimate of 46% of the land area in continuous vegetation (tundra) of some type and 15% with shrub and heath elements. Palynology of sediment cores taken from Nettilling Lake permitted extrapolation from present bioclimatic conditions to 4750 years B.P. *Betula* and therefore elements of a low arctic vegetation association appear to have been present in the area during most of that period, indicating a local bioclimatic system that has been relatively stable under regional variations of climate.

Koerner, R. M. 1980. The Problem of Lichen-Free Zones in Arctic Canada. ***Arctic and Alpine Research*** 12:87-94.

Abstract taken directly from text
The origin of lichen-free areas in the High Arctic has been attributed to lichen-kill under permanent snowfields developed *300* yr ago during the Little Ice Age. There are inconsistencies in this hypothesis, particularly in regard to the manner of lichen-kill, the mechanism of dead lichen removal once the previously ice-covered ground is exposed again, the period when the lichen-kill occurred, and the form of lichen trimlines. An alternative hypothesis is suggested whereby lichen-free areas occur where seasonal snowfields persist for a much greater part of the summer than elsewhere. As a result the lichen growth season there is very short.

Liptzin, D. 2006. A Banded Vegetation Pattern in a High Arctic Community on Axel Heiberg Island, Nunavut, Canada. ***Arctic, Antarctic, and Alpine Research*** 38:216-223.

Abstract taken directly from text
On Axel Heiberg Island, Nunavut, Canada, a banded vegetation pattern occurred on a hillside where patterned ground and unidirectional abiotic fluxes, such as down slope water flow or wind, were not present. The parent material was the obvious source of the plant pattern, as the soils occurred on five distinct types of alluvial deposits. To examine the observed pattern, plants were inventoried and soils were sampled in July 1999. Twelve vascular species of plants, but no non-vascular species, were present at the site. Neither water, often thought to limit plant distribution in the High Arctic, nor any of the other

measured soil variables, predicted plant abundance. The best predictor of plant abundance, based on regression tree analysis, was total soil nitrogen; however, higher plant density was associated with lower nitrogen. The five soil types differed in plant density and soil properties. Even though the sand soil always had soil nutrients equal to or lower than the blocky clay soil, the sand and clay soils had the highest plant density and the blocky clay soil the lowest. Although the vegetation pattern is obvious, the underlying mechanism creating the pattern is not.

McLaren, J. R. 2006. Effects of Plant Functional Groups on Vegetation Dynamics and Ecosystem Properties. ***Arctic*** 59:449-452.

Abstract not available [excerpts directly from text]
There is the growing concern that species loss will have important effects on ecosystem functioning. Recently, removal experiments in natural communities are being promoted as a more realistic way to examine the consequences of biodiversity loss. The questions that are asked are 1) Do different functional groups have different effects on community dynamics and ecosystem processes?; and 2) Does the role of a functional group change when the environment changes? The study area is near Kluane Lake in the south western Yukon. Three grassland plant functional groups, graminoids, nonleguminous forbs (hereafter called forbs), and legumes, were transplanted and grown in plots with different combinations of these plants. Litter decomposition results indicate that grasses play an important role in this ecosystem in controlling nutrient recycling. The research examines the role that different functional groups play in determining ecosystem processes within a natural grassland. It also looks at whether the roles are consistent between environments or whether environmental change may also lead to changes in the relationship between plant functional groups and their environment.

Molenaar, J. G. 1987. An Ecohydrological Approach to Floral and Vegetational Patterns in Arctic Landscape Ecology. ***Arctic and Alpine Research*** 19:414-424.

Abstract taken directly from text
Water is a fundamental landscape ecological factor. Its behavior in space and time, governed by initial and independent state factors such as climate and topography, largely controls the spatial patterning of primary plant species and vegetation types. The ecologically relevant quantitative and qualitative characteristics of the water regime at a given locality depend largely on its position relative to its hydrological source-sink system. These characteristics influence plant life conditions within the site directly (e.g., moisture supply) and indirectly (e.g., nutrient supply, pH). This complex of relationships is contained in an ecohydrological approach developed in The Netherlands and adapted to arctic conditions present in central southeast Greenland. It is suggested that this approach may help to increase our understanding of the local to regional patterning in the plant cover and to recognize conditions of special interest and vulnerability. Therefore, it may assist in predicting the impact of both natural changes and human activities and in tracing general processes of succession and possibilities for conservation and regeneration.

Mori, A., T. Osono, S. Iwasaki, M. Uchida and H. Kanda. 2006. Initial recruitment and establishment of vascular plants in relation to topographical variation in microsite conditions on a recently-deglaciated moraine on Ellesmere Island, high arctic Canada. ***Polar Bioscience*** 19:85-95.

Abstract taken directly from text
We investigated the effects of topographical positions (moraine ridge, upper side slope and lower side slope) within a recently-deglaciated young moraine on initial recruitment and establishment of vascular plants. Compared with the moraine ridge, the upper slope had similar/higher abundance of vascular plants in terms of percent cover, frequency occurrence, species number, and density/biomass of a dominating species, *Salix arctica*. Establishment and growth of vascular plants are generally inhibited on unstable habitats; nevertheless, on this newly-formed moraine, every attribute measured for vascular plants implied a higher probability of vascular plant recruitment on the upper slope, where substrate is less stable than on the ridge. Further, the microsite with greater vascular plant abundance, *S. arctica*

density and *S. arctica* aboveground/leaf biomass accumulated more organic materials regardless of topographical positions, and such an organic accumulation was deepest on the upper slope, suggesting that relatively-successful plant establishment occurs on this site. This is further supported by the *S. arctica* population structure, which implies a relatively-constant juvenile supply on the upper slope. Along a slope, unstable gravels easily slide down hill. This topographical process may cause large rock size and high surface cover by rocks on the lower slope. On the upper slope, the percent cover by rocks had therefore become smaller, leading to high cover by fine-grained sediments, which retain moisture favorable for germination and growth of vascular plants. This would enhance the emergence of pioneer vascular plant species, probably resulting in higher vascular plant abundance, density and biomass of *S. arctica* on the upper slope. This study suggests that during primary succession following deglaciation in the high arctic the upper slope of a newly-formed glacier moraine may be an important location for the initial recruitment and establishment of pioneer vascular plant species, such as *S. arctica*.

Murrary, D. F. 1994. Floristics, Systematics, and the Study of Arctic Vegetation: A Commentary. ***Journal of Vegetation Science*** 5:777-780.

<u>*Abstract taken directly from text*</u>
Some remarks are made on the special problem encountered in arctic plant geography and vegetation studies, viz. the circumpolar distribution of many taxa, which may have been described independently in different countries. 80% of the arctic bryophytes, 70% of the lichens and 50% of the vascular plants have a circumpolar distribution and especially amongst the vascular plants there are several cases of confusion. Special attention is paid to *Dupontia fisheri* s.l., *Carex aquatilis* s.l. and *C. bigelowii* s.l. Especially for a classification of vegetation based on floristic data, having a list of accepted plant names and knowing their synonyms is of paramount importance. An electronic database for arctic vegetation will foster, if not require, more unified approaches to the description of plant communities.

Oksanen, L. and R. Virtanen. 1997. Adaptation to Disturbance as a part of the Strategy of Arctic and Alpine Plants. In: ***Disturbance and Recovery in Arctic Lands***, ed. by R. M. M. Crawford, Kluwer Academic Publishers, Netherlands. pp. 91-113.

<u>*Abstract not available [excerpts directly from text]*</u>
There are many good reasons to be concerned about the impacts of various kinds of man-made disturbance on arctic and alpine ecosystems. However, it is argued in this paper that the traditional temperate-zone-oriented view of arctic and alpine ecosystems as extremely vulnerable to all kinds of disturbance is based partially on false generalizations. Similarly, the concept that arctic plants are unable to invade disturbed sites by means of sexual reproduction is also open to question. These false generalizations can lead to unnecessary defeatism in restoration problems and to unwarranted restrictions in the use of the tundra for grazing, which can be detrimental to biological diversity. It was concluded that the claims that the Arctic is a stress-influenced ecosystem with high sensitivity to disturbance and low capacity of recovery is only partially true. It applies primarily to poorly drained low and middle arctic grass-sedge tundras, where physical disturbance initiates secondary changes via its impact on permafrost and where the total seed production of the plant community is low. However, most arctic habitats are naturally highly disturbed, and adaptations to different kinds of disturbance are an essential part of the life history strategy of typical arctic plants.

Ostendorf, B. and J. F. Reynolds. 1998. A model of arctic tundra vegetation derived from topographic gradients. ***Landscape Ecology*** 13:187-201.

<u>*Abstract taken directly from text*</u>
We present a topographically-derived vegetation model (TVM) that predicts the landscape patterns of arctic vegetation types in the foothills of the Brooks Range in northern Alaska. In the Arctic there is a strong relationship between water and plant structure and function and TVM is based on the relationships between vegetation types and slope (tan β) and discharge (δ), two independent variables that can be easily derived from digital terrain data. Both slope and discharge relate to hydrological similarity within a

landscape: slope determines the gravitational hydrological gradient and hence influences flow velocity, whereas discharge patterns are computed based on upslope area and quantify lateral flow amount. TVM was developed and parameterized based on vegetation data from a small 2.2 km^2 watershed and its application was tested in a larger 22 km^2 region. For the watershed, TVM performed quite well, having a high spatial resolution and a goodness-of-fit ranging from 71–78%, depending on the functions used. For the larger region, the strength of the vegetation types predictions drops somewhat to between 56-59%.We discuss the various sources of error and limitations of the model for purposes of extrapolation.

Posse, G. and A. M. Cingolani. 2000. Environmental Controls of NDVI and Sheep Production in the Tierra del Fuego Steppe of Argentina. ***Applied Vegetation Science*** 3:253-260.

<u>*Abstract taken directly from text*</u>
We analysed vegetation dynamics in Tierra del Fuego steppes using Normalized Difference Vegetation Index (NDVI) data provided by advanced very high-resolution radiometer (AVHRR) on board the National Oceanic and Atmospheric Administration (NOAA) polar satellite. Our objective, at a regional scale, was to analyse the spatial variability of NDVI dynamics in relation to parent material and geographic location, representing the fertility and climate gradients respectively; at a local scale, it was to analyse the inter-annual variability associated with climate and its relation with sheep production indices. The general pattern of NDVI dynamics was analysed with Principal Component Analysis. We found that the geographic location was more important than landscape type in explaining NDVI dynamics despite the fact that the variation in landscape type reflects a fertility gradient strongly associated with floristic composition and secondary productivity. Discriminant Analysis was performed to identify the variables that better distinguish geographic units. The Northern region (with the lowest precipitation and the highest temperatures) had lower NDVI values over the year. In the Central region, NDVI reached the highest value of the season, surpassing both other regions. The Southern region (the coldest and moistest) had its growth pattern displaced towards the summer. For the Central region we analysed 10 years of monthly NDVI data with PCA. We found that precipitation from August to December and winter temperature are the most important determinants of overall NDVI values. Lamb production was correlated with spring and early summer NDVI values. Sheep mortality is affected by low NDVI values in late summer and high annual amplitude. Satellite information allowed us to characterize the vegetation dynamics of three ecological areas across the Fuegian steppe.

Rannie, W. F. 1985. Summer Air Temperature and Number of Vascular Species in Arctic Canada. ***Arctic*** 39:133-137.

<u>*Abstract taken directly from text*</u>
Exceptionally high correlations ($r = 0.90-0.97$) between number of vascular species and various indices of summer warmth at 38 localities in the Canadian Arctic support Young's contention that summer thermal regime is the most important ecological factor controlling the broad zonation of arctic flora. Highest correlations ($r= 0.97$) are with July mean temperature and mean number of degree-days above 0°C in July. Regression equations relating July mean temperature and number of species indicate a diversity gradient of about 25 species per degree. These equations provide estimates of species numbers or July temperatures in areas with poor climate or botanical data and may also be used to identify anomalous conditions.

Rayback, S. A. and G. H. R. Henry. 2005. Dendrochronological Potential of the Arctic Dwarf-Shrub *Cassiope Tetragona*. ***Tree-Ring Research*** 61:43-53.

<u>*Abstract taken directly from text*</u>
In this report, we describe the use of dendrochronological techniques on the circumpolar, evergreen dwarf-shrub, *Cassiope tetragona.* Using techniques such as cross-dating and standardization, and the software programs COFECHA and ARSTAN, we developed *C. tetragona* growth and reproduction chronologies for sites in the Canadian High Arctic. High-resolution chronologies may be used to

reconstruct past climate and phase changes in large-scale modes of atmospheric circulation (*e.g.* Arctic Oscillation, North Atlantic Oscillation), to investigate the growth and reproductive responses of the plant to ambient and manipulated environmental variables, and to reconstruct the plant's past ecohydrology ($\delta^{18}O$, δD, $\delta^{13}C$), gas exchange ($\delta^{13}C$) and mineral nutrition ($\delta^{15}N$). As *C. tetragona* is a circumpolar species, chronologies may be developed throughout the Arctic at sites where no trees exist, and thus provide new information on the past climate and environmental history of sites and regions previously unstudied.

Risto, V., J. Oksanen, L. Oksanen and V. Y. Razzhivin. 2006. Broad-scale vegetation-environment relationships in Eurasian high-latitude areas. ***Journal of Vegetation Science*** 17:519-528.

Abstract taken directly from text
Question: How is tundra vegetation related to climatic, soil chemical, geological variables and grazing across a very large section of the Eurasian arctic area? We were particularly interested in broad-scale vegetation-environment relationships and how well do the patterns conform to climate-vegetation schemes.
Material and Methods: We sampled vegetation in 1132 plots from 16 sites from different parts of the Eurasian tundra. Clustering and ordination techniques were used for analyzing compositional patterns. Vegetation-environment relationships were analysed by fitting of environmental vectors and smooth surfaces onto non-metric multidimensional scaling scattergrams.
Results: Dominant vegetation differentiation was associated with a complex set of environmental variables. A general trend differentiated cold and continental areas from relatively warm and weakly continental areas, and several soil chemical and physical variables were associated with this broad-scaled differentiation. Especially soil chemical variables related to soil acidity (pH, Ca) showed linear relationships with the dominant vegetation gradient. This was closely related to increasing cryoperturbation, decreasing precipitation and cooler conditions. Remarkable differences among relatively adjacent sites suggest that local factors such as geological properties and lemming grazing may strongly drive vegetation differentiation.
Conclusions: Vegetation differentiation in tundra areas conforms to a major ecocline underlain by a complex set of environmental gradients, where precipitation, thermal conditions and soil chemical and physical processes are coupled. However, local factors such as bedrock conditions and lemming grazing may cause marked deviations from the general climate-vegetation models. Overall, soil chemical factors (pH, Ca) turned out to have linear relationship with the broad-scale differentiation of arctic vegetation.

Schaefer, J. A. and F. Messier. 1995. Scale-Dependent Correlations of Arctic Vegetation and Snow Cover. ***Arctic and Alpine Research*** 27:38-43.

Abstract taken directly from text
We examined microscale correlations between tundra vegetation and snow cover on southeastern Victoria Island, arctic Canada. Univariate and multivariate relationships were assessed using correlation analysis and canonical correspondence analysis (CCA). Scale was modified by altering the size of the sampling unit (i.e., grain) from 1 to 1000 m. Correlation coefficients between single species and thickness of snow generally increased with increasing scale. At the largest scale, maximal correlations were found between mean thickness and percent cover of graminoids (r = 0.76) and *Saxifraga oppositifolia* (r = -0.67). Both snow thickness and graminoid cover were negatively related to elevation at least at the smallest grain. CCA revealed that lowland species *(Carex atrofusca, C. aquatilis C. bigelowii, Eriophorum angustifolium, Arctagrostis latifolia, Equisetum* spp., *Salix lanata)* exhibited positive associations with the thickness, basal hardness, and mean hardness of snow cover, and the frequency of pukak (depth hoar). Upland species *(Cassiope tetragona, Cetraria* spp., *Oxytropis* spp., *Saxifraga oppositifolia)* showed the converse relationships. These patterns were generally consistent across scales. Snow cover variables accounted for an increasing proportion of the variance in plant composition as scale increased.

Knight Piésold
CONSULTING

Shaver, G. R., L. C. Johnson, D. H. Cades, G, Murray, J. A. Laundre, E. B. Rastetter, K. J. Nadelhoffer and A. E. Giblin. 1998. Biomass and CO2 Flux in Wet Sedge Tundras: Responses to Nutrients, Temperature, and Light. ***Ecological Monographs*** 68:75-97.

Abstract taken directly from text

The aim of this research was to analyze the effects of increased N or P availability, increased air temperature, and decreased light intensity on wet sedge tundra in northern Alaska. Nutrient availability was increased for 6-9 growing seasons, using N and P fertilizers in factorial experiments at three separate field sites. Air temperature was increased for six growing seasons, using plastic greenhouses at two sites, both with and without N + P fertilizer. Light intensity (photosynthetically active photon flux) was reduced by 50% for six growing seasons at the same two sites, using optically neutral shade cloth. Responses of wet sedge tundra to these treatments were documented as changes in vegetation biomass, N mass, and P mass, changes in whole-system CO_2 fluxes, and changes in species composition and leaf-level photosynthesis. Biomass, N mass, and P mass accumulation were all strongly P limited, and biomass and N mass accumulation also responded significantly to N addition with a small N × P interaction. Greenhouse warming alone had no significant effect on biomass, N mass, or P mass, although there was a consistent trend toward increased mass in the greenhouse treatments. There was a significant *negative* interaction between the greenhouse treatment and the N + P fertilizer treatment, i.e., the effect of the two treatments combined was to reduce biomass and N mass significantly below that of the fertilizer treatment only. Six years of shading had no significant effect on biomass, N mass, or P mass. Ecosystem *CO,* fluxes included net ecosystem production (NEP; net CO_2 flux), ecosystem respiration (RE, including both plant and soil respiration), and gross ecosystem production (GEP; gross ecosystem photosynthesis). All three fluxes responded to the fertilizer treatments in a pattern similar to the responses of biomass, N mass, and P mass, i.e., with a strong P response and a small, but significant, N response and N X P interaction. The greenhouse treatment also increased all three fluxes, but the greenhouse plus N + P treatment caused a significant *decrease* in NEP because RE increased more than GEP in this treatment. The shade treatment increased both GEP and RE, but had no effect on NEP. Most of the changes in *CO,* fluxes per unit area of ground were due to changes in plant biomass, although there were additional, smaller treatment effects on CO_2 fluxes per unit biomass, per unit N mass, and per unit P mass. The vegetation was composed mainly of rhizomatous sedges and rushes, but changes in species composition may have contributed to the changes in vegetation nutrient content and ecosystem-level CO_2 fluxes. *Carex cordorrhiza,* the species with the highest nutrient concentrations in its tissues in control plots, was also the species with the greatest increase in abundance in the fertilized plots. In comparison with *Er&phorum angustifolium,* another species that was abundant in control plots, *C. cordorrhiza* had higher photosynthetic rates per unit leaf mass. Leaf photosynthesis and respiration of *C, cordorrhiza* also increased with fertilizer treatment, whereas they decreased or remained constant in *E. angustifolium* The responses of these wet sedge tundras were similar to those of a nearby moist tussock tundra site that received an identical series of experiments. The main difference was the dominant P limitation in wet sedge tundra vs. N limitation in moist tussock tundra. Both tundras were relatively unresponsive to the increased air temperatures in the greenhouses but showed a strong negative interaction between the greenhouse and fertilizer treatments. New data from this study suggest that the negative interaction may be driven by a large increase in respiration in warmed fertilized plots, perhaps in relation to large increases in P concentration.

Sturm, M., J. Schimel, G. Michaelson, J. M. Welker, S. F. Oberbauer, G. E. Liston, J. Fahnestock and V. E. Romanovsky. 2005. Winter Biological Processes Could Help Convert Arctic Tundra to Shrubland. ***BioScience*** 55:17-26.

Abstract taken directly from text

In arctic Alaska, air temperatures have warmed 0.5 degrees Celsius (°C) per decade for the past 30 years, with most of the warming coming in winter. Over the same period, shrub abundance has increased, perhaps a harbinger of a conversion of tundra to shrubland. Evidence suggests that winter biological processes are contributing to this conversion through a positive feedback that involves the snow-holding capacity of shrubs, the insulating properties of snow, a soil layer that has a high water

content because it overlies nearly impermeable permafrost, and hardy microbes that can maintain metabolic activity at temperatures of –6°C or lower. Increasing shrub abundance leads to deeper snow, which promotes higher winter soil temperatures, greater microbial activity, and more plant-available nitrogen. High levels of soil nitrogen favor shrub growth the following summer.With climate models predicting continued warming, large areas of tundra could become converted to shrubland, with winter processes like those described here possibly playing a critical role.

Svoboda, J. and G. H. R. Henry. 1987. Succession in Marginal Arctic Environments. ***Arctic and Alpine Research*** 19:373-384.

Abstract taken directly from text

In a broad sense the entire Arctic might be considered a "marginal" environment. Polar deserts and semi-deserts are marginal for establishment of vascular plants sensu stricto. In extreme polar habitats some populations of plants are not fully self-sustaining. These may not produce viable seed and depend on propagules dispersed from more favorable habitats, which may be quite remote. These marginal populations rarely progress beyond the initial invasion phase of succession. The second phase, stand formation and build-up of a critical standing crop which would lead to habitat improvement and finally to replacement of pioneer species, rarely occurs. Rather, the colonizers have been historically subjected to repetitive additional constraints such as short-term climatic variations, and unfavorable summer weather patterns, which result in meager progress and low survival rates. Instead of a progressive succession we often find evidence of slow advancement, holding position, retardation, retrogression, and reinvasion. In marginal habitats, the progress of succession can be defined as a function of the biological *driving forces* which are intrinsic to the invading and establishing species, and the environmental *resistances* which represent a sum of the adverse factors hindering the success of species establishment. Theoretically, the progress of re-vegetation and directional change in the plant community can be measured as a *successional half-time,* i.e., time required to achieve the mid-point of development expected in a particular habitat situation. In marginal habitats, this half-time can be measured on a time scale of millennia and may be virtually infinite.

Tape, K., M. Sturm and C. Racine. 2006. The evidence for shrub expansion in Northern Alaska and the Pan-Arctic. ***Global Change Biology*** 12:686-702.

Abstract taken directly from text

One expected response to climate warming in the Arctic is an increase in the abundance and extent of shrubs in tundra areas. Repeat photography shows that there has been an increase in shrub cover over the past 50 years in northern Alaska. Using 202 pairs of old and new oblique aerial photographs, we have found that across this region spanning 620km east to west and 350km north to south, alder, willow, and dwarf birch have been increasing, with the change most easily detected on hill slopes and valley bottoms. Plot and remote sensing studies from the same region using the normalized difference vegetation index are consistent with the photographic results and indicate that the smaller shrubs between valleys are also increasing. In Canada, Scandinavia, and parts of Russia, there is both plot and remote sensing evidence for shrub expansion. Combined with the Alaskan results, the evidence suggests that a pan-Arctic vegetation transition is underway. If continued, this transition will alter the fundamental architecture and function of this ecosystem with important ramifications for the climate, the biota, and humans.

Tedrow, J. C. F. and H. Harries. 1960. Tundra Soil in Relation to Vegetation, Permafrost and Glaciation. ***Oikos*** 11:237-249.

Abstract

The arctic tree line is widely accepted as the southern boundary of the tundra. The arctic tree line will be defined as the polar boundary of spruce, larch, or pine, whichever occurs farthest north. North of the tree line two principal climatic types of vegetation can be distinguished. The first, representing the typical arctic tundra, is confined to vast northern areas with very low precipitation, cool and short summers, and a long and extremely cold winter. The second type owes its existence to a warmer, maritime climate, with high precipitation distributed over the whole year, a cool but relatively long summer, and a relatively mild winter with much snow. This has been termed maritime tundra. In order to classify soil types into groups, they were separated based on vegetative cover. Field investigations revealed that highly different soil morphologies existed under major vegetative types, such as black earths of the grasslands and the podzolic soils of the temperate forest areas. This same line of reasoning was extended into the arctic and sub-arctic areas. A soil boundary was inferred at the forest-tundra transition, but field studies indicate that this boundary has only minor, if any, significance in the pedologic sense, and that this boundary does not necessarily mark a change in qualitative soil processes.

Thompson, D. C. 1980. A Classification of the Vegetation of Boothia Peninsula and the Northern District of Keewatin, NWT. ***Arctic*** 33:73-99.

Abstract taken directly from text
The vegetation of Boothia Peninsula and the northern District of Keewatin (212,500 km^2) was surveyed, and a vegetation classification suitable for synoptic level surveys of wildlife habitat was produced. A total of 45 plant communities was recognized on Boothia Peninsula. Principal components and discriminant function analysis were used to identify seven significant groupings of these communities. These seven groups, designated as the vegetation groups for Boothia Peninsula, were: Sedge Meadows, Willow Hummocks, Lichen-Dryas Plateaus, Seepage Slopes, Moss Tundra, Purple-Saxifrage Plains, and Rock Barrens. Forty-two plant communities were recognized in the northern District of Keewatin. The six significant groupings which resulted, and which were designated as the vegetation groups for the northern District of Keewatin, were: Sedge Meadows, Willow-Sedge Meadows, Orthophyll Shrub, Lichen-Heath Plateaus, Lichen Uplands, and Barrens. The species composition and relationship to the physical environment for each of these vegetation groups is described.

Van Der Wal, R. and R. W. Brooker. 2004. Mosses mediate grazer impacts on grass abundance in arctic ecosystems. ***Functional Ecology*** 18:77-86.

Abstract taken directly from text
1) Large herbivores have significant impacts on the structure and function of temperate and tropical ecosystems. Yet herbivore impacts on arctic systems, particularly the mechanisms by which they influence plant communities, are largely unknown.
2) High arctic vegetation, commonly overlying permafrost soils, is often moss-dominated with sparse vascular plant cover. We investigated the potential influence of large herbivores on arctic plant communities via their impact on the depth of the moss layer, leading to warmer soils and potentially benefiting vascular plants.
3) We found that grazer impacts on moss depth, and subsequently soil temperature, may influence vascular plant abundance and community composition because of the observed positive but growth-form-specific response of vascular plants to soil warming, promoting grasses in particular.
4) We propose that the positive association of grasses and large herbivores in arctic moss-dominated systems results from two simultaneously operating positive feedback loops. First, herbivore grazing and trampling reduces moss layer depth, increasing soil temperatures. Second, grasses benefit directly from grazers as a result of additional nutrients from faeces and urine. Additionally, the tolerance of grasses to grazing may enable grasses to expand despite the losses suffered from herbivory.

Walker, D. A., E. Binnian, B. M. Evans, N. D. Lederer, E. Nordstrand and P. J. Webber. 1989. Terrain, Vegetation and Landscape Evolution of the R4D Research Site, Brooks Range Foothills, Alaska. ***Holarctic Ecology*** 12:238-261.

Abstract taken directly from text
Maps of the vegetation and terrain of a 22 km^2 area centered on the Department of Energy (DOE) R4D (Response, Resistance, Resilience to and Recovery from Disturbance in Arctic Ecosystems) study site in the Southern Foothills Physiographic Province of Alaska were made using integrated geobotanical mapping procedures and a geographic-information system. Typical landforms and surface forms include

hill-slope water tracks, Sagavanirktok-age till deposits, non-sorted stone stripes, and colluvial-basin deposits. Thirty-two plant communities are described; the dominant vegetation (51% of the mapped area) is moist tussock-sedge, dwarf-shrub tundra dominated by *Eriophorum vaginaturn* or *Carex bigelowii.* Much of the spatial variation in the mapped geobotanical characters reflects different-aged glaciated surfaces. Shannon-Wiener indices indicate that the more mature landscapes. Represented by re-transported hill-slope deposits and basin colluvium, are less heterogeneous than newer landscapes such as surficial till deposits and floodplains. A typical toposequence on a mid-Pleistocene-age surface is discussed with respect to evolution of the landscape. Thick *Sphagnum* moss layers occur on lower hill-slopes, and the patterns of moss-layer development, heat flux, active layer thickness, and ground-ice are seen as keys to developing thermokarst-susceptibility maps.

Walker, D. A., H. E. Epstein, W. A. Gould, A. M. Kelley, A. N. Kade, J. A. Knudson, W. B. Krantz, G, Michaelson, R. A. Peterson, C. Ping, M. K. Raynolds, V. E. Romanovsky and Y. Shur. 2004. Frost-Boil Ecosystems: Complex Interactions between Landforms, Soils, Vegetation and Climate. ***Permafrost and Periglacial Processes*** 15:171-188.

<u>*Abstract taken directly from text*</u>
Frost boils in northern Alaska vary from large, 2–3-m diameter, barren non-sorted circles to completely vegetated hummocks. Summer warmth increases southwards from the coast. Average thaw-layer thickness shows the opposite trend. Frost heave shows no trend along the climate gradient but is affected by soil texture. Heave is greatest on frost boils with fine-grained sediments. Biomass increases from 183 gm^{-2} at the coast to 813 gm^{-2} in the Arctic Foothills. An aggrading permafrost table is evident in most of the frost-boil soil profiles, indicating that, over time, accumulation of plant biomass leads to reduced thaw-layer thickness. A conceptual model suggests how vegetation affects the morphology of patterned ground forms. In the coldest parts of the High Arctic well-developed frost boils do not form and there is little vegetation on frost boils or the inter-boil areas. In the warmest parts of the Low Arctic, vegetation is usually sufficient to stabilize the frost boil soils. Frost boils play an important role in Arctic ecosystems functions, including the flux of trace gases to the atmosphere, flux of water and nutrients to streams, and the recycling of important nutrients to wildlife populations.

Walker, D. A., W. A. Gould, H. A. Maier and M. K. Raynolds. 2002. The Circumpolar Arctic Vegetation Map: AVHRR-derived base maps, environmental controls, and integrated mapping procedures. ***International Journal of Remote Sensing*** 23:4551-4570.

<u>*Abstract taken directly from text*</u>
A new false-colour-infrared image derived from biweekly 1993 and 1995 Advanced Very High Resolution Radiometer (AVHRR) data provides a snow-free and cloud-free base image for the interpretation of vegetation as part of a 1:7.5 M-scale Circumpolar Arctic Vegetation Map (CAVM). A maximum-NDVI Normalized DiVerence Vegetation Index) image prepared from the same data provides a circumpolar view of vegetation green-biomass density across the Arctic. This paper describes the remote sensing products, the environmental factors that control the principal vegetation patterns at this small scale, and the integrated geographic information-system (GIS) methods used in making the CAVM.

Walker, D. A., W. D. Billings and J. G. de Molenaar. 1997. Snow-Vegetation Interactions in Tundra Environments. In: ***Snow Ecology: An Interdisciplinary Examination of Snow-covered Ecosystems***, ed. by H. G. Jones, J. W. Pomeroy, D. A. Walker and R. W. Hoham. Cambridge University Press, New York. pp. 266-324.

<u>*Abstract not available [excerpts directly from text]*</u>
Snow affects the plant species and ecosystem processes of numerous biomes, and tundra biomes are the most affected by it. Snow not only influences the distribution of plant communities along topographic gradients, but also has effects on plant physiology and growth. The need for snow-vegetation research is especially important in the face of possible climate change in northern latitudes. The effects of altered snow regimes are of particular concern in the Arctic and Subarctic where changes in winter snow regimes

and associated vegetation changes could dramatically change soil surface temperatures and permafrost conditions, the flux of nutrients, energy, greenhouse gases from the soil, and the way in which these systems are utilized by animals and man.

Walker, M. D. 1995. Patterns and Causes of Arctic Plant Community Diversity. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 3–20.

Abstract taken directly from text
Attempts to explain and quantify community diversity have been a major paradigm in the development of modern ecology (e.g. Pielou 1975; MacArthur 1960; Whittaker 1965). Questions of the functional significance of diversity, and indeed whether species diversity alone has any functional significance, are also abundant (e.g. Hurlbert 1971; May 1973; Schulze and Mooney 1993). The taxonomic and genetic diversity within a community, the diversity among communities, and the diversity of communities in a landscape all contribute to regional diversity and are all aspects of community diversity. Genetic and species diversity are the building blocks of communities, and define the set of potential plant communities for a given region, but the plant communities into which these taxonomic and genetic unites are organized are the most direct and easily measurable indication of overall ecosystem diversity, because they represent the integration of species and landscape. Understanding how the diversity of communities may change following a directional change in climate requires an understanding of the processes that control diversity at different levels.

Webber, P. J. 1971. ***Gradient Analysis of the Vegetation around the Lewis Valley North-Central Baffin Island, Northwest Territories, Canada***. Ph.D. Thesis, Department of Biology, Queen's University, Kingston, ON.

Abstract taken directly from text
This study examines the vascular vegetation of 200 km^2 of the High Arctic tundra adjacent to the north-western margins of the Barnes Ice Cap, Baffin Island. This region had not been visited by botanists before this study began in 1963. Lichenometry and comparative geomorphology show that most land surfaces in the Study Area were de-glaciated during the last 500 years and that 30% have been exposed for plant colonization for less that 300 years. Recent de-glaciation, marginal climate, and low habitat diversity combine to produce a vascular flora of only 78 species. Vascular vegetation is seldom continuous, is largely restricted to fine grained and sufficiently moist soils, and is usually in young valley-bottoms. The coincidence of vascular vegetation with surfaces of similar age and elevation prevented definitive studies of succession and the effects of elevation on vegetation. Inferential studies based on general observation suggest that all allogenic processes predominate over autogenic processes in many plant successions. The oldest surfaces, found in the uplands, are block-fields formed by the removal of fines. The Arctic Hamada is stable and supports rock-lichen communities and it may be regarded as a topoedaphic climax. Gradient analysis methods were employed to describe the structure, composition, controlling environmental factors, and species ecology of the vegetation, and to examine the level of integration and complexity of the tundra ecosystem. Eighty-two stands of vascular vegetation were sampled and in addition to all vascular plants, common cryptograms were recorded. Simple, direct, one-dimensional arrangements of stands along a complex moisture gradient and a complex snow cover gradient gave useful information on the moisture and snow preferences of species. An indirect, three-dimensional ordination of 42 related stands, using stand composition and a slightly modified Bray and Curtis method, proved effective in achieving the aims of this study. The remaining 40 stands could not be ordinated because of their dissimilarity with one another and with the group of 42 ordinated stands. The Controlling environmental complexes, indicated by the three axes of the ordination, were water/soil organic matter (X), soil mechanical composition (Y), and snow cover/soil reaction (Z). The vegetation composition and ecology of species was interpreted from these results. An indirect ordination based on the environmental characteristics of each stand was not successful. The use of the Bray and Curtis ordination, rather than other more recent and sophisticated procedures, is justified by its success and by a discussion of recent literature. The first axis of an indirect, two-dimensional, Bray and Curtis, ordination

of 40 species corresponded to a moisture gradient and the second axis to a snow cover gradient. Cluster Analysis and classification of 56 stands on the basis of their similarity produced eight stand noda. The remaining 26 stands were rudimentary and/or unique and had little in common with any other stands. The presence of noda appears to result from frequent sampling and occurrence of similar habitat types rather than the existence of discrete communities. Cluster analysis and classification was also made of the 40 species used in the species ordination. Four species noda were found and they corresponded with one or more of the stand noda. The results of the gradient and cluster analyses indicate that the vegetation is not a haphazard mixture of species and that each species has a distinct and different environmental range. Competition between species is reduced in many situations especially in pioneer or open communities. The reduction in competition may be responsible for the ubiquity of so many species. The success of the ordinations is taken as an indication that the sampled vegetation was part of a relatively simple ecosystem with few components and few overriding environmental variables. A trail study was made in which indirect stand ordination was used in conjunction with vegetation mapping to provide estimates of the primary productivity of a mapped area. This application of the ordination still needs rigorous testing but, if proven valid, its worth to tundra ecology would be considerable.

Whittaker, R. H. 1965. Dominance and Diversity in Land Plant Communities. ***Science*** 147:250-260.

Abstract not available [excerpts directly from text]
This article looks at plant species-diversity measurements taken in Great Smoky Mountains National Park. These values cover a wide range, but variations in species-diversity do not simply parallel variations in community production. In the Great Smoky Mountains, production and diversity are not significantly correlated either in vegetation or in samples of foliage insects. The magnificent redwood forests of the California and Oregon coasts, probably among the most productive of temperate-zone climax forests, have low species-diversity. Based on data from the Great Smoky Mountains, it is possible to rank most of the vascular plant species in a community by relative amounts of net annual production. Productivity seems to be the best measure of the success or importance of a plant in a community. Curves of decreasing productivity connect the few most important species (the dominants) with a larger number of species of intermediate important (whose number primarily determines the community's diversity or richness in species) and a smaller number of rare species. These curves are of varied forms and are believed to express different patterns of competition and niche differentiation in communities.

Wilson, J. W. 1952. Vegetation Patterns Associated with Soil Movement on Jan Mayen Island. ***Journal of Ecology*** 40:249-264.

Abstract taken directly from text
1) The most general vegetation of Jan Mayen is a moss mat, which is often interrupted by bare patches so that it forms regular patterns, e.g. polygons, terraces and stripes.
2) This patterning results from movement and sorting of soil particles due to gravity and/or solifluction; restriction of soil movement by barriers of vegetation is also sometimes involved.
3) Each type of pattern is characteristic of ground sloping at a certain angle. On any hillside the various patterns follow one another in regular sequence as the slope changes. The full sequence of ten patterns, and also abbreviated sequences developed on shallow hillsides, are described and are exemplified by a transect across a crater system.
4) Terraces and probably the other patterns move gradually down the hillsides on which they occur. This movement, by lessening the angle of slope, gradually simplifies the pattern sequence on any hillside; and by filling up the barren valleys, brings progressively greater expanses devoid of vegetation.
5) On local, agglomerate soils a different terrace form develops, in which downhill movement of the soil mass buries vegetation, folding it within the hillside. The colonization by plants away from the infolding region is demonstrated.
6) It is suggested that terracing develops only where the vegetation is of a certain vigour. Growth which is too weak (as on north-facing slopes at Jan Mayen) or too strong (as on south-facing slopes in Alaska and the Cairngorms) may not produce the terrace form.

Wilson, J. W. 1959. Notes on Wind and its Effects in Arctic-Alpine Vegetation. ***Journal of Ecology*** 47:415-427.

Abstract taken directly from text
The vegetation of arctic-alpine regions is strongly affected by wind; in exposed sites the plants grow poorly and may be wind-pruned or even killed. Observations at Jan Mayen Island (71" N) showed that the difference in growth-rates between an exposed hilltop and a sheltered hollow was greater than that reported in similar comparisons in temperate regions. Arctic-alpine regions are characteristically windswept, but wind speeds fall off sharply close to the ground surface owing to its braking effect. Foliage also offers strong resistance. Consequently, shoots projecting above the general level suffer especially high winds, but most foliage (being low-growing) lies in comparatively calm air. Wind speeds in normal weather among vegetation in exposed positions in the Cairngorms were not high-a few decimetres per second generally, and less in dense foliage and in eddy zones. Evaporation rates around these plants were closely related to wind speeds. Excessive transpiration may kill projecting shoots rarely in summer and more often (at least in the case of shrubs and trees) in winter when the soil is frozen; but the general depression of growth-rates by wind seems not to be primarily a result of drying, since in summer the plants of most-though not all-arctic-alpine regions have a high water status. Wind cools foliage, especially in sunny weather, and this effect is unusually marked in arctic-alpine vegetation; it amounted to up to 7" C in observations at Cornwaliis Island (75" N). Moreover, at low temperatures plant growth becomes especially sensitive to temperature conditions. It is concluded that the potent effect of wind on arctic-alpine vegetation is generally a result not so much of high wind speed as of special sensitivity of plant growth to wind; and that this sensitivity is due less to drying and more to cooling than under temperate conditions.

2.5 WILDLIFE

2.5.1 General

Chernov, Y. I. 1995. Diversity of the Arctic Terrestrial Fauna. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 81-95.

Abstract not available [excerpts directly from text]
It is presently impossible to say exactly how many animal species dwell in the Arctic. The reasons for this are (1) the lack of taxonomic and faunistic knowledge about many groups of arctic animals; (2) incomplete collections and data on regional faunas; (3) a large number of incompatible synonyms used by taxonomists in Russia, North America, and Western Europe. The Arctic has about 1-3% of the world's fauna, depending on the taxonomic group. Each group decreases in abundance toward high latitudes, reflecting direct or indirect effects of temperature. Within a given taxonomic group, evolutionary primitive lineages tend to predominate in the arctic fauna. The low number of species in the Arctic is compensated by high densities of individuals (e.g. cranefiles and lemmings). Decreasing heat input at high latitudes explains the strong correlation between summer temperature and biological diversity. In the Arctic the relationships between levels of diversity are unusual. Although the diversity of local concrete faunas (gamma diversity) and landscape diversity (beta diversity) are low, a large portion of these species is found within a given community (high alpha diversity).

Gilchrist, G., M. Mallory and F. Merkel. 2005. Can Local Ecological Knowledge Contribute to Wildlife Management? Case Studies of Migratory Birds. ***Ecology and Society*** 10(1):20 [online] URL:http://www.ecologyandsociety.org/vol10/iss1/art20/

Abstract taken directly from text
Sound management of wildlife species, particularly those that are harvested, requires extensive information on their natural history and demography. For many global wildlife populations, however, insufficient scientific information exists, and alternative data sources may need to be considered in

management decisions. In some circumstances, local ecological knowledge (LEK) can serve as a useful, complementary data source, and may be particularly valuable when managing wildlife populations that occur in remote locations inhabited by indigenous peoples. Although several published papers discuss the general benefits of LEK, few attempt to examine the reliability of information generated through this approach. We review four case studies of marine birds in which we gathered LEK for each species and then compared this information to empirical data derived from independent scientific studies of the same populations. We then discuss how we attempted to integrate LEK into our own conservation and management efforts of these bird species with variable success. Although LEK proved to be a useful source of information for three of four species, we conclude that management decisions based primarily on LEK, in the absence of scientific scrutiny, should be treated with caution.

Hines, J. E., R. F. Decker and S. Moore. 1988. ***Observations of Wildlife and Wildlife Habitat in Aukuittuq National Park Reserve***. File Report No.79, Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 50 pp.

Abstract taken directly from text
A reconnaissance level survey of the wildlife and wildlife habitat in Auyuittuq National Park Reserve, Baffin Island, was conducted from 1985-87. One species of fish, 23 species of birds, and 9 species of mammals were found during the surveys. Population densities of all species appeared to be low and most species of terrestrial wildlife were associated with the rather limited distribution of continuous vegetation. Such habitat covered only 15% of the park and was restricted mainly to lower elevations (<500m) in the fiords and valleys. Most abundant birds were snow buntings (*Plectrophenax nivalis)*, Lapland longspurs (*Calcarius lapponicus*), water pipits (*Anthus spinoletta*), Canada geese (*Branta canadensis)*, snow geese (*Chen caerulescens*), and glaucous gulls (*Larus hyperboreus*). Typical terrestrial mammals were arctic hares (*Lepus arcticus*) and lemmings (*Lemmus sibiricus, Dicrostonyx torquatus*). Preferred habitats of the 5 commonly observed species were documented. Economically important or sensitive species such as barren-ground caribou (*Rangifer tarandus groenlandicus*), gyrfalcons (*Falco rusticolus*), and peregrine falcons (*Falco peregrinus*) exist at very low densities in the park. Areas of importance to caribou, and nesting geese, gulls, and raptors, are mapped. Four areas of apparent significance to wildlife are delineated: (1) the south-western part of the park, (2) the Owl River Valley, (3) Nedluksiak Fiord – Isurtuq River, and (4) the Kivitoo Peninsula. Our present knowledge of the wildlife resources of the park is poor and recommendations are presented on how information gaps can be filled.

Jefferies, R. L. and J. P. Bryant. 1995. The Plant-Vertebrate Herbivore Interface in Arctic Ecosystems. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 271-281.

Summary taken directly from text
1) The mutual amplification of the effects of interactions between climate, vegetation, and herbivores on ecosystem function and biodiversity in tundra and boreal forest regions are examined.
2) Vertebrate herbivores, which have catholic diets, exploit the mosaic of vegetation types in which species differ in their chemical defences and nutritional qualities. Climatic change may be expected to affect plant-herbivore relationships by altering the absolute/ relative abundances of plant growth forms.
3) Increases in abundance of shrubs as the forest-tundra ecotone moves north will lead to a loss of existing tundra vegetation which, in turn, may result in the extinction of vertebrate herbivore populations. The shrubs may be rich in secondary compounds that deter herbivores. The destabilization of the Beringia ecosystem and the extinction of mega-herbivore population serve as a model for the likely sequence of events following climate change.
4) Recent rapid increases in breeding populations of lesser snow geese, probably as a result of anthropogenic influences, have lead to the partial destruction of tundra coastal ecosystems and loss of biodiversity. The destruction has been enhanced by the direct and indirect effects of weather patterns during the last decade which may be linked to global climate change.

5) These anthropogenic-triggered events amplify top-down and bottom-up trophic processes, resulting in sudden shifts in sizes of populations (and loss of biodiversity) in these relatively simple coastal communities dependent on a few species.
6) In spite of the different spatial and temporal scales involved in the two examples discussed, climate acts as a trigger that initiates a sequence of changes as a result of its effect on other processes. Recognition of further examples of coupled feedback cycles which result in synergistic effects on ecosystems and changes in biodiversity is urgent.

Seegar, W. S., P. N. Cutchis, M. R. Fuller, J. J. Suter, V. Bhatnagar and J. G. Wall. 1996. Fifteen Years of Satellite Tracking Development and Application to Wildlife Research and Conservation. ***John Hopkins APL Technical Digest*** 17:401-411.

Abstract taken directly from text
A small satellite-based tracking system that is light enough to be carried on birds was developed in the 1980s at the Applied Physics Laboratory. A new, more capable generation is now under development that will contain, in addition to the Argos tracking platform transmitter terminal, a global positioning system receiver and a complement of advanced sensors. The sensors may include a digital audio capture system and a black-and-white charge-coupled device camera. The history of the program and plans for future development are discussed.

Wildlife Management Advisory Council (NWT). 2003. ***Selected Bibliography of Wildlife Research in the Inuvialuit Settlement Region***. 360 pp. (no abstract)

2.5.2 Birds

2.5.2.1 General

Abraham, K. F., R. L. Jefferies and R. F. Rockwell. 2005. Goose-induced Changes in Vegetation and Land Cover between 1976 and 1997 in an Arctic Coastal Marsh. ***Arctic, Antarctic, and Alpine Research*** 37:269-275.

Abstract taken directly from text
Since the 1970s, a breeding colony of lesser snow geese (*Chen caerulescens caerulescens* L.) at La Perouse Bay, Manitoba, has grown 8% annually. This increase has led to significant loss of plant cover in all major salt- and freshwater coastal habitats between 1976 and 1997. A series of transects established in 1976 was resurveyed in 1997. Exposed sediment, extent and type of vegetative cover, and aquatic areas were recorded along transects using a classification of 12 a priori classes. Five regions within the colony were identified, and changes in vegetation cover differed among these and depended on unique combinations of vegetation class and year. Grubbing by geese has led to loss of graminoid plants, especially in intertidal and supratidal marshes. Exposed sediments have largely replaced previously vegetated areas since 1976. Species characteristic of disturbed sites have colonized exposed sediment with the most abundant species varying according to soil conditions. In intertidal marshes, willow cover declined in association with the development of hypersalinity after loss of the graminoid mat, but willow cover increased at the base of well-drained beach ridges and in a river delta with ample winter snow accumulation and freshwater flow in spring that protected ground vegetation. Most of the expected successional trends associated with isostatic uplift and changes in soil organic matter failed to occur because of intense goose foraging throughout the 20 years. The likelihood of sustained recovery of plant communities in the immediate coastal zone is very low, as long as goose numbers continue to increase. Indirect effects of vegetation loss (e.g., hypersalinity) and subsequent erosion of exposed sediments following grubbing will delay plant colonization and retard succession.

Abraham, K. F., R. L. Jefferies and R. T. Alisauskas. 2005. The dynamics of landscape change and snow geese in mid-continent North America. ***Global Change Biology*** 11:841-855.

Abstract taken directly from text
The Mid-Continent Population of the lesser snow goose, which breeds in the eastern and central Canadian Arctic and sub-Arctic, and winters in the southern United States and northern Mexico has increased 5–7% annually from the late 1960s to the mid-1990s, largely because of increased survival in response to an agricultural food subsidy. The rise in numbers complements the increased use of nitrogen fertilizers and a corresponding rise in yields of rice, corn, and wheat along the flyways and on the wintering grounds. In sub-Arctic migration areas and at Arctic breeding colonies, foraging by high numbers of birds has led to loss of coastal vegetation, adverse changes in soil properties and the establishment of an alternative stable state of exposed sediment, which can be detected with LANDSAT imagery. At a local scale, gosling growth, size and survival decreased in affected areas and other taxa have been adversely affected. The food subsidy on wintering and migration areas appears insufficient to meet reproductive demands as foraging in spring continues to occur on southern Hudson Bay staging and nesting areas. The recent introduction of liberal hunting regulations may reduce population size in the near term, but the re-vegetation of these coastal ecosystems will take decades to achieve. The present pattern of vegetation loss in these Arctic coastal systems is likely to continue in the foreseeable future.

Alisauskas, R. T., J. W. Charlwood and D. K. Kellett. 2006. Vegetation Correlates of the History and Density of Nesing by Ross's Geese and Lesser Snow Geese at Karrak Lake, Nunavut. ***Arctic*** 59:201-210.

Abstract taken directly from text
Growth in populations of Ross's geese (*Chen rossii*) and less snow geese (*C. caerulescens*) has led to concerns about destructive grazing of Arctic ecosystems. We estimated the extent and composition of plant communities at Karrak Lake, Nunavut, where populations of both goose species have grown geometrically over the past three decades. Proportion of land covered by vegetation was lower in areas where geese had nested for more than 20 years in areas with no previous nesting history. Vegetative cover also declined with increasing nest density of both species. Species richness and diversity of vegetation was higher in more recently colonized areas of nesting that in areas with over 20 years of goose nesting. Exposed mineral substrate, exposed peat, and *Senecio congestus* were more prevalent in areas with a 10-year or long or long history of goose nesting than in areas with less than 10 years of nesting. These patterns confirm that increasing numbers of nesting Ross's geese and lesser snow geese have altered the spatial distribution of vegetation surrounding Karrak Lake and reduced the species richness of local plant communities.

Baker, B. W., B. S. Cade, W. L. Mangus and J. L. McMillen. 1995. Spatial Analysis of Sandhill Crane Nesting Habitat. ***Journal of Wildlife Management*** 59:752-758.

Abstract taken directly from text
Ecologists need to understand how species' habitat requirements change across spatial scales, and how scale influences spatial analyses across heterogeneous landscapes. We used a geographic information system (GIs) to analyze nesting greater sandhill crane *(Grus canadensis tabida)* use of habitat at multiple spatial scales. We collected data on a 11,487-ha portion of Seney National Wildlife Refuge (NWR), Michigan, during 1984-87. Percent composition of 17 habitat variables (4 upland classes, 6 wetland classes, 6 water regimes, and total wetland) was compared around nest sites and random points for 5 circular buffers with radii of 50, 100, 200, 419, and 709 m. Cranes selected ($P < 0.01$) nest sites in or near seasonally flooded emergent (non-woody) wetlands and avoided ($P < 0.01$) forested uplands. There was no ($P > 0.01$) habitat selection beyond 200 m from a nest. Beyond this distance our analysis was inconclusive, in part, because larger buffer scales increased heterogeneity and overlap among nest and random buffers. Observers should consider scale of analysis when investigating spatial patterns of use of habitat.

Bechet, A, A. Reed, N. Plante, J.-F. Giroux and G. Gauthier. 2004. Estimating the Size of the Greater Snow Goose Population. ***Journal of Wildlife Management*** 68:639-649.

Abstract taken directly from text
Accurate and precise estimation of the size of animal populations is critical to sound management and conservation. The size of the greater snow goose (*Chen caerulescens atlantica*) population has been monitored since 1965 by means of an aerial photographic survey conducted every spring in southern Quebec, Canada. As the population increased, the estimation of its size evolved from total counts of the birds on photographs (1965–1990) to sampling the photographed flocks (1991–2000). From 1998 to 2000, we implemented a protocol to estimate the proportion of flocks missed by the photographic survey. This was achieved using radio-marked geese that were tracked by independent observers during the aerial survey. The proportion of radio-marked geese detected during the survey was used to estimate the proportion of the population that was photographed. The estimated size of the photographed population was based on a combined stratified ratio estimator using partial counts and visual estimates of flocks in 3 size classes. The estimated size of the photographed population had a coefficient of variation (CV) of 2-6%. This precision was achieved by counting only 15% of the photographed geese on average, which was a large gain in logistical efficiency considering the size of the population. We found no evidence for over-dispersion of the number of radio-marked birds (n = 70 in 1998, n = 41 in 2000) encountered in each flock. In 1999, technical problems with radio-transmitters prevented a reliable total population size estimate. In 1998 and 2000, we estimated that the photographic crew missed 11 and 29%, respectively, of the radio-marked geese present. The CV of the total population size estimates were 5.8% in 1998 and 11.1% in 2000. As the proportion of missed flocks increases, the number of radio-marked birds required to obtain a CV of 5% increases with a concomitant increase of cost. We highlight spatial and temporal changes in the spring distribution of greater snow geese staging in southern Quebec and suggest that adjustments of timing and coverage of the surveys will be required to maintain and improve the accuracy of the population size estimates at low cost.

Bechet, A., J. Giroux and G. Gauthier. 2004. The effects of disturbance on behaviour, habitat use and energy of spring staging snow geese. ***Journal of Applied Ecology*** 41:689-700.

Abstract taken directly from text
1) For many species, human-induced disturbances can severely influence an individual's pay-off; however, energy-cost variations from different disturbance types have rarely been reported.
2) We evaluated the dynamic behavioural responses of staging greater snow geese *Anser caerulescens atlanticus* to different types of disturbance in southern Quebec, Canada, between 1997 and 2000. We specifically considered the impact of a unique measure, a spring conservation hunt implemented in agricultural habitats in 1999.
3) We tracked 237 radio-tagged females for 2764 h and recorded 697 take-offs following fortuitous disturbance, scaring and hunting in three regions characterized by different habitats. Geese used cornfields in south-western Quebec, *Scirpus* marshes and hayfields in the upper St Lawrence estuary, and *Spartina* marshes and hayfields in the lower estuary.
4) Overall, disturbance levels increased in the upper and lower estuary during years with hunting, mostly through an increase in hunting and scaring activities.
5) The probability of geese returning to a refuge after disturbance in agricultural habitats increased in years with hunting except in the corn-growing region. The short-term energy gain of geese resuming feeding after disturbance was less than before disturbance, and this difference was greater in years with hunting. Distances flown after disturbance decreased with flock size and were longer after scaring and hunting than after fortuitous disturbances in the *Scirpus* region.
6) Overall, habitat use varied among years and associated estimated energy gain decreased markedly in both years with hunting in the *Spartina* and corn-growing region, but did not change in the *Scirpus* region. Changes in behaviour due to disturbance, and especially those associated with hunting, probably contributed to the reduced body condition of staging greater snow geese during years with hunting.
7) From a methodological viewpoint, we highlight the importance of tracking the behaviour of individual animals after disturbance to properly evaluate its impact. From a conservation perspective, we provide empirical arguments to limit the hunting of breeding waterfowl during their prenuptial migration in order to facilitate their fattening and forthcoming reproduction. From a management standpoint, we suggest that a side-effect of disturbance induced by spring hunting to control overabundant populations may be reduced

fattening and breeding output among birds that survive. Together, these data emphasize further the importance of measuring the direct and indirect effects of disturbance rather than assuming effects from the incidence of the disturbance alone.

Bergman, R. D. and D. V. Derksen. 1977. Observations on Arctic and Red-throated Loons at Storkersen Point, Alaska. ***Arctic*** 30:41-51.

Habitat requirements of arctic loons (*Gavia arctica*) and red-throated loons (*Gavia stellata*) were studied at Storkersen Point on the Arctic coastal plain of Alaska from 1971 to 1975. Nest success ranged from 28 to 92 per cent and 33 to 78 per cent for arctic and red-throated loons, respectively. Loons were ecologically isolated in their feeding habits and use of wetlands. Arctic loons fed to their young invertebrates captured in the nest pond, and red-throated loons fed to theirs fish captured from the Beaufort Sea. Both species preferred islands as nest substrates, but arctic loons utilized large ponds with stands of *Arctophila fulva* wetlands for nesting, whereas, red-throated loons used smaller, partially-drained basins most frequently.

Bety, J., G. Gauthier, J. Giroux and E. Korpimaki. 2001. Are goose nesting success and lemming cycles linked? Interplay between nest density and predators. ***Oikos*** 93:388-400.

Abstract taken directly from text

The suggested link between lemming cycles and reproductive success of arctic birds is caused by potential effects of varying predation pressure (the Alternative Prey Hypothesis, APH) and protective association with birds of prey (the Nesting Association Hypothesis, NAH). We used data collected over two complete lemming cycles to investigate how fluctuations in lemming density were associated with nesting success of greater snow geese (*Anser caerulescens atlanticus*) in the Canadian High Arctic. We tested predictions of the APH and NAH for geese breeding at low and high densities. Goose nesting success varied from 22% to 91% between years and the main egg predator was the arctic fox (*Alopex lagopus*). Nesting associations with snowy owls (*Nyctea scandiaca*) were observed but only during peak lemming years for geese nesting at low density. Goose nesting success declined as distance from owls increased and reached a plateau at 550 m. Artificial nest experiments indicated that owls can exclude predators from the vicinity of their nests and thus reduce goose egg predation rate. Annual nest failure rate was negatively associated with rodent abundance and was generally highest in low lemming years. This relationship was present even after excluding goose nests under the protective influence of owls. However, nest failure was inversely density-dependent at high breeding density. Thus, annual variations in nest density influenced the synchrony between lemming cycles and oscillations in nesting success. Our results suggest that APH is the main mechanism linking lemming cycles and goose nesting success and that nesting associations during peak lemming years (NAH) can enhance this positive link at the local level. The study also shows that breeding strategies used by birds (the alternative prey) could affect the synchrony between oscillations in avian reproductive success and rodent cycles.

Boyd, H. 2000. Population modeling and management of Snow Geese. ***Occasional Paper***, Number 102, Canadian Wildlife Service, Ottawa, ON.

Abstract taken directly from text

Interest in the effect of spring hunting on goose population dynamics has arisen recently in two quite different contexts: measuring the impact of spring harvests by aboriginal hunters, and predicting the potential for using spring harvest to control populations. I developed a matrix-based population model to quantify the relative impact of spring versus autumn harvests on the population dynamics of Lesser Snow Geese *Anser caerulescens caerulescens* nesting around the Hudson Bay lowlands. Key parameters affecting the conclusions of the model were the relative vulnerability of young and adults in each season and the pro portion of adults losing mates in spring that subsequently fail to breed or have reduced breeding success. With a range of assumptions about these parameters, the estimated impact of a spring harvest was between 1.1 and 1.5 times the impact of shooting the same number of birds in early autumn. The relative impact would be greater if the spring harvest were directed at breeding adults and reduced if it were directed at young geese. If it becomes necessary to set quotas for aboriginal hunters, these results can be used to apportion the harvest between spring and autumn. These results can also be used, in conjunction with estimates of the likely success rates of hunters, to predict the value of spring harvest as a tool to control goose populations. If such a harvest is planned, additional research is needed to determine the relative vulnerability of young and adults in spring, as well as the effects of mate loss in spring on breeding success.

Populations of Lesser Snow Geese *Anser caerulescens caerulescens* in the mid-continent of North America have increased to the point where they are causing serious damage to some Arctic coastal ecosystems. A recent modelling exercise by R.F. Rockwell and colleagues (referred to as the Original Model) suggested that increasing harvest rates of adults to approximately twice the average level in recent years would lead to negative population growth and hence (under certain assumptions) be sufficient to control the population. However, some of the parameters in their models appear to have been inappropriate. Based on revised parameters, which are consistent with analyses of recent data, we suggest that an increase of 3.0- to 7.3-fold in the harvest, relative to the same period analyzed in the Original Model, would have been required to reduce populations at the desired rate in 1994. Despite recent increases in harvest, we predict that a further increase of 2.1- to 4.7-fold, relative to the estimated harvest for 1997, would be needed in 1999 to achieve this population reduction. Wildlife managers need to be aware of these larger targets when considering appropriate measures to control the population.
Given the uncertain ties in many parameter estimates, further modelling, combined with ongoing monitoring of population size and demo graphic parameters, will be required to evaluate and refine any management actions.

Bradley, M., G. Court, R. Johnstone, T. Duncan, M. Setterington and A. Franke. 2005. ***Climate Change-What Could it Mean for Arctic-Nesting Peregrine Falcons?*** Poster, presented at ArcticNet, contact: alastair.franke@ualberta.ca.

<u>*Abstract not available [excerpts directly from text]*</u>
At Rankin Inlet, the climate is characterized by short, cool summers and long, cold winters. The Inlet freezes completely in November and does not break up again until July. Southwest-facing cliffs provide nesting habitat for Peregrine Falcons, which arrive at the study area in mid- to late May and lay eggs the first week of June. The high variability in breeding success at Rankin Inlet was strongly associated with weather. In some years, the study population has experienced almost total reproductive failure resulting from summer rainfall and spring snow storms. Studies on climate change have reported increased variability in weather. Assuming these trends continue, the effect of increased environmental stochasticity on productivity of Arctic-nesting Peregrine Falcons has the potential to decrease overall long term productivity.

British Columbia Ministry of Environment. 1999. ***Inventory Methods for Waterfowl and Allied Species: Loons, Grebes, Swans, Geese, Ducks, American Coot and Sandhill Crane***. Standards for Components of British Columbia's Biodiversity, No. 18, prepared by Ministry of Environment, Lands and Parks, Resources Inventory Branch for the Terrestrial Ecosystem Task Force Resources Inventory Committee, published by The Province of British Columbia, Resources Inventory Committee. 82 pp.

<u>*Abstract not available [excerpts directly from text]*</u>
Waterfowl and allied species – ducks, geese, swans, loons, coots, grebes, and cranes, comprise an important and diverse component of British Columbia's avifauna. There are many reasons why it is important to inventory this group of birds. Effects on wetlands and coastal habitats can be assessed by monitoring waterfowl populations. Monitoring waterfowl can also be used to set hunting regulations or to gain knowledge about bird populations. Mark/recapture analysis can be used to gain information on waterfowl populations, and air photo techniques can be suitable for obtaining an accurate absolute abundance estimate of numbers and sometimes age ratios of large conspicuous birds concentrated in a defined area.

Buchanan, G., J. Peace-Higgins, M. Grant, D. Robertson and T. Waterhouse. 2005. Characterization of moorland vegetation and the prediction of bird abundance using remote sensing. ***Journal of Biogeography*** 32:697-707.

Abstract taken directly from text

Aims: To characterize and identify upland vegetation composition and height from a satellite image, and assess whether the resulting vegetation maps are accurate enough for predictions of bird abundance.

Location: South-east Scotland, UK. Methods Fine-taxa vegetation data collected using point samples were used for a supervised classification of a Landsat 7 image, while linear regression was used to model vegetation height over the same image. Generalized linear models describing bird abundance were developed using field-collected bird and vegetation data. The satellite-derived vegetation data were substituted into these models and efficacy was examined.

Results: The accuracy of the classification was tested over both the training and a set of test plots, and showed that more common vegetation types could be predicted accurately. Attempts to estimate the heights of both dwarf shrub and graminoid vegetation from satellite data produced significant, but weak, correlations between observed and predicted height. When these outputs were used in bird abundance-habitat models, bird abundance predicted using satellite-derived vegetation data was very similar to that obtained when the field-collected data were used for one bird species, but poor estimates of vegetation height produced from the satellite data resulted in a poor abundance prediction for another.

Conclusions: This pilot study suggests that it is possible to identify moorland vegetation to a fine-taxa level using point samples, and that it may be possible to derive information on vegetation height, although more appropriate field-collected data are needed to examine this further. While remote sensing may have limitations compared with relatively fine-scale fieldwork, when used at relatively large scales and in conjunction with robust bird abundance–habitat association models, it may facilitate the mapping of moorland bird abundance across large areas.

Calvert, A. M. and G. Gauthier. 2005. Effects of exceptional conservation measures on survival and seasonal hunting mortality in greater snow geese. ***Journal of Applied Ecology*** 42:442-452.

Abstract taken directly from text

1) Large-scale conservation measures aimed at reducing the abundance of a wild population offer a unique opportunity to study the impacts of human exploitation on demographic parameters. We examined the effects of a spring conservation harvest and liberalized autumn/winter regulations introduced recently to control the rapid population growth of greater snow geese *Anser caerulescens atlantica*.

2) We predicted that these changes in regulations affected survival and recovery probabilities, as well as kill rates. This was evaluated by analysing data on geese shot by hunters before and after implementation of these measures.

3) Annual survival and recovery probabilities were estimated using likelihood-based ring recovery models, and we developed a new, flexible seasonal model to determine the specific effects of regulation changes made during different hunting seasons. We used harvest survey data to estimate ring-reporting rate, and thus to convert recovery rates into kill rates.

4) Adult recovery and kill rates increased considerably with the implementation of the new measures in 1998–99. The addition of the spring harvest in Québec and the liberalized winter regulations in the USA had the largest impacts, whereas autumn regulation changes in Québec apparently had little effect. Juvenile recovery and kill rates also showed a moderate increase, but were highly variable.

5) We observed a decline in mean annual adult survival rate, from 83·0% to 72·5%, although the implementation of conservation measures did not fully explain temporal variation in adult survival; juvenile survival showed no change. Adult survival was negatively related to harvest rate in adults but not in juveniles.

6) We demonstrate that the spring conservation harvest led to a decrease in adult survival and an increase in hunting mortality, and probably contributed to the decline in abundance observed since its implementation. However, regulations during the traditional autumn and winter hunting seasons could also be manipulated for future population control once the spring conservation harvest is discontinued.

Our approach for evaluating hunting mortality on a seasonal basis should be useful in the management of other migratory populations that move through several jurisdictions.

Decarie, R., F. Morneau, D. Lambert, S. Carriere and J. L. Savard. 1995. Habitat Use by Brood-Rearing Waterfowl in Subarctic Quebec. ***Arctic*** 48:383-390.

Abstract taken directly from text

Aerial surveys of waterfowl were conducted in subarctic Québec in 1989 and 1990 on randomly selected 100 km^2 plots. We used logistic regression for modelling relationships between the presence of waterfowl broods and habitat characteristics. For each species, models of habitat use were generated with one data set and tested with two others. We also compared the frequency distributions of broods of each species in different habitat types. Correct-classification rates of models varied between 0.53 and 0.77. Sensitivity of models generally increased when applied to validation data sets. Models showed that green-winged teals (*Anas crecca*) avoided lakes > 501 ha and used vegetated lakes, ponds and fens or bogs more than predicted by their availability. Black scoters (*Melanitta nigra*) and surf scoters (*M. perspicillata*) were found mostly on small lakes (< 10 ha) and medium lakes (10–100 ha). Black scoters were associated with the presence of ponds and lakes with sedge and grass, whereas surf scoters were not. The presence of scaup (*Aythia* spp.) broods was associated with the presence of vegetation. Green-winged teals were observed more often on bogs than were either scoters or scaups. Black scoters were observed more often on ponds and less often on medium-sized lakes than surf scoters and scaups. The latter differed in their use of lakes < 10 ha: surf scoters, like black scoters, mostly used un-vegetated lakes, while scaups and green-winged teals mostly used vegetated lakes. The accuracy and precision of logistic models may be enhanced by additional habitat variables, careful selection of sample-cell size and further investigation of the breeding biology of the surveyed species.

Dickson, D. L. 1993. Breeding biology of red-throated loons in the Canadian Beaufort Sea region. ***Arctic*** 46:1-7.

Abstract taken directly from text

The breeding biology of the red - throated loon in the Canadian Beaufort Sea region was investigated from 1985 to 1989. Five study plots were established with a total area of 276 km 2 and over 200 pairs of loons on territory each breeding season. Loon densities ranged from 0.6 pairskm (-2) on the Yukon coast to 1.8 pairskm (-2) at Toker Point on the Tuktoyaktuk Peninsula. An average of 73% of the pairs on territory nested each year. Productivity averaged 0.63 youngnesting pair (-1). The median date of egg laying ranged from 19 to 24 June in four years, but was 3 July in a year when spring thaw was late. The chicks fledged a mean of 47 d after hatch (n = 10), the first clutch chicks leaving the nesting pond in late August to mid - September. In all but one year, the mortality rate was higher for eggs than chicks, with egg losses peaking in the second half of incubation. Most (82%) chick losses occurred within three weeks of hatch (n = 61). Just 13% of the ponds were occupied in all five years of the study, while 39% were used in only one year. At two of the study plots, ponds with pairs that successfully reared at least one chick had a greater tendency to be occupied the following year than did ponds with unsuccessful pairs. At the other three plots, reuse of ponds was independent of breeding success the previous year.

Dierschke, J. and F. Bairlein. 2004. Habitat selection of wintering passerines in salt marshes of the German Wadden Sea. ***Journal of Ornithology*** 145:48-58.

Abstract taken directly from text

The salt marshes of the Wadden Sea are important wintering areas for some species of granivorous passerines, which have declined considerably since the 1960s. We investigated the habitat choice of all wintering passerines in eight study areas in German salt marshes with special consideration of human impact on these habitats. Granivorous species that almost exclusively winter in salt marshes, Shorelark (*Eremophila alpestris*), Snow Bunting (*Plectrophenax nivalis*) and Twite (*Carduelis flavirostris*) were concentrated in the lower salt marsh vegetation and in the driftlines, while all other species preferred the high upper salt marsh communities, although Rock Pipits (*Anthus petrosus littoralis*) fed in muddy areas along ditches. Shorelarks switched habitat in conditions where seeds were scarce to feed instead on arthropods in upper salt marshes. Intensively sheep-grazed upper salt marshes resemble lower salt marshes in their vegetation and were therefore mainly visited by Shorelarks, Snow Buntings and Twites. In winter, the drift-line is preferred by the two former species, while in autumn and spring more birds foraged in the salt marshes. Twites prefer to feed mainly on seeds of *Salicornia*. Areas with *S. europaea* are visited mainly in late autumn and early winter, while areas with *S. stricta* are used throughout the winter because of a steady supply of seeds. Several years after embankment, polders are hardly used any more by the lower salt marsh species as the habitat changes into freshwater marshes. Large embankment projects since the early 1960s have included salt marshes and intertidal flats, and the resultant loss of habitat is responsible for the decline of lower salt marsh species. For other passerine species the effects of reclamation are unknown. The effects of intensified grazing on the wintering populations of Shorelark, Snow Bunting and Twite are still unresolved. Reducing the human impact on salt marshes will, in the long run, probably lead to a natural salt marsh with much variety in elevation and in its corresponding vegetation and bird communities. Meanwhile, management by grazing might be required in parts of the salt marshes.

Earnst, S. L., R. A. Stehn, R. M. Plate, W. W. Larned and E. J. Mallek. 2005. Population Size and Trend of Yellow-Billed Loons in Northern Alaska. ***Condor*** 107:289-304.

<u>*Abstract taken directly from text*</u>

The Yellow-billed Loon (*Gavia adamsii*) is of conservation concern due to its restricted range, small population size, specific habitat requirements, and perceived threats to its breeding and wintering habitat. Within the U.S., this species breeds almost entirely within the National Petroleum Reserve-Alaska, nearly all of which is open, or proposed to be opened, for oil development. Rigorous estimates of Yellow-billed Loon population size and trend are lacking but essential for informed conservation. We used two annual aerial waterfowl surveys, conducted 1986–2003 and 1992–2003, to estimate population size and trend on northern Alaskan breeding grounds. In estimating population trend, we used mixed-effects regression models to reduce bias and sampling error associated with improvement in observer skill and annual effects of spring phenology. The estimated population trend on Alaskan breeding grounds since 1986 was near 0 with an estimated annual change of 20.9% (95% CI of 23.6% to 11.8%). The estimated population size, averaged over the past 12 years and adjusted by a correction factor based on an intensive, lake-circling, aerial survey method, was 2221 individuals (95% CI of 1206–3235) in early June and 3369 individuals (95% CI of 1910–4828) in late June. Based on estimates from other studies of the proportion of loons nesting in a given year, it is likely that1000 nesting pairs inhabit northern Alaska in most years. The highest concentration of Yellow-billed Loons occurred between the Meade and Ikpikpuk Rivers; and across all of northern Alaska, 53% of recorded sightings occurred within 12% of the area.

Earnst, S. L., R. Platte and L. Bond. 2006. A landscape-scale model of yellow-billed loon (*Gavia adamsii*) habitat preferences in northern Alaska. ***Hydrobiologia*** 567:227-236.

<u>*Abstract taken directly from text*</u>

We modeled yellow-billed loon (Gavia adamsii) habitat preferences in a 23,500 km^2 area of northern Alaska using intensive aerial surveys and landscape-scale habitat descriptors. Of the 757 lakes censused, yellow-billed loons occupied 15% and Pacific loons (G. pacifica) 42%. Lake area, depth, proportion of shoreline in aquatic vegetation, shoreline complexity, hydrological connectivity (stream present within 100 m or absent), and an area–connectivity interaction were positive, significant predictors of yellow-billed loon presence in a multivariate logistic regression model, but distance to nearest river or Beaufort Sea coast were not. Predicted yellow-billed loon presence was 13 and 4.7 times more likely on deep and medium lakes, respectively, than on shallow lakes that freeze to the bottom. On small lakes (<60 ha), predicted yellow-billed loon presence was 4.8–1.7 times more likely on lakes with hydrological connectivity than without, but connectivity was not important at most lake sizes (65–750 ha). Yellow-billed loon broods depend on fish available in the brood-rearing lake, and we suggest that a dependable supply of fish is more likely in larger lakes, those deep enough to have open water under winter ice, and those near streams. Highly convoluted shorelines and those with aquatic vegetation provide loon nesting and brood-rearing sites, as well as fish habitat. Pacific loon absence was a significant, positive predictor when added to the habitat model, indicating that yellow-billed loons were four times more likely on lakes without Pacific loons.

Eberl, C. and J. Picman. 1993. Effect of Nest-Site Location on Reproductive Success of Red-Throated Loons (*Gavia Stellata*). ***Auk*** 110:436-444.

<u>*Abstract taken directly from text*</u>

The Red-throated Loon (*Gavia stellata*) nests on the shores of freshwater ponds of the Arctic tundra and forages in nearby marine waters. We examined the effects of distance of the nest from foraging waters and of microclimate at the nest site on the loon's reproductive success. As distance from the ocean increased, both density and nesting success decreased. Although hatching success did not vary with distance, success in rearing chicks was significantly lower at distances greater than 9 km from the ocean. Loons with nests further from the ocean fed chicks less often and spent more time on foraging flights than did loons nesting within 9 km of the ocean. Brood reduction in nests far from the ocean presumably resulted from nestling starvation, and possibly also from higher predation due to less effective nest defense. We suggest that the higher density of breeding loons in areas near the ocean reflects preference of these birds for nesting grounds that are closer to their foraging areas. Microclimatic conditions also influenced reproductive success. In areas available for nesting earlier in the year, the loons initiated nesting earlier, but the probability of their reproductive failure due to predation was higher. However, successful pairs in these areas raised larger broods (two chicks) more often than those in areas where birds started breeding later.

Eriksson, M. O. G. 1994. Susceptibility to freshwater acidification by two species of loon: Red-throated Loon (*Gavia stellata*) and Arctic Loon (*Gavia arctica*) in southwest Sweden. ***Hydrobiologia*** 279/280:439-444.

<u>*Abstract taken directly from text*</u>

In southwest Sweden, the two species of loon, *Gavia stellata* and *G. arctica,* have shown different trends in population size and production of young during the last decades. Both species fish in oligotrophic freshwaters, susceptible to acidification. The number of breeding sites occupied by *G. stellata* has been reduced by almost 50% during the last 40-50 years. For *G. arctica,* there are no indications of significant declines in population size or reproductive success during the last 20 years. The different trends in numbers and production of young might reflect different susceptibility to the ecological changes in acidified lakes. *G. stellata* prefer fishing lakes with high abundance of *Acerina cernua* and salmonid and cyprinid fish, such as *Coregonus albula* and *Rutilus rutilus.* They also feed their pre-fledged chicks almost entirely on cyprinid and salmonid fish. *G. arctica* prefer fishing lakes with high transparency and, when feeding in groups, high abundance of *Percafluviatilis.* Their young can be fed on aquatic insects as a supplement to the fish diet. Thus, *G. stellata* to a higher degree than *G. arctica* relies on fish which are susceptible to low pH, and *G. arctica* may also benefit from the increased abundance of aquatic insects in lakes with reduced predation from fish. Furthermore, high water transparency is important for the selection of lakes by *G. arctica* but not by *G. stellata.* In *G. stellata,* high contents of mercury in eggs can be related to the intake of fish in lakes affected by acidification.

Fast, P. L. F., H. G. Gilchrist and R. G. Clark. 2005. Nest Site Use by Arctic-Nesting Common Eiders: Relationships with Habitat Features, Microclimate and Nesting Success. Poster, presented at ArcticNet; Department of Biology, University of Saskatchewan; Canadian Wildlife Service, Ottawa; Department of Biology, Carleton University.

<u>*Abstract not available [excerpts directly from text]*</u>

This project was aimed at conservation and management research of common eiders by providing insights into ecological processes affecting breeding success. Objectives were investigating eider nest site selection patterns, considering these habitat selection results based on natural selection and adaptive response. Natural selection theory is recommended in this project as a tool to frame habitat use studies.

Non-random patterns of nest use occurred at the study site, and some variables associated with likelihood of use were also associated with success. To predict whether populations will be able to adopt new habitat selection strategies in response to contemporary climate changes, the researchers stress the need to understand mechanisms underlying habitat choices and evaluate whether these birds are sufficiently responsive to keep pace with climate change.

Field, R., M. R. North and J. Wells. 1993. Nesting Activity of Yellow-Billed Loons on the Colville River Delta, Alaska, After the Exxon Valdez Oil Spill. ***Wilson Bulletin*** 105:325-332.

<u>*Abstract taken directly from text*</u>
During the summer after the Exxon Vuldez oil spill in Prince William Sound in March 1989, we surveyed Yellow-billed Loons (*Gavia adumsii*) on lakes in the Colville River delta in northern Alaska. A study in 1983-1984 documenting nesting activity in the same area provided a baseline for comparisons of possible effects of the spill on nesting activity. Density of adult loons in 1989 was similar to densities in 1983-1984. We located 26 pairs of Yellow-billed Loons in 29 nesting territories. However, only 42% of the loon pairs nested in 1989, compared to 76% nesting pairs in 1983 and 79% in 1984.

Gauthier, G., J. Bety, J.-F. Giroux and L. Rochefort. 2004. Trophic Interactions in a High Arctic Snow Goose Colony. ***Integrative and Comparative Biology*** 44:119-129.

<u>*Abstract taken directly from text*</u>
We examined the role of trophic interactions in structuring a high arctic tundra community characterized by a large breeding colony of greater snow geese (*Chen caerulescens atlantica*). According to the exploitation ecosystem hypothesis of Oksanen *et al.* (1981), food chains are controlled by top-down interactions. However, because the arctic primary productivity is low, herbivore populations are too small to support functional predator populations and these communities should thus be dominated by the plant/herbivore trophic-level interaction. Since 1990, we have been monitoring annual abundance and productivity of geese, the impact of goose grazing, predator abundance (mostly arctic foxes, *Alopex lagopus*) and the abundance of lemmings, the other significant herbivore in this community, on Bylot Island, Nunavut, Canada. Goose grazing consistently removed a significant proportion of the standing crop (~40%) in tundra wetlands every year. Grazing changed plant community composition and reduced the production of grasses and sedges to a low-level equilibrium compared to the situation where the presence of geese had been removed. Lemming cyclic fluctuations were strong and affected fox reproduction. Fox predation on goose eggs was severe and generated marked annual variation in goose productivity. Predation intensity on geese was closely related to the lemming cycle, a consequence of an indirect interaction between lemming and geese via shared predators. We conclude that, contrary to the exploitation ecosystem hypothesis, both the plant/herbivore and predator/prey interactions are significant in this arctic community.

Gauthier, G., J.-F. Giroux, A. Reed and A. Bechet. 2005. Interactions between land use, habitat use, and population increase in greater snow geese: what are the consequences for natural wetlands? ***Global Change Biology*** 11:856-868.

<u>*Abstract taken directly from text*</u>
The North American greater snow goose population has increased dramatically during the last 40 years. We evaluated whether refuge creation, changes in land use on the wintering and staging grounds, and climate warming have contributed to this expansion by affecting the distribution, habitat use, body condition, and migration phenology of birds. We also reviewed the effects of the increasing population on marshes on the wintering grounds, along the migratory routes and on the tundra in summer. Refuges established before 1970 may have contributed to the initial demographic increase. The most important change, however, was the switch from a diet entirely based on marsh plants in spring and winter (rhizomes of *Scirpus/Spartina*) to one dominated by crops (corn/young grass shoots) during the 1970s and 1980s. Geese now winter further north along the US Atlantic coast, leading to reduced hunting mortality. Their migratory routes now include portions of south-western Quebec where corn production

has increased exponentially. Since the mid-1960s, average temperatures have increased by 1-2.4 degrees C throughout the geographic range of geese, which may have contributed to the northward shift in wintering range and an earlier migration in spring. Access to spilled corn in spring improved fat reserves upon departure for the Arctic and may have contributed to a high fecundity. The population increase has led to intense grazing of natural wetlands used by geese although these habitats are still largely undamaged. The foraging in fields allowed the population to exceed limits imposed by natural marshes in winter and spring, but also prevented permanent damage because of their overgrazing.

Gottschalk, T. K., F. Huettmann and M. Ehlers. 2005. Thirty years of analyzing and modeling avian habitat relationships using satellite imagery data: a review. ***International Journal of Remote Sensing*** 26:2631-2656.

Abstract not available [excerpts directly from text]
The application of remote sensing and Geographic Information Systems (GIS) technologies provides powerful tools when used to investigate wildlife and its habitat for an analysis or modelling approach. In this context, birds have been of great and progressive value as biological and environmental indicators. In order to learn about the common approaches used—its methods, processing steps, trends, advantages and challenges—over 120 representative publications of the last 30 years that made use of satellite images for avian applications have been reviewed. The reviewed studies have shown that GIS-based analyses of satellite and bird data have been well established for efficient ecosystem descriptions and species modelling within a large range of scales and habitats. In order to improve the quality of inference and for comparative analyses, it is recommended that further studies are documented in detail. Also, in order to verify and improve the obtained results, additional ground data on the main structure of the vegetation relevant to the bird species in question are usually necessary. Satellite-based remote sensing applications in ornithology could be used increasingly for assisting in habitat evaluation, habitat modelling and monitoring programmes and in achieving overall wildlife conservation and management objectives effectively. This is especially true for remote regions of the world that are difficult to access where few habitat studies have been undertaken to date but whose study is urgently needed.

Jefferies, R. L., R. F. Rockwell and K. F. Abraham. 2004. Agricultural Food Subsidies, Migratory Connectivity and Large-Scale Disturbance in Arctic Coastal Systems: A Case Study. ***Integrative and Comparative Biology*** 44:130-139.

Abstract taken directly from text
An allochthonous input can modify trophic relationships, by providing an external resource that is normally limiting within a system. The subsidy may not only elicit a growth response of the primary producers via a bottom-up effect, but it also may lead to runaway herbivore growth in the absence of increased predation. If the consumer is migratory and predation is similarly dampened in the alternative system, the increased numbers may produce a top-down cascade of direct and indirect effects on an ecosystem that may be a great distance from the source of the subsidy. In an extreme case, it can lead to a catastrophic shift in ecosystem functioning as a result of biotic exploitation that produces an alternative stable state. The loss of resilience is particularly sensitive to herbivore density which can result in two different outcomes to the vegetation on which the consumer feeds. Over-compensatory growth of aboveground biomass gives way to sward destruction and near irreversible changes in soil properties as density of a herbivore increases. A striking temporal asymmetry exists between a reduction in the consumer population and recovery of damaged vegetation and degraded soils.

Johnson, S. R. and L. E. Noel. 2005. Temperature and Predation Effects on Abundance and Distribution of Lesser Snow Geese in the Sagavanirktok River Delta, Alaska. ***Waterbirds*** 28:292-300.

Abstract taken directly from text
The largest and most productive colony of Snow Geese (*Chen caerulescens caerulescens*) in Alaska for two decades (1980-1999) was on Howe Island in the outer Sagavanirktok River Delta. Petroleum development began in this area during the mid-1980s, and studies of Snow Geese on Howe Island were

conducted annually since 1980. Annual gosling production remained high and the colony expanded during 1980-1993; thereafter both gosling production and colony size declined. During 1980-1993, gosling production was highly and positively correlated with mean daily air temperature during the 1-25 June incubation period, and predation at the colony was insignificant. After 1993, there was an increase in predation on Snow Goose eggs at Howe Island by Grizzly Bears (*Ursus arctos*) and other mammalian and avian predators, which resulted in the decline of the Howe Island colony. New Snow Goose colonies east of the oil fields expanded during the decline on Howe Island. Evidence suggests that this eastward expansion likely resulted from dispersal or displacement of geese from Howe Island. After 1993, the effects of predation confounded the known effects of spring temperatures, and predation became the significant factor influencing gosling production. Increased predators in the Prudhoe Bay area and at Howe Island were suspected to be linked to the availability of human food waste and refuse and to the cessation of hunting and trapping in the area. Recently imposed mitigation measures have included better refuse and waste management and removal of problem bears. These measures should result in reduced predation and increased productivity at the Howe Island Snow Goose colony.

Kark, S., T. F. Allnutt, N. Levin, L. L. Manne and P. H. Williams. 2007. The role of transitional areas as avian biodiversity centres. ***Global Ecology and Biogeography*** 16:187-196.

Abstract taken directly from text
Aim: With the ever-increasing threats to biodiversity, efforts are being directed towards identifying hotspots of special importance for conservation. In particular, there has been an effort to identify irreplaceable regions that are especially rich in rare species. Areas of transition between ecological systems in which multiple species coincide are expected, almost by definition, to be species-rich. Here, we examine whether this is simply a result of an overlap between two communities in boundary regions, or whether boundary areas also hold concentrations of rare (e.g. range-limited) species. We ask whether an analysis that includes areas of transition may be a useful contribution to the identification of biodiversity centres.
Location and methods: To address these questions, we examined the relationship between passeriform richness and range size rarity of approximately 2300 bird species in 4889 1° New World grid cells, and the distance of the cells to boundaries between adjacent plant-based ecoregions.

Kinzel, P. J., J. M. Nelson, R. S. Parker and L. R. Davis. 2006. Spring Census of Mid-Continent Sandhill Cranes Using Aerial Infrared Videography. ***Journal of Wildlife Management*** 70:70-77.
Abstract taken directly from text
Aerial infrared videography was used to map spatial distributions of nocturnal sandhill crane (*Grus canadensis*) flocks and determine crane densities within roosts as an alternative to the currently used diurnal photo-corrected ocular transect method to estimate the size of the mid-continental population. The densities determined from samples taken over the course of a night show variability. Densities measured early in the night (2100 to 2300 hrs) were generally lower than those measured in the time period after midnight and up until cranes prepared to depart their roosts before sunrise. This suggests that cranes may be more active early in the night and possibly still settling into their roosts at this time. For this reason, densities and areas measured later at night and into the early morning were used to estimate population size. Our methods estimated that the annual crane populations along the central Platte River in Nebraska were higher than estimates from the ocular transect method; however both methods showed a similar trend with time. Our population size estimates likely were higher because our methodology provided synoptic imagery of crane roosts along the entire study reach when all cranes had returned to the river, and the nocturnal densities were higher than previous estimates using observations from late evening or early morning. In addition to providing a tool for estimating annual population size, infrared videography can be utilized over time to identify spatial changes in the roosting patterns that may occur as a result of riverine management activities.

Klicka, J., R. M. Zink and K. Winker. 2003. Longspurs and snow buntings: phylogeny and biogeography of a high-latitude clade (*Calcarius*). ***Molecular Phylogenetics and Evolution*** 26:165-175.

Abstract taken directly from text

Using complete cytochrome b sequence data, we determined that the genus *Calcarius*, as presently recognized, is paraphyletic. *Calcarius* plus *Plectrophenax* form a highly supported clade composed of two subclades, a ''snow bunting'' clade comprised of *Plectrophenax* plus *Calcarius mccownii* (formerly in the monotypic genus *Rhynchophanes*), and a ''collared'' longspur clade of *Calcarius lapponicus*, *ornatus*, and *pictus*. Contrary to conventional thought, *Calcarius* is not phylogenetically close to either *Calamospiza* or *Emberiza*.Unlike these two genera, the taxonomic affinities of *Calcarius* appear to lie outside of the sparrow (tribe *Emberizini*) assemblage. *Calcarius* appears to be a relatively old songbird lineage, originating between 4.2 and 6.2 million years ago. Within *Calcarius*, *pictus* and *ornatus* form a closely related sister pair (2.9% divergent), as do *Calcarius nivalis* and *hyperboreus* (0.18% divergent). The group (*Calcarius*, *sensu lato*) is inferred to have its origins at relatively high latitudes in the New World.

Krapu, G. L., J. L. Eldridge, C. L. Gratto-Trevor and D. A. Buhl. 2006. Fat Dynamics of Arctic-Nesting Sandpipers During Spring in Mid-Continent North America. ***Auk*** 123:323-334.

Abstract taken directly from text

We measured fresh body mass, total body fat, and fat-free dry mass (FFDM) of three species of Arctic-nesting calidrid sandpipers (Baird's Sandpiper [*Calidris bairdii*], hereafter "BASA"; Semipalmated Sandpiper [*C. pusilla*], hereafter "SESA"; and White-rumped Sandpiper [*C. fuscicollis*], hereafter "WRSA") during spring stopovers in the Prairie Pothole Region (PPR) of North Dakota, and evaluated the contribution of stored fat to (1) energy requirements for migration to their Arctic breeding grounds and (2) nutrient needs for reproduction. All spring migrant WRSA (n = 124) and BASA (n = 111), and all but 2 of 99 SESA we collected were ≥2 years old. Male and female BASA migrated through North Dakota concurrently, male SESA averaged earlier than females, and WRSA males preceded females. Fat indices (ratio of fat to FFDM) of male and female SESA and WRSA averaged approximately twice those of male and female BASA. Total body fat of male and female BASA increased with date in spring 1980, but not in 1981; slopes were similar for both sexes each year. Male and female SESA arrived lean in 1980 and 1981, and total body fat increased with date in both years, with similar slopes for all combinations of sex and year. Male and female WRSA arrived lean in 1980–1981 and 1981, respectively, and total body fat increased with date, whereas females arrived with fat reserves already acquired in 1980. Interspecific and sex differences in migration schedules probably contributed to variation in fat storage patterns by affecting maintenance energy costs and food availability. Estimated flight ranges of BASA suggest that few could have met their energy needs for migration to the breeding grounds exclusively from fat stored by the time of departure from North Dakota. Estimated flight ranges of SESA and WRSA, along with fresh body masses of both species when live-trapped on or near their breeding grounds in northern Canada, suggest that major parts of both populations stored adequate fat by departure from temperate mid-continental North America to meet their energy requirements for migration and part of their nutrient needs for reproduction.

Lake, B. C., M. S. Lindberg, J. A. Schmutz, R. M. Anthony and F. J. Broerman. 2006. Using Videography to Quantify Landscape-Level Availability of Habitat for Grazers: An Example with Emperor Geese in Western Alaska. ***Arctic*** 59:252-260.

Abstract taken directly from text

We present a videography approach to estimating large-scale availability of grazing lawns, an important food resource used by broods of emperor geese (*Chen canagica*) on the Yukon-Kuskokwim Delta, Alaska. Sampling was conducted in 1999, 2003, and 2004 at six locations that encompassed ~40% of the North American population of breeding emperor geese. We conducted ground truthing in 2003 and 2004 to estimate how accurately grazing lawn was classified. Overall, classification accuracy for grazing lawn and non-grazing lawn habitat was greater than 91%. Availability of grazing lawns was stable among years, but varied both among and within locations. Some locations have up to three times as much available grazing lawn, which in combination with densities of geese, likely represents dramatic variation in per capita food availability. Our results suggest that videography is a useful way to sample quickly across a large region and accurately identify fine-scale habitats. We present its use for estimating the

availability of a preferred food resource for emperor geese, but the method could be applied to many other cases.

Lepage, D., D. N. Nettleship and A. Reed. 1998. Birds of Bylot Island and Adjacent Baffin Island, Northwest Territories, Canada, 1979 to 1997. ***Arctic*** 51:125-141.

<u>*Abstract taken directly from text*</u>
Observations of birds in the Bylot Island region from 1979 to 1997, with emphasis on the southwest part of the island each summer since 1989, revealed an avifauna composed of 63 species, of which 35 were breeding. Thirteen species are new records for the region, including one for the Northwest Territories (black-headed gull *Larus ridibundus*) and two for the Canadian Arctic Archipelago (killdeer *Charadrius vociferus*; mew gull *Larus canus*). Two species, Canada goose (*Branta canadensis*) and red knot (*Calidris canutus*), were also confirmed as breeders for the first time in the region. A summary of these avifaunal observations, along with a review of previous observations made in the region, allows changes in population size and status of individual species to be identified. These records combined with those from earlier studies give a total of 74 species for the Bylot Island region, 45 confirmed as breeders. This makes the avian community in the area one of the most diverse known north of 70˚N latitude in the Canadian Arctic Archipelago.

Lin, Y., M. Yeh, D. Deng and Y. Wang. 2008. Geostatistical approaches and optimal additional sampling schemes for spatial patterns and future sampling of bird diversity. ***Global Ecology and Biogeography*** 17:175-188.

<u>*Abstract taken directly from text*</u>
Aim: To evaluate geo-statistical approaches, namely kriging, co-kriging and geo-statistical simulation, and to develop an optimal sampling design for mapping the spatial patterns of bird diversity, estimating their spatial autocorrelations and selecting additional samples of bird diversity in a 2450 km^2 basin.
Location: Taiwan
Methods: Kriging, co-kriging and simulated annealing are applied to estimate and simulate the spatial patterns of bird diversity. In addition, kriging and co-kriging with a genetic algorithm are used to optimally select further samples to improve the kriging and co-kriging estimations. The association between bird diversity and elevation, and bird diversity and land cover, is analysed with estimated and simulated maps.
Results: The Simpson index correlates spatially with the normalized difference vegetation index (NDVI) within the micro-scale and the macro-scale in the study basin, but the Shannon diversity index only correlates spatially with NDVI within the micro-scale. Co-kriging and simulated annealing simulation accurately simulate the statistical and spatial patterns of bird diversity. The mean estimated diversity and the simulated diversity increase with elevation and decrease with increasing urbanization. The proposed optimal sampling approach selects 43 additional sampling sites with a high spatial estimation variance in bird diversity.
Main conclusions: Small-scale variations dominate the total spatial variation of the observed diversity due to a lack of spatial information and insufficient sampling. However, simulations of bird diversity consistently capture the sampling statistics and spatial patterns of the observed bird diversity. The data thus accumulated can be used to understand the spatial patterns of bird diversity associated with different types of land cover and elevation, and to optimize sample selection. Co-kriging combined with a genetic algorithm yields additional optimal sampling sites, which can be used to augment existing sampling points in future studies of bird diversity.

Mainguy, J., G. Gauthier, J.-F. Giroux and I. Duclos. 2006. Habitat use and behaviour of Greater Snow Geese during movements from nesting to brood-rearing areas. ***Canadian Journal of Zoology*** 84: 1096-1103.

<u>*Abstract taken directly from text*</u>
Many pre-cocial birds make long-distance movements with their young after hatch to reach the best foraging sites. On Bylot Island, Nunavut, a large number of Greater Snow Goose (*Chen caerulescens*

atlantica L., 1758) families move 30 km from the main nesting colony (MNC) to reach the main brood-rearing area (MBR) soon after hatch. Geese moving from the MNC to the MBR generally rear lighter and smaller goslings than geese that avoid this movement by bother nesting and rearing their brood at the MBR. In this study, we tested the hypotheses that use of low-quality habitats and an increase in the time spent walking at the expense of foraging during movements could explain the reduced growth of goslings in those families. We conducted visual observations to compare habitat use and selection as well as behaviour of geese during brood movements from the MNC to the MBR (i.e., at a transit area) with those of families that had already settled at the MBR. We also conducted aerial tracking to monitor habitat use of 16 radio-marked females during and after brood movements. Streams, wet polygons, and lakes, considered high-quality habitats in terms of feeding opportunities and predator refuges, were preferred, while upland, a low-quality habitat, was avoided at both the transit area and the MBR. However, broods were found in the upland habitat more often during movements than once settled on a rearing site. The behaviour of unmarked geese at the transit site did not differ from that of geese at the MBR. We suggest that reduced food intake in low-quality habitats during movements, but not the increase in time spent walking, may explain the reduction in growth observed at fledging in goslings moving from the MNC to the MBR.

McLaren, P. and M. A. McLaren. 1982. Waterfowl Populations in Eastern Lancaster Sound and Western Baffin Bay. ***Arctic*** 35:149-157.

<u>*Abstract taken directly from text*</u>
The seasonal distributions of oldsquaws *(Clangula hyemalis),* common eiders *(Somareria mollissima)* and king eiders (S.*specrabilis)* were determined through aerial surveys in eastern Lancaster Sound (1976, 1978, 1979) and northwest Baffin Bay (1978, 1979). Sightings of geese are summarized in an Appendix. The major spring influx of both eiders occurs about the second week of May but most oldsquaws do not arrive until the first half of June. In spring, all three species are rare in offshore areas, are most abundant along coasts in the northern half of the study area, and tend to depart to nesting areas during the last week of June. Oldsquaws molt along coasts of Lancaster Sound and northwest Baffin Bay, but both species of eiders undertake molt migrations. Three waves of eider out-migration were detected in 1976 and 1978. Distribution and movements within the study area are related to probable migration routes and ice conditions.

Morrison, R. I. G. 1997. The Use of Remote Sensing to Evaluate Shorebird Habitats and Populations on Prince Charles Island, Foxe Basin, Canada. ***Arctic*** 50:55-75.

<u>*Abstract taken directly from text*</u>
Landsat-5 Thematic Mapper imagery was used to produce a 17-habitat classification of Prince Charles Island, Foxe Basin, Northwest Territories, through a combination of supervised and unsupervised approaches. Breeding shorebirds and habitats were surveyed at 35 study plots in July 1989. Habitat-specific breeding densities calculated from these observations were used to estimate total populations of breeding shorebirds on the island based on areas of habitat derived from the classified image. Breeding densities were further modelled in two ways: first, to adjust for distance from the coast, where regression analyses found a significant relationship between distance and density, and second, to include only those pixels of areas considered suitable for breeding, using results of a proximity analysis to determine habitat associations between known breeding locations (pixels) and other habitats. Six species of shorebirds were found breeding on Prince Charles Island, with a combined population (after modelling) estimated at 294,000 pairs. Comparison of breeding densities and estimated populations of shorebirds with those recorded at other arctic locations indicated that Prince Charles Island supports highly significant numbers of shorebirds, especially white-rumped sandpipers and red phalaropes. Comparison of reference areas of known habitat with those on the classified image indicated classification accuracy averaged over 90%. Remote sensing appears to offer a reliable method for assessing habitats and regional breeding populations of birds in at least some areas, providing that classification methods are carried out in a carefully controlled manner. Use of the method over broad areas of the Arctic would require considerable work to recalibrate imagery for different geographic regions.

Ngai, J. T. and R. L. Jefferies. 2004. Nutrient limitation of plant growth and forage quality in Arctic coastal marshes. ***Journal of Ecology*** 92:1001-1010.

Abstract taken directly from text
1) Foraging by geese has led to vegetation loss in salt marshes along the Hudson Bay coast and lesser snow geese are increasingly grazing inland freshwater marshes. We determined whether different nutrients limit the growth of forage plants in the two habitats, and whether these differences affect the nutritional quality of vegetation available to geese at La Pérouse Bay, Manitoba.
2) Results from fertilization experiments indicate that primary productivity in the salt marsh is both nitrogen and phosphorus limited, whereas the freshwater marsh is phosphorus limited. Total amounts of calcium, magnesium and potassium in above-ground biomass per unit area showed similar differences in limitation.
3) Leaves of preferred forage species have higher nutrient concentrations (nitrogen, phosphorus, calcium, potassium, magnesium, sodium) and lower C : N and C : P ratios than alternative forage. The main forage species in the salt marsh (*Puccinellia phryganodes*) has higher nutrient content per unit mass, for nitrogen, magnesium, calcium and sodium, than the major freshwater marsh species (*Carex aquatilis*). The difference in nutritional quality of forage between the marshes is likely to have had consequences for goose fitness, and may have contributed to the reported declines in gosling survivorship and size.
4) At moderate grazing intensities, seasonal growth of salt-marsh forage is maintained by addition of nitrogen and, to a lesser extent, phosphorus from high numbers of goose faeces to swards. In contrast, the low densities and low phosphorus content of goose faeces in the phosphorus-limited freshwater marsh mean that plants are unlikely to recover rapidly from the effects of grazing. As a consequence, the freshwater marsh is likely to become increasingly less productive as foraging intensifies.
5) Nutrient gradients in vegetation across an ecotone and changes in foraging behaviour have resulted in adverse effects on both the growth rates of individuals and the population structure of a herbivore.

Palomino, D. and L. M. Carrascal. 2007. Threshold distances to nearby cities and roads influence the bird community of a mosaic landscape. ***Biological Conservation*** 140:100-109.

Abstract taken directly from text
Urban developments and road networks extend their impacts on the surrounding habitats along a variable distance, affecting birds living in natural environments. This study identifies the threshold distances upon which several cities and roads, located across a large mosaic landscape of ca. 300 km^2 in central Spain, alter the abundance patterns of the native avifauna. Total species richness, total bird abundance, and abundance of different guilds of birds which are potentially sensitive to human disturbances were modelled by means of tree regression analyzes. Nearby cities do not affect the total bird species richness in natural habitats of the study region. Total bird abundance increases near urban areas, mainly through its positive influence on urban-exploiter species. The effect of roads is negative and highly generalized, although threshold distances to roads vary among different groups of species. The bird communities of deciduous woodlands (ash groves, oak patches and poplars) show higher resilience to deleterious influences from nearby cities and roads. It would be desirable not to build new scattered urban developments within the remnant natural areas of this heavily fragmented region, because their existence and connection to the nearby cities by new roads would add 'invisible' negative effects on the native bird fauna (e.g. on some threatened species from open habitats), considering the buffer distances determining most significant impacts (400 m for urban areas, and 300 m for roads).

Renaud, W. E., S. R. Johnson and P. D. Hollingdale. 1979. Breeding Birds of Arctic Bay, Baffin Island, NWT, with Notes on the Biogeographic Significance of the Avifauna. ***Arctic*** 32:122-134.

Abstract taken directly from text
The known avifauna of the Arctic Bay area consists of 38 species, of which 22 are probable or proven breeders and 3 are permanent residents. Arctic Bay appears to be in a transition area between characteristic high arctic and low arctic forms. Eurasian or Greenlandic forms include breeding Ringed

Plover and 'Greenland' Hoary Redpoll; and transient Wheatear, Red Knot and Ruddy Turnstone. The absence, of several sea-associated species as breeders or even transients may be attributed to the normal late ice break-up in Admiralty Inlet.

Rodrigues, R. 1994. Microhabitat Variables Influencing Nest-Site Selection by Tundra Birds. ***Ecological Applications*** 4:110-116.

Abstract taken directly from text
Studies were performed to determine what types of microhabitat characteristics attract the most common bird species to nest at particular sites on tundra habitats in the Prudhoe Bay oil field. Microhabitat variables of 2 × 2 m plots centered on bird nests were measured and compared with those of plots centered on random points. Results indicated differences in amount of micro-relief, graminoid and shrub/forb cover, roughness of topography, and presence of water among species. These differences have implications for management of abandoned gravel sites as oil production declines in the Prudhoe Bay oil field. The amount and variability of microrelief plays an important role in influencing nest-site selection. Birds do not require total coverage by graminoid and shrub/forb plant species at nest sites. Water plays an important role by influencing plant growth at disturbed gravel sites.

Romero, L. M., K. K. Soma and K. M. O'Reilly. 1998. Hormones and Territorial Behavior during Breeding in Snow Buntings (*Plectrophenax nivalis*): An Arctic-Breeding Songbird. ***Hormones and Behavior*** 33:40-47.

Abstract taken directly from text
We examined hormonal profiles and behavior associated with maintaining a single-purpose territory in an Arctic-breeding songbird—the snow bunting (*Plectrophenax nivalis*). Snow buntings differ from many other Arctic-breeding passerines by using nest cavities, an uncommon and defended resource, but not relying upon the surrounding territory for forage. Circulating levels of testosterone in males were high when territories were established and then decreased over the breeding season. LH secretion was enhanced in females while laying eggs, followed by detectable levels of estradiol during incubation. Both sexes showed equivalent corticosterone responses to the stress of being captured and held. Male snow buntings vigorously defended territories in response to a simulated territorial intrusion both when initiating breeding and when feeding young. Exogenous testosterone implants surprisingly inhibited physical aggression but enhanced singing when birds were feeding young, thus suggesting that song and physical aggression are mediated by different hormonal mechanisms at this time of year. Together, these results contrast with hormonal profiles and behavior in other Arctic-breeding passerines.

Rosenfield, R. N., J. W. Schneider, J. M. Papp and W. S. Seegar. 1995. Prey of Peregrine Falcons Breeding in West Greenland. ***Condor*** 97:763-770.

Abstract taken directly from text
Previous studies on the diet of Peregrine Falcons (*Falco peregrinus*) in Greenland were based primarily on prey remains, an indirect technique that may produce biased results. Earlier estimates of prey biomass are too general and speculative to be conclusive. No other study provided data on the age of prey species or showed that Rock Ptarmigan (*Lagopus mutus*) can be an important component in the diet of Greenland peregrines. We used direct observations of prey deliveries and collection of prey remains to assess prey (in terms of frequency of occurrence and biomass) of breeding Peregrine Falcons in West Greenland. We also determined prey selection in relation to local prey availability. During 492 hr of observation at two eyries we found that four small passerines-Lapland Longspur (*Calcarius lapponicus*), Northern Wheatear (*Oenanthe oenanthe*), Common Redpoll (*Carduelisflammea*), and Snow Bunting (*Plectrophenax nivalis*)- contributed over 80% of the prey items delivered, with the longspur being the principal prey species in terms of frequency of occurrence and biomass. However, ptarmigan contributed almost as much biomass as longspurs at one eyrie. Fledglings of all these bird species provided the majority of items and biomass at both eyries. Analysis of 676 prey items from prey remains at 159 eyries showed similar frequencies and rankings for the prey species comprising the majority of the diet of

Peregrine Falcons as determined by prey deliveries. Lapland Longspur was taken in proportion to its availability near two eyries; ptarmigan and Snow Buntings were taken more frequently than expected. Local differences in prey use (especially ptarmigan) were found.

Smith, P. A., H. G. Gilchrist and M. R. Forbes. 2005. ***Effects of Nest Site and Parental Behaviour on Shorebird Reproductive Success***. Poster, Carleton University and Canadian Wildlife Service, Ottawa, ON.

<u>*Abstract [excerpts directly from text]*</u>
Many studies have demonstrated that nest sites are selected actively, such that microhabitat at nest sites differs from random sites. However, far fewer studies have clearly demonstrated that such microhabitat preferences are adaptive; i.e., that individuals nesting in preferred microhabitats experience higher nest success in the long run. This study looks at shorebird nest habitat and parental behaviour to determine which factor has the greater influence on nest success in a tundra system. The researchers tested for patterns of nest preference by contrasting nests with random sites, and looked for differences between the microhabitat of successful and unsuccessful nests to test for adaptive nest site choice. According to the researchers, they found clear evidence that the nest site selection was non-random, but little evidence that variation in the habitat of nest sites contributed to variation in reproductive success.

Strong, P. I. V. 1990. The Suitability of the Common Loon as an Indicator Species. ***Wildlife Society Bulletin*** 18:257-261.

<u>*Abstract not available [excerpts directly from text]*</u>
Indicator species are used widely to monitor environmental conditions despite inherent problems in the indicator species concept and recent criticisms. Loons are generally considered to be good indicators of high quality lacustrine habitats and are used as indicators in some studies and monitoring programs. This paper evaluates the suitability of the common loon as an indicator species and discusses the limitations of population measurements commonly used to assess the status of loon populations. Although common loons can habituate to human disturbance, there seems to be great variation in the response of individuals. The common loon has a long life span, and the fact that it is in a high trophic level in aquatic food webs makes it useful in studies of environmental contaminants that bio-accumulate. However, its niche breadth, variability in response, and migratory nature make it undesirable as an indicator of local habitat quality. Loon populations are unlikely to change quickly in response to environmental conditions and may be difficult to survey. Additionally, there are no data suggesting that there is a strong correlation between common loon populations and populations of other species that are found in the same habitat. Overall, the common loon is a poor choice for use as an indicator species.

Wiklund, C. G., N. Kjellen and E. Isakson. 1998. Mechanisms Determining the Spatial Distribution of Microtine Predators on the Arctic Tundra. ***Journal of Animal Ecology*** 67:91-98.

<u>*Abstract taken directly from text*</u>
1) We studied the spatial distribution of avian microtine predators using data from 19 study areas on the tundra of northern Siberia.
2) Numbers of snowy owls, and long-tailed skuas and pomarine skuas depended
strongly on lemming density. However, a significant relationship between lemming density and number of rough-legged buzzards appeared first after removal of the effect of snowy owl abundance on the distribution of rough-legged buzzards.
3) We applied a recently developed method (Manly 1995) to examine co-occurrences of species and found that rough-legged buzzards and snowy owls did not co-occur while snowy owls, long-tailed skuas and pomarine skuas did.
4) There are large differences in nest construction and chick behaviour between rough-legged buzzards and the three other species. Moreover, the snow owl is a polyphagous predator preying also on large birds including raptor chicks. Therefore, we propose that reduced risk of nest predation favours rough-legged buzzards nesting away from snowy owls.

5) Variations in abundance of the two lemming species did not seem to influence the distributions of snowy owls and rough-legged buzzards. Neither was it likely that latitudinally related factors such as breeding season length affected the distribution of rough-legged buzzards.

Wilson, D. J. and R. G. Bromley. 2001. Functional and numerical responses of predators to cyclic lemming abundance: effects on loss of goose nests. ***Canadian Journal of Zoology*** 79:525-532.

Abstract taken directly from text
The alternative-prey hypothesis predicts that predation on goose eggs will be most severe the year following a lemming peak. We tested this by investigating how predators of goose eggs responded to lemming abundance on the Kent Peninsula, Nunavut, Canada, where nest success of white-fronted geese (*Anser albifrons frontalis*) and Canada geese (*Branta canadensis hutchinsii*) fluctuates widely. The main predators of both goose eggs and lemmings are arctic foxes (*Alopex lagopus*), glaucous gulls (*Larus hyperboreus*), and parasitic jaegers (*Stercorarius parasiticus*). Foxes responded functionally to lemming density: in prime goose-nesting areas they spent less time foraging during the peak lemming year than during the increase, and were seen foraging in prime nesting areas less often during the peak than during the decline. However, numbers of fox sightings in the study area during the nesting period did not differ significantly among years. The total response (functional × numerical) of gulls was lowest at the lemming peak and highest during the increase. The total response of parasitic jaegers did not vary significantly among years. Hence, we predicted that the number of nests lost to all predators combined should be lowest at the peak and possibly highest during the increase. During the 3 years of this study, loss of Canada goose nests was lowest at the peak but highest during the decline, and annual losses of white-fronted goose nests varied little. In cycles prior to this study, nest loss was high in declines but not particularly low during peaks. Several factors may alter the functional and numerical responses of predators, obscuring the simple pattern of nest loss predicted by the alternative-prey hypothesis.

2.5.2.2 Foxe Basin & Hudson Strait

Alerstam, T., G. A. Gudmundsson, M. Green and A. Hedenstrom. 2001. Migration along Orthodromic Sun Compass Routes by Arctic Birds. ***Science*** 291:300-303.

Abstract taken directly from text
Flight directions of birds migrating at high geographic and magnetic latitudes can be used to test bird orientation by celestial or geomagnetic compass systems under polar conditions. Migration patterns of arctic shorebirds, revealed by tracking radar studies during an icebreaker expedition along the Northwest Passage in 1999, support predicted sun compass trajectories but cannot be reconciled with orientation along either geographic or magnetic loxodromes (rhumb lines). Sun compass routes are similar to orthodromes (great circle routes) at high latitudes, showing changing geographic courses as the birds traverse longitudes and their internal clock gets out of phase with local time. These routes bring the shorebirds from high arctic Canada to the east coast of North America, from which they make transoceanic flights to South America. The observations are also consistent with a migration link between Siberia and the Beaufort Sea region by way of sun compass routes across the Arctic Ocean.

Allard, K. A., A. R. Breton, H. G. Gilchrist and A. W. Diamond. 2006. Adult Survival of Herring Gulls Breeding in the Canadian Arctic. ***Waterbirds*** 29:163-168.

Abstract taken directly from text
Apparent survival of adult Herring Gulls (*Larus argentatus*) occupying two distinct breeding habitats within the East Bay Migratory Bird Sanctuary, on Southampton Island, Nunavut was estimated. The first group occurred on a small island where 30 pairs bred at relatively high densities sympatrically with Common Eider (*Somateria mollissima*), on whose eggs they feed. The larger group occurred at lower densities on a wet coastal plain on the surrounding Southampton Island mainland, where nesting birds were sparsely distributed. Program Mark was used to analyze capture-mark-resight (CMR) data obtained over six years from 62 adults captured between 1998 and 2002; 47 and 15 nesting on the island and mainland respectively. Factors in models included group and time effects on survival and reduced time effects on

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encounter probabilities; additional factors and interactions were not tested due to sparse data. High model selection uncertainty and wide 95% confidence intervals around model effect sizes precluded ability to draw inferences concerning the importance of group and time factors in survival. Given these results, focus was placed mainly on an estimate of annual survival (0.87±0.03 SE) from the time- and group-independent model. This is the only known survival estimate produced for Herring Gull adults at the northern limit of their North American breeding range and falls within the wide range of values reported elsewhere.

Andres, B. A. 2006. An Arctic-Breeding Bird Survey on the Northwestern Ungava Peninsula, Quebec, Canada. ***Arctic*** 59:311-316.

<u>*Abstract taken directly from text*</u>
Knowledge of breeding bird distribution and abundance in the Canadian Arctic remains rudimentary for many species, particularly for shorebirds and songbirds. To help fill this gap, randomly selected plots were surveyed on the north-western coast of the Ungava Peninsula, Quebec, Canada, during 2002. Thirty-eight species were recorded at 34 sites, where small songbirds were much more frequent than shorebirds. Breeding waterbirds were more abundant at low elevations near the cost, and songbirds tended to be more abundant at higher elevations. A high occurrence of nesting hawks and owls was probably the result of a high lemming population. Information from the survey extending the known breeding ranges of green-winged teal, spotted sandpiper, pectoral sandpiper, dunlin, American golden-plover, Wilson's snipe, and short-eared owl. Further work on the Ungava Peninsula would likely document additional Arctic-breeding bird species. A more thorough knowledge of Arctic-breeding bird distribution will be needed to determine how species might be affected by global climate change.

Bart, J., B. Andres, S. Brown, G. Donaldson, B. Harrington, V. Johnston, S. Jones, G. Morrison and S. Skagen. 2002. ***The Program for Regional and International Shorebird Monitoring (PRISM)***. U.S.D.A. Forest Service.

<u>*Abstract taken directly from text*</u>
This report describes the "Program for Regional and International Shorebird Monitoring" (PRISM). PRISM is being implemented by a Canada-United States Shorebird Monitoring and Assessment Committee formed in 2001 by the Canadian Shorebird Working Group and the U.S. Shorebird Council. PRISM provides a single blueprint for implementing the shorebird conservation plans recently completed in Canada and the United States. The goals of PRISM are to (1) estimate the size of breeding populations of 74 shorebird taxa in North America; (2) describe the distribution, abundance, and habitat relationships for each of these taxa; (3) monitor trends in shorebird population size; (4) monitor shorebird numbers at stopover locations, and; (5) assist local managers in meeting their shorebird conservation goals. PRISM has four main components: arctic and boreal breeding surveys, temperate breeding surveys, temperate nonbreeding surveys, and neotropical surveys. Progress on, and action items for, each major component are described. The most important major tasks for immediate action are carrying out the northern surveys, conducting regional analyses to design the program of migration counts, and evaluating aerial photographic surveys for migration and winter counts.

Batt, B. D. J., editor. 1998. ***The Greater Snow Goose: report of the Arctic Goose Habitat Working Group***. Arctic Goose Joint Venture Special Publication. U.S. Fish and Wildlife Service, Washington, D.C. and Canadian Wildlife Service, Ottawa, Ontario. 88 pp.

<u>*Abstract taken directly from text*</u>
The spring population of the greater snow goose has increased from less than 50,000 birds in the late 1960s to about 700,000 in the spring of 1997. The growth rate of the population is approximately 9% per year, about twice the rate of the mid-continent lesser snow goose. The population is doubling about every eight years and there are no signs to indicate any slowing of this pattern. At this rate, numbers of greater snow geese should reach 1,000,000 by 2002 and 2,000,000 by 2010. The geese heavily use traditional spring and fall staging areas along the St. Lawrence River. The numbers of birds have far exceeded the

carrying capacity of the natural marshes and the birds have expanded their use of habitat into surrounding farmlands. The long-term integrity of the marshes is threatened with continuing degradation but these changes are not believed to be permanent or irreversible if the impact of the geese could be reduced. Wintering habitat on the Atlantic Coast is severely impacted at a few traditionally used sites. However, this damage is limited in relation to the total amount of salt marsh available and these damaged areas are likely to recover if management practices can be implemented to redistribute the birds to other unused salt marsh areas. On wintering areas, the increased numbers of geese is also being sustained by their use of agricultural habitats. Some localized crop damage occurs but it is not extensive. However, damage to hayfields near spring staging areas along the St. Lawrence River is severe, widespread and of considerable economic significance. This is a major management problem for wildlife agencies and will worsen as the greater snow goose population continues to grow. However, even if population growth is arrested, the birds have adapted so thoroughly to these agricultural habitats that the impacts by the geese will remain very extensive and will require innovative corrective measures.

Bechet, A., J. Martin, P. Meister and C. Rabouam. 2000. A Second Breeding Site for Ross's Gull (*Rhodostethia rosea*) in Nunavut, Canada. ***Arctic*** 53:234-236.

Abstract taken directly from text
Only 15 cases of breeding of Ross's gull *Rhodostethia rosea* are known outside of Siberia. While numerous birds are regularly seen in the fall at Point Barrow, Alaska, until now only one breeding locality has been known for Nunavut, Canada. We found a second breeding locality in Nunavut in the northwestern corner of Prince Charles Island (Foxe Basin). We observed one pair incubating two eggs on a small island (30 m in diameter) situated in a medium-sized lake, on a low plateau at the top of a complex of raised beaches. None of the reports on aerial or land surveys of this region have mentioned the reproduction of this species, though unpublished aerial observations suggest that the species has been present during the 1980s. Outside Siberia, this species seems to be characterized by an irregular and scattered distribution of its breeding sites.

Bergman, R. D. and D. V. Derksen. 1977. Observations on Arctic and Red-throated Loons at Storkersen Point, Alaska. ***Arctic*** 30:41-51.

Abstract taken directly from text
Habitat requirements of arctic loons (*Gavia arctica*) and red-throated loons (*Guviu stellata*) were studied at Storkersen Point on the Arctic coastal plain of Alaska from 1971 to 1975. Nest success ranged from 28 to 92 per cent and 33 to 78 per cent for arctic and red-throated loons, respectively. Loons were ecologically isolated in their feeding habits and use of wetlands. Arctic loons fed to their young invertebrates captured in the nest pond, and red-throated loons fed to theirs fish captured from the Beaufort Sea. Both species preferred islands as nest substrates, but arctic loons utilized large ponds with stands of *Arctophila fulva* wetlands for nesting, whereas, red-throated loons used smaller, partially-drained basins most frequently.

Bottitta, G. E. 1999. Energy Constraints on Incubating Common Eiders in the Canadian Arctic (East Bay, Southampton Island, Nunavut). ***Arctic*** 52:425-437.

Abstract not available [excerpts directly from text]
Common eider ducks have a circumpolar distribution. Several populations that occur in polar areas during the summer move to northern or temperate coastal areas during winter. All eider species have delayed reproductive maturity, low rates of recruitment, and high rates of adult survival (often 15+ years). These characteristics, coupled with their gregarious nature, render eider ducks highly vulnerable to the effects of hunting, lead poisoning, contaminants, and oil pollution. This paper gives an overview of a research project where the cost of reproduction was examined by manipulation of the incubation period length. The clutch manipulations helped to determine the correlation between physiological condition and incubation behaviours of incubating females and their nest outcome. As predicted, females with shortened incubation experienced the highest nest success. Extended-incubation females had a lower body

condition and demonstrated a greater tendency to abandon the nest in the final days before hatch than either shortened-incubation or control hens.

Bray, R. and T. H. Manning. 1943. Notes on the Birds of Southampton Island, Baffin Island and Melville Peninsula. ***Auk*** 60:504-536.

<u>*Abstract not available [excerpts directly from text]*</u>
This paper summarizes the observations Reynold Bray made on a number of bird species while travelling in the Arctic (including Southampton Island, Baffin Island and Melville peninsula) as a member of the British Canadian Arctic Expedition. Observations include those on the Common Loon, Pacific Loon, Red-throated Loon, Atlantic Fulmar and Whistling Swan.

DeVink, J. A., H. G. Gilchrist and A. W. Diamond. 2005. Effects of Water Salinity on Growth and Survival of Common Eider (*Somateria Mollissima*) Ducklings. ***Auk*** 122:523-529.

<u>*Abstract taken directly from text*</u>
The need for fresh water may affect growth and survival of young waterfowl, including ducklings of sea ducks that are routinely raised in coastal marine habitats. We studied the influence of water salinity on growth and survival of Common Eider (*Somateria mollissima*) ducklings collected from nests on Southampton Island, Nunavut, Canada, in July 2001 and 2002. In 2001, 50 ducklings were partitioned into five groups (n = 10) and assigned a water salinity treatment for 6.5 days. Treatments included fresh water (<1 ppt NaCl), brackish water (11 ppt or 21 ppt), seawater (33 ppt), and a mixed regime (<1 ppt for 12 h, followed by 33 ppt for six days). In 2002, the experiment was replicated twice with different ducklings. Overall, growth rates were negatively correlated, and mortality rates positively correlated, with water salinity: 3%, 17%, and 60% of ducklings died in the <1-ppt, 11-ppt, and 21-ppt treatment groups, respectively; and 100% died in the 33-ppt and mixed-regime groups. The results confirm that fresh water is required for growth and survival of Common Eider ducklings immediately after hatch, which suggests that sources of fresh water in brood-rearing areas are an important requirement for successful reproduction.

Donaldson, G. M., C. Hyslop, R. I. G. Morrison, H. L. Dickson and I. Davidson. 2000. ***Canadian Shorebird Conservation Plan***. Canadian Wildlife Service, Ottawa, ON.

<u>*Abstract taken directly from text*</u>
Canada's national biodiversity strategy calls on government and other stakeholders to attack the causes of biodiversity loss at their source and prevent further endangerment of species. Certainly there is cause for concern for Canadian shorebird species. Fully two-thirds of Canada's shorebird populations show downward trends according to survey data. No single cause accounts for these declines; clearly the situation warrants concern. Canada has a unique responsibility with respect to shorebirds. For many species, more than half of their breeding range occurs in Canada. Opportunity exists to cooperate with ongoing conservation initiatives such as the Western Hemisphere Shorebird Reserve Network (WHSRN), U.S. Shorebird Conservation Plan, Partners in Flight, Wings Over Water, North American Bird Conservation Initiative, North American Waterfowl Management Plan, and others. The plan's vision is for healthy populations of shorebirds to be distributed across their range and diversity of habitats in Canada and throughout their global range. The plan thus recognizes the need to collaborate internationally as well as regionally and locally. The Canadian Shorebird Conservation Plan has five goals designed to fulfill the needs for research, monitoring, and evaluation as well as conservation, communication, and international linkages. Those goals are: 1) Sustain the distribution, diversity, and abundance of shorebird populations within Canada and restore populations of declining, threatened, and endangered species; 2) Secure and enhance sufficient high-quality habitat to support healthy populations of shorebirds throughout their ranges in Canada; 3) Ensure that information on shorebird conservation needs and practices is widely available to decision makers, land managers, and the public; 4) Ensure that coordinated shorebird conservation efforts are in place, on the ground, throughout the range of Canadian shorebird species; 5) Ensure that shorebird conservation efforts are guided by common principles throughout the Western

Hemisphere. The implementation of strategies aimed at achieving these goals will be overseen by a national working group made up of partners committed to shorebird conservation. A science support team will ensure that actions are based on sound science and will address information gaps.

Forbes, G., K. Robertson, C. Ogilvie and L. Seddon. 1992. Breeding Densities, Biogeography, and Nest Depredation of Birds on Igloolik Island, NWT. ***Arctic*** 45:295-303.

Abstract taken directly from text
The avifauna of Igloolik Island and immediate vicinity was studied during two breeding seasons in 1985-86. This is the first study to compile an intensive record of avifaunal migration patterns and nesting activity, density and success for Igloolik Island. Data for these years are supplemented by the observations of earlier explorers and researchers. During our two seasons of survey, we recorded 40 species of birds, of which 25 nested on the island. Combining our records with previously published data, a total of 48 species have been recorded, with 30 species nesting. Several interspecies matings of gulls and the first confirmed breeding record of purple sandpiper *(Calidris maritima)* for the Melville Peninsula area were recorded. The density of breeding birds on Igloolik Island (28.5 pairs-km^{-2}) is similar to other eastern high arctic sites at that latitude. Issues related to the biogeographic comparisons of arctic sites are discussed. In late August, the eastern end of the island acts as a significant staging area for gull species, oldsquaw *(Clangula byemalis)* and arctic tern *(Sterna paradisaea).* A combined average of 58.3% of the nests of six species were depredated. As many as 73% of red-throated loon *(Gavia stellafa)* and 93% of arctic tern nests suffered mainly human-related egg predation.

Francis, C. M. and F. Cooke. 1992. Migration Routes and Recovery Rates of Lesser Snow Geese from Southwestern Hudson Bay. ***Journal of Wildlife Management*** 56:279-286.

Abstract taken directly from text
Patterns of band recoveries for hunted populations of birds provide information on the hunting pressure to which the population is subject; yet little is known about these patterns in lesser snow geese (*Chen caerulescens caerulescens*). Consequently, we compared recovery patterns for lesser snow geese nesting at La Perouse Bay, Manitoba (LPB) and Cape Henrietta Maria, Ontario (CHM) between 1970 and 1979 to test whether geese from both colonies followed the same migration routes and experienced the same hunting pressure. Relatively few geese from LPB were recovered along Hudson Bay, but large numbers were recovered in southern Manitoba and North Dakota. In contrast, geese from CHM were recovered in large numbers around James Bay, but then most appeared to migrate directly to stopover sites along the Missouri River. Further south, recovery distributions from both colonies were similar, but geese from CHM tended to be recovered further east than those from LPB, particularly on the Gulf Coast. Within each colony, blue phase geese migrated further east than white geese, but differences were small compared with inter-colony differences. Overall, direct recovery rates for adults banded at CHM were about 40% lower ($P < 0.0001$) than those from LPB, but survival rates were similar (LPB = 82%, CHM = 83%, $P = 0.6$). The lower reported harvest of geese from CHM may be partly balanced by a larger unreported harvest by Cree Indians around James Bay. Both survival and recovery rates for individual breeding colonies need to be carefully monitored for optimal management in view of recent population changes.

Gaston, A. J. 2002. Studies of high-latitude seabirds. 5. Monitoring Thick-billed Murres in the eastern Canadian Arctic, 1976-2000. ***Occasional Paper***, Number 106, Canadian Wildlife Service, Ottawa, ON. 52 pp.

Abstract taken directly from text
Hunting of Thick-billed Murres *(Uria lomvia)* in winter off Newfoundland and Labrador is thought to be a major cause of adult mortality for the populations involved. Regulations for this hunt were adjusted in 1993 to effect a 50% reduction in the harvest. I examined trends in banding recoveries and population parameters for the breeding colony at Coats Island in northern Hudson Bay to see whether the intended reduction in the harvest level had measurable effects on the population. Banding recoveries of first-winter

birds showed no change over the period considered (bandings in 1984-1998, recoveries up to 2000-2001 winter), but recoveries of birds more than 2 years old, especially breeding-age birds, decreased sharply around 1990. The difference in trends between age classes suggested that a change in the wintering behaviour of birds in their third year and older took place about 1990, making them less likely to be killed by hunters. There was no indication that the change in regulations affected the survival of breeding adults, which remained fairly constant at about 90% per annum. This observation was consistent with the virtual disappearance of breeding-age birds from the hunting recoveries after 1990. An improvement in the recruitment of 4- and 5-year-olds was noted after 1996, coinciding with the recruitment of cohorts reared subsequent to the change in regulations. This improved recruitment may have been the result of reduced hunting pressure on birds in their second year. It appears that environmental changes preceding the changes in hunting regulations may have preempted the intended effect of the new regulations, causing them to have little impact on the Coats Island population.

Gaston, A. J. and D. N. Nettleship. 1982. Factors Determining Seasonal Changes in Attendance at Colonies of the Thick-Billed Murre Uria Iomvia. ***Auk*** 99:468-473.

Abstract taken directly from text
A comparison of the inter-year variation in attendance patterns of Thick-billed Murres (Uria lomvia) with the variation in egg size and chick growth rates suggests that the number of birds in attendance at a murre colony at any time during the breeding season is determined principally by the availability of food in surrounding waters. This effect operates mainly through the behavior of a large floating population of prospectors. When food is abundant, numbers on the cliffs will be high because birds have plenty of time to spare. Conversely, when food is scarce, numbers will be low because birds must devote most of their time to feeding. Implicit in the hypothesis is the assumption that birds strive to maximize the amount of time that they spend at the breeding colony in order to improve their chances of acquiring and retaining a breeding site.

Gaston, A. J. and G. Donaldson. 1995. Peat Deposits and Thick-billed Murre Colonies in Hudson Strait and Northern Hudson Bay: Clues to Post-Glacial Colonization of the Area by Seabirds. ***Arctic*** 48: 354-358.

Abstract taken directly from text
Deposits of peat moss are found in association with several major seabird colonies in the area of Hudson Strait and northern Hudson Bay. Because such deposits are absent from similar ground away from seabird colonies, they seem to have developed as a result of manuring by the birds. Consequently dates for the base of the peat provide minimum dates for the establishment of the bird colonies. Dates obtained at three colonies suggest that they were established 1500 –3800 years ago, well after the opening up of Hudson Strait. The colony at Akpatok Island, in Ungava Bay, was established earlier than the two colonies farther west, at Digges and Coats Islands, which accords with the idea that colonization of the region took place from the Atlantic.

Gaston, A. J. and H. Ouellet. 1997. Birds and Mammals of Coats Island, NWT. ***Arctic*** 50:101-118.

Abstract taken directly from text
We summarize records of birds and mammals obtained at Coats Island, Northwest Territories during one visit by a National Museum of Natural Sciences expedition and fourteen visits by Canadian Wildlife Service field crews to the northeast corner of the island, as well as records obtained from the journals of the Hudson's Bay Company post active on the island from 1920 to 1924. The terrestrial mammal fauna is very depauperate, lacking any small herbivores. Consequently, predators specializing in small mammals—such as ermine, snowy owl, and long-tailed jaeger, all common on nearby Southampton Island—are rare or absent from Coats Island, except in passage. In addition, there are no snow goose colonies on Coats Island, although good numbers of Canada geese breed there, and some brant may also do so. This means that grazing on the island is mainly confined to the resident caribou population. The absence of small mammals and the relatively low density of geese may have accounted for the poor

results of fox trapping during the period when the Hudson's Bay Company post was operating. Numbers of most marine mammals appear to have changed little since the 1920s, although bowhead whales may have become rarer, with only two sightings since 1981, compared to several annually in the 1920s. Winter records from the 1920–24 post journals suggest that waters off Coats Island are within the wintering range of beluga, walrus, and thick-billed murres. Eighty-four species of birds have been seen since 1975; this number includes many sightings of vagrant birds well outside their normal ranges. This may be accounted for by the comparative lushness of the vegetation surrounding the thick-billed murre colony, which attracts birds from long distances.

Gaston, A. J., K. Woo and J. M. Hipfner. 2003. Trends in Forage Fish Populations in Northern Hudson Bay since 1981, as Determined from the Diet of Nestling Thick-Billed Nurries *Uria lomvia*. ***Arctic*** 56: 227-233.

Abstract taken directly from text

Trends in the composition of nestling thick-billed murre diets were analyzed for the period 1980–2002 on the basis of observations of food delivered to nestlings at two breeding colonies in northern Hudson Bay. The incidence of arctic cod, sculpins, and benthic Zoarcidae decreased and the incidence of capelin and sandlance increased over the period considered. Arctic cod fell from a mean of 43% of deliveries in the mid-1980s to 15% in the late 1990s; benthic species (zoarcids and sculpins) fell from 36% to 15%, while capelin increased from 15% to 50% over the same period. July ice cover in Hudson Bay approximately halved during 1981–99. We suggest that the observed changes in diet composition reflect changes in the relative abundance of the fish species involved and that the decline in arctic cod and increase in capelin and sandlance were associated with a general warming of Hudson Bay waters, the result of ongoing climate change in the region.

Gaston, A. J., R. Decker, F. G. Cooch and A. Reed. 1986. The Distribution of Larger Species of Birds Breeding on the Coasts of Foxe Basin and Northern Hudson Bay, Canada. ***Arctic*** 39:252-296.

Abstract taken directly from text

Aerial surveys of large birds on the coasts of Foxe Basin and northem Hudson Bay were carried out in late June and early July in 1979, 1983 and 1984. Greatest numbers of birds were seen along low-lying coasts backed by wet lowland tundra, particularly where these merged into extensive inter-tidal flats. These areas have emerged from the sea only during the past 2000 years. Even in areas of wet lowland tundra, all species except jaegers appeared to be patchy in their distribution, the patches being unrelated to obvious features of the habitat. We suggest that breeding habitat for many species is not completely occupied, at least in normal breeding seasons. We propose that statutory protection be extended to all or parts of Prince Charles and Air Force islands, which support high numbers of several species and are currently unprotected.

Gaston, A. J., S. A. Smith, R. Saunders, G. I. Storm and J. A. Whitney. 2007. Birds and marine mammals in southwestern Foxe Basin, Nunavut, Canada. ***Polar Record*** 43:33-47.

Abstract taken directly from text

The south-western part of Foxe Basin is a little known region of the Canadian Arctic, being difficult to access during the summer because of heavy and unpredictable ice conditions. Surveys of birds and marine mammals in the area were carried out by lightweight expeditions in the summers of 1994 and 1995, using sea-kayaks, as well as a Peterhead boat from the nearest community, at Repulse Bay. The area supports important populations of narwhal, bowhead whales and walrus, as well as significant concentrations of shorebirds, common eiders, black guillemots, and perhaps one third of the world's Thayer's gulls. New information was obtained on the status and abundance of these species and novel observations were made on the feeding ecology and breeding phenology of the gulls.

Heide-Jorgensen, M. P. and K. L. Laidre. 2004. Declining Extent of Open-water Refugia for Top Predators in Baffin Bay and Adjacent Waters. ***Ambio*** 3:487-494.

Abstract taken directly from text
Global climate change is expected to severely impact Arctic ecosystems, yet predictions of impacts are complicated by region-specific patterns and nonuniform trends. Twentyfour open-water overwintering areas (or "microhabitats") were identified to be of particular importance for eight seabird and marine mammal species in the eastern Canadian High Arctic and Baffin Bay. Localized trends in the available fraction of open-water were examined in March during 1979-2001, derived from approximate sea ice concentrations from satellite-based microwave telemetry. Declines in the fraction of open-water were identified at microhabitats in Baffin Bay, Davis Strait, coastal West Greenland, and Lancaster Sound. Increases in open-water were observed in Hudson Bay, Hudson Strait, and Foxe Basin. The biological importance of each microhabitat was examined based on species distribution and abundance. Potential consequences of reduced open-water for top marine predators include impacts on foraging efficiency and oxygen and prey availability.

Hicklin, P. W. and W. R. Barrow. 2004. The Incidence of Embedded Shot in Waterfowl in Atlantic Canada and Hudson Strait. ***Waterbirds*** 27:41-45.

Abstract taken directly from text
From 1989-1998, in Canada's Atlantic Provinces and eastern sub-arctic region, migrant Canada Geese (*Branta Canadensis*), wintering American Black Duck (*Anas rubripes*), Mallard (*A. platyrhynchos*) and incubating Common Eider (*Somateria mollissima*) were captured and examined with a fluoroscope to determine if shotgun pellets were embedded in their tissues. Of 1,624 birds examined, 25% carried embedded shotgun pellets. The highest proportion of birds carrying pellets was recorded in the sample of female Common Eider captured on nests in Labrador, followed by female eiders nesting in Newfoundland, Quebec and Nova Scotia and migrant Canada Geese in spring in Prince Edward Island.

Hipfner, J. M., A. J. Gaston and H. G. Gilchrist. 2005. Variation in Egg Size and Laying Date in Thick-Billed Murre Populations Breeding in the Low Arctic and High Arctic. ***Condor*** 107:657-664.

Abstract taken directly from text
We used data collected across 28 years (1975–2002) to compare how timing of laying and egg size respond to environmental variability in two low-arctic and two high-arctic Thick-billed Murre (*Uria lomvia*) populations. Ice conditions strongly affect food availability to marine birds in the Arctic, and the percentage of the sea's surface covered by ice within 300 km of the breeding colony varied more among years near the start of laying at our high-arctic study colonies (Prince Leopold and Coburg Islands, Nunavut, Canada) than at our low-arctic study colonies (Coats and Digges Islands, Nunavut). However, mean values differed little. These results indicate that Thick-billed Murres breeding in the High Arctic experience more variable ice conditions, but not necessarily more severe ice conditions, during the period of egg formation. In response, both median laying date and mean egg size varied more among years at high-arctic than at low-arctic colonies. Several lines of evidence suggested that the variation was a result of within-female effects, i.e., phenotypic plasticity rather than different individuals breeding in years in which environmental conditions differed. Previous studies have shown that Thick-billed Murres lay eggs later in years of heavier ice coverage, especially in the High Arctic where ice conditions can be severe, and only in the High Arctic was later laying associated with reduced egg size. The relationship tended towards a negative asymptote suggesting that each female may have her own minimum egg size. Our results show that Thick-billed Murres that inhabit a more variable environment display greater variability in life-history traits. More generally, they offer insight into mechanisms linking environmental heterogeneity to phenotypic variation in life-history traits.

Huettmann, F. and A. W. Diamond. 2001. Seabird colony locations and environmental determination of seabird distribution: a spatially explicit breeding seabird model for the Northwest Atlantic. ***Ecological Modelling*** 141:261-298.

Abstract taken directly from text

We investigated whether proximity to a seabird colony is a constraining factor for seabird distribution in summer for the most abundant breeding species in the Canadian North Atlantic. We started with 20 environmental data sets for the marine environment from the Internet/www and governmental sources. These environmental factors were spatially stratified and overlaid in a GIS (SPANS Geographic Information System) with the PIROP (Programme integer des recherches sur les oiseaux pe´lagiques) database for pelagic seabirds in order to analyse how these environmental factors explain the distribution of observed seabirds (presence/absence). A Generalized Linear Model (GLM) was used to explore the significant influences of these factors on seabird distribution, and a Classification and Regression Tree (Cart) then allowed for a detailed description of seabird distribute ion, and for a spatial modeling approach. The specific seabird model predictions were evaluated by distance to the next seabird colony of seabirds observed, and by its geo-referenced residuals using a partition tree. Our results suggest that northern and southern breeding sectors differ in the distribution-determining predictors for seabirds. Foraging distances are longer in the northern breeding sector, which may be related to a richer habitat in the study area south of 52° latitude N. Our models suggest spatial separation between breeders and non-breeders.

Kellett, D. K. and R. T. Alisauskas. 1997. Breeding Biology of King Eiders Nesting on Karrak Lake, Northwest Territories. ***Arctic*** 50:47-54.

Abstract taken directly from text

We studied various aspects of the breeding biology of king eiders (*Somateria spectabilis*) nesting at Karrak Lake, south of Queen Maud Gulf in the central Canadian Arctic. We found 41 nests distributed among 10 islands in Karrak Lake; to our knowledge, this represents the largest number of king eider nests studied at one site. We suspect that island nesting by king eiders is more common than has been previously reported. King eiders favoured mid-sized islands (0.002–0.081 km^2) over very small (less than 0.002 km^2) or very large (greater than 0.081 km^2) islands. Mean clutch size was 5.4 ± 1.7 (SD) eggs. Apparent nest success was 69.4%, with a composite Mayfield estimate of nest success over egg laying and incubation of 48.7% (95% CI: 47.4–50.0%). Nest success was uncorrelated with date of nest initiation or island size, but eiders nesting on islands farther from the mainland had greater success than those nesting on islands closer to the mainland. Additionally, nest success was greater on islands with more nesting eiders and on islands with nesting arctic terns (*Sterna paradisaea*).

Latour, P. B., J. Leger, J. E. Hines, M. L. Mallory, D. L. Mulders, H. G. Gilchrist, P. A. Smit, D. L. Dickson. 2008. Key Migratory Bird Terrestrial Habitat Sites in the Northwest Territories and Nunavut. ***Occasional Paper***, Number 114, Canadian Wildlife Service, Ottawa, ON. 122 pp.

Abstract not available [with excerpts directly from text]

This report provides a general description, including the biology, sensitivities and conflicts, of bird habitat sites in the Northwest Territories and Nunavut. An example would be Western Cumberland Sound Archipelago (NU Site 29). Its coastline has many fiords and bays with numerous small islands. The key habitat site is composed of the many cliff faces and islands on the coast, between Clearwater Fiord and Chidliak Bay. Several thousand Common Eiders concentrate along the coasts and fiords. Over 1000 Black Guillemots were surveyed in Cumberland Sound in August 1977. Hundreds of Iceland Gulls are found near August in this area. North-western Cumberland Sound is an important area for a variety of marine mammals, including beluga, various seal species, and walrus. No potential conflicts are seen, but seabirds are sensitive to disturbance and pollution of their staging and foraging areas.

Luukkonen, D. R., H. H. Prince and R. C. Myut. 2008. Movements and Survival of Molt Migrant Canada Geese from Southern Michigan. ***Journal of Wildlife Management*** 72:449-462.

Abstract taken directly from text

We studied movements and survival of 250 female giant Canada geese (*Branta canadensis maxima*) marked during incubation with either satellite-monitored platform transmitting terminals or very high frequency radio transmitters at 27 capture areas in southern Michigan, USA, in 2000–2003. We destroyed nests of 168 radio-marked females by removing eggs after day 14 of incubation, and we left nests of 82 incubating hens undisturbed after capture and marking. Of females whose nests we experimentally destroyed, 80% subsequently migrated from breeding areas to molt remiges in Canada. Among 82 nests left undisturbed, 37 failed due to natural causes and 51% of those females departed. Migration incidence of birds that nested in urban parks was low (23%) compared with migration incidence of birds that nested in other classes of land use (87%). Departure of females from their breeding areas began during the second and third weeks of May, and most females departed during the last week of May and first week of June. Based on apparent molting locations of 227 marked geese, birds either made long-distance migratory movements .900 km, between latitudes 518 and 648 N, or they remained on breeding areas. Molting locations for 132 migratory geese indicated 4 primary destinations in Canada: Western Ungava Peninsula and offshore islands, Cape Henrietta Maria, Northeast James Bay and offshore islands, and Belcher Islands, Hudson Bay, Canada. Following molt of remiges, Canada geese began to return to their former nesting areas from 20 August through 3 September, with 37% arriving on or before 15 September and 75% arriving on or before 1 October. Migration routes of geese returning to spring breeding areas were relatively indirect compared with direct routes taken to molting sites. Although overall survival from May through November was 0.81 (95% CI: 0.74–0.88), survival of migratory geese marked on breeding sites where birds could be hunted was low (0.60; 95% CI: 0.42–0.75) compared with high survival of birds that remained resident where hunting was restricted (0.93; 95% CI: 0.84–0.97). Nest destruction can induce molt migration, increase hunting mortality of geese returning from molting areas, and reduce human–goose conflicts, but managers also should consider potential impacts of increasing numbers of molt migrants on populations of subarctic nesting Canada geese.

Manning, T. H. 1942. Blue and Lesser Snow Geese on Southampton and Baffin Islands. ***Auk*** 59:158-175.

<u>*Abstract not available [with excerpts directly from text]*</u>
This paper presents the findings of T. H. Manning when he visited Bay of God's Mercy to observe a colony of Blue and Lesser Snow Geese. The goose nests were situated almost entirely on grassy islands in the mouth of Boas River, where they were comparatively safe from foxes. In 1934, the concentrated breeding area covered about three square miles, with about fifteen birds to 10,000 square yards. In the hundreds of nests seen, the average number of eggs for a Snow Goose was five or six, while seven was not uncommon. Three nests had eight, and two held nine eggs. The Blue Goose and hybrid nests had rather fewer, at most, five eggs. Snow and Blue Geese nesting in the colony do not hybridize in the proportion that would be expected if the birds were identical species.

Morrison, R. I. G. 1997. The Use of Remote Sensing to Evaluate Shorebird Habitats and Populations on Prince Charles Island, Foxe Basin, Canada. ***Arctic*** 50:55-75.

<u>*Abstract taken directly from text*</u>
Landsat-5 Thematic Mapper imagery was used to produce a 17-habitat classification of Prince Charles Island, Foxe Basin, Northwest Territories, through a combination of supervised and unsupervised approaches. Breeding shorebirds and habitats were surveyed at 35 study plots in July 1989. Habitat-specific breeding densities calculated from these observations were used to estimate total populations of breeding shorebirds on the island based on areas of habitat derived from the classified image. Breeding densities were further modelled in two ways: first, to adjust for distance from the coast, where regression analyses found a significant relationship between distance and density, and second, to include only those pixels of areas considered suitable for breeding, using results of a proximity analysis to determine habitat associations between known breeding locations (pixels) and other habitats. Six species of shorebirds were found breeding on Prince Charles Island, with a combined population (after modelling) estimated at 294 000 pairs. Comparison of breeding densities and estimated populations of shorebirds with those recorded at other arctic locations indicated that Prince Charles Island supports highly significant numbers of shorebirds, especially white-rumped sandpipers and red phalaropes. Comparison of reference areas of known habitat with those on the classified image indicated classification accuracy

averaged over 90%. Remote sensing appears to offer a reliable method for assessing habitats and regional breeding populations of birds in at least some areas, providing that classification methods are carried out in a carefully controlled manner. Use of the method over broad areas of the Arctic would require considerable work to recalibrate imagery for different geographic regions.

Morrison, R. I. G., R. E. Gill Jr., B. A. Harrington, S. Skagen, G. W. Page, C. L. Gratto-Trevor and S. M. Haig. 2001. Estimates of shorebird populations in North America. ***Occasional Paper***, Number 104, Canadian Wildlife Service, Ottawa, ON. 64 pp.

Abstract taken directly from text
Estimates are presented for the population sizes of 53 species of Nearctic shorebirds occurring regularly in North American, plus four species that breed occasionally. Population estimates range from a few tens to several millions. Overall, population estimates most commonly fall in the range of hundreds of thousands, particularly the low hundreds of thousands; estimated population sizes for large shorebird species currently all fall below 500 000. Population size is inversely related to size (mass) of the species, with a statistically significant negative regression between log (population size) and log (mass). Two outlying groups are evident on the regression graph: one, with populations lower than predicted, includes species considered to be either “at risk” or particularly hard to count, and a second, with populations higher than predicted, includes two species that are hunted. Shorebird population sizes were derived from data obtained by a variety of methods from breeding, migration, and wintering areas, and formal assessments of accuracy of counts or estimates are rarely available. Accurate estimates exist only for a few species that have been the subject of detailed investigation, and the likely accuracy of most estimates is considered poor or low. Population estimates are an integral part of conservation plans being developed for shorebirds in the United States and Canada and may be used to identify areas of key international and regional importance.

Nettleship, D. N. and A. R. Lock. 1974. Black-Legged Kittiwakes Breeding in Labrador. ***Auk*** 91:173-174.

Abstract not available [with excerpts directly from text]
The breeding distribution of the Black-legged Kittiwake (*Rissa tridactyla*) in Canada has long interested ornithologists because the birds are concentrated at both the northern (Lancaster Sound region) and southern (Newfoundland and Gulf of St. Lawrence) extremities of the range. Except for relatively small numbers nesting on the east coast of Baffin Island and in eastern Hudson Strait (Resolution Island, Loks Lands, Button Islands), a large hiatus exists between these two breeding groups. The kittiwake has been known in Labrador only as an abundant summer resident in the past. All the available evidence indicators that this colony on Outer Gannet Island is of recent origin, especially as neither Austin nor Tuck found it nesting there during their seabird censuses. Its presence also suggests that where suitable habitat exists on the Labrador coast, kittiwakes may attempt to breed and that they may already occur as a sparsely distributed and marginal breeding population between the two major groups. It also seems quite likely that this northern expansion is a consequence of the rapid increase in kittiwake numbers noted throughout its extensive breeding range, apparently the main cause of the expansion already recorded at the southern periphery of its range in eastern North America.

Orr, C. D. and R. M. P. Ward. 1982. The Autumn Migration of Thick-billed Murres near Southern Baffin Island and Northern Labrador. ***Arctic*** 35:531-536.

Abstract taken directly from text
Aerial surveys were used to assess the timing and route of the swimming migration of Thick-billed Murres *(Uriu lomvia)* near southern Baffin Island and northern Labrador in the autumn of 1977,1978 and 1979. Several hundred thousand adults and chicks from six southern Baffin area colonies departed east through Hudson Strait, in the direction of surface currents, in the latter half of August. Most murres from three eastern Hudson Strait colonies were in offshore waters in early September, arrived in the northern Labrador Sea within a few days, and were followed later in September by murres from three western

Hudson Strait colonies. From the Labrador Sea, murres go to marine wintering sites around Newfoundland. Murres from a large colony on southeast Baffin Island apparently did not migrate to the Labrador Sea through western Davis Strait; instead, they either migrated through central Davis Strait *en route* to Newfoundland, or east to west Greenland, which was also the probable destination of many adult murres which flew by a drillship in southwest Davis Strait.

Sea Duck Joint Venture. 2003. ***Species Status Reports***. NABCI/NAWMP Coordination Office, Canadian Wildlife Service, Environment Canada, Gatineau, Quebec. 85 pp.

Abstract not available [with excerpts directly from text]

Because the paucity of information is the main limiting factor to the conservation of sea ducks, the compilation of objective status and trend data for each species or population and the identification of critical information gaps became the first tasks of the SDJV. This document summarizes the most basic management information available in a series of species status reports that are intended to be starting points for the SDJV science program. For the purposes of the Sea Duck Joint Venture the status reports concentrate on the level of knowledge as of the year 2000 for the following aspects of North American sea ducks: Population Delineation, Distribution, Abundance, Population Trends, Harvest, Management and Conservation Concern. This report provides information on the Common Eider from a number of different areas, the King Eider, the Spectacled Eider, the Steller's Eider, the Harlequin Duck, the Long-tailed Duck, the Surf Scoter, the Black Scoter, the White Winged Scoter, the Common Goldeneye, the Barrow's Goldeneye, the Bufflehead, the Common Merganser, the Red Breasted Merganser, and the Hooded Merganser.

Sheaffer, S. E. and R. A. Malecki. 1996. Predicting Breeding Success of Atlantic Population Canada Geese from Meteorological Variables. ***Journal of Wildlife Management*** 60:882-890.

Abstract taken directly from text

Management strategies for sustained harvest and long-term viability of Atlantic Population Canada geese (*Branta canadensis*) require evaluations of annual breeding success before establishing fall harvest regulations. The only quantitative measure of the annual breeding success of this population is the proportion of young geese in the fall harvest that is not available when harvest regulations are set in late July. Because the majority of Atlantic Population Canada geese breed in the sub-arctic regions of the Ungava Peninsula in northern Quebec, spring climatic conditions are potential predictors of annual production for this population. We used tail-fan data from the Maryland harvest to calculate an index of the proportion of young geese (Y,) in the fall population, 1963-94. We used 1963-87 weather data to develop multiple linear regression models to predict Y, and validated these models by predicting Y, for 1988-94. Models with the greatest predictive ability included the average daily mean temperature and the number of days of snowfall in May and June. The final model included 6 parameters and accounted for 78.7% of the total variability in Y, ($P = 0.001$). This analysis demonstrates the potential use of climatic data to predict an index of annual production derived from harvest age ratios. The usefulness of this technique will depend on periodic assessment of predictive models as more data is gathered, and evaluation of harvest tail-fan surveys as indices to breeding success.

Smith, P. A., H. G. Gilchrist and J. N. M. Smith. 2007. Effects of Nest Habitat, Food, and Parental Behavior on Shorebird Nest Success. ***Condor*** 109:15-31.

Abstract taken directly from text

In environments such as arctic tundra, where bird densities are low and habitats are comparatively homogeneous, suitable nest sites likely are not limited. Under these conditions, reproductive success of birds may be determined by factors other than the habitat characteristics of nest sites. We studied the relative influence of nest habitat, food, nest distribution, and parental behavior on the reproductive success of tundra-breeding shorebirds at East Bay, Southampton Island, Nunavut, Canada. From 2000 to 2002, we monitored the nests of five species: Black-bellied Plover (*Pluvialis squatarola*), Semi-palmated Plover (*Charadrius semipalmatus*), Ruddy Turnstone (*Arenaria interpres*), White-rumped Sandpiper

(*Calidris fuscicollis*), and Red Phalarope (*Phalaropus fulicarius*). For each species, habitat differed between nest sites and random sites. In contrast, habitat differed between successful and failed nest sites only for White-rumped Sandpipers. Shorebirds did not prefer to nest in habitats where food was most abundant. Although nest success varied among species in all years, artificial nest experiments suggested that interspecific variation in predation rate was not related to habitat type. Instead, the marked interspecific variation in nest success may have been related to incubation behavior. Species taking fewer incubation recesses had higher nest success, although these results should be viewed as preliminary. The factor with the greatest inter-annual influence on nest success was fluctuating predation pressure, apparently related to the abundance of predators and lemmings.

Smith, P. A., H. G. Gilchrist, J. N. M. Smith and E. Nol. 2007. Annual Variation in the Benefits of a Nesting Association Between Red Phalaropes (*Phalaropus fulicarius*) and Sabine's Gull (*Xema sabini*). ***Auk*** 124:276-290.

Abstract taken directly from text
By nesting near aggressive birds, timid species can reap the benefits of aggressive nest defence while avoiding the costs. Red Phalaropes (*Phalaropus fulicarius*; hereafter "phalaropes") typically nest in grass-sedge marshes, but nests have also been noted in rocky coastal habitats. We studied the reproductive ecology of phalaropes at East Bay, Southampton Island, Nunavut, to determine whether their use of coastal nest areas reflected a protective nesting association with an aggressive larid, the Sabine's Gull (*Xema sabini*; hereafter "gull"). From 2000 to 2002, we found and monitored 29 phalarope nests with gull nests nearby (≤150 m away) and 26 without gulls nearby. Coastal phalarope nests were nearer to gull nests than expected by chance. No habitat differences were detected between coastal areas with and without gull nests, but only three phalarope nests were found in coastal areas without gull nests. Thermistor probes inserted in phalarope nests revealed that incubators with gulls nearby behaved less cryptically, taking more frequent and longer incubation recesses. In human-approach experiments, phalaropes with gulls nearby flushed earlier than those without gulls. In 2000 and 2001, hatch success was 17–20% higher for phalaropes with gulls nearby, but these nests had lower success rates than those without nearby gulls in 2002. These gulls are able to defend their nests from avian predators only; in 2002, arctic foxes (*Alopex lagopus*) were abundant, and their primary prey, collared lemmings (*Dicrostonyx torquatus*), were scarce. We suggest that phalaropes select coastal areas near gulls, but that this association is beneficial to phalaropes only in years when egg predation by arctic foxes is low.

Soper, J. D. 1930. Explorations in Foxe Peninsula and Along the West Coast of Baffin Island. ***Geological Review*** 20:397-424.

Abstract not available [with excerpts directly from text]
The Foxe Peninsula, long referred to as Foxe Land, comprises the entire south-western extremity of Baffin Island. Into this area the author proceeded under instructions from the North West Territories and Yukon Branch, Department of the Interior, Canada, in July, 1928, to inquire into Eskimo conditions and the wild life of the region and to conduct exploratory surveys on the coast and in the interior. Up to this time the coast of Foxe Peninsula had never been surveyed in detail ─ except in limited sections ─ from Cape Dorchester to Chorkbak Inlet. It was found to contain many fair-sized lakes, rivers, and granite ranges of great interest.

Soper, J. D. 1940. Local Distribution of Eastern Canadian Arctic Birds. ***Auk*** 57:13-21.

Abstract not available [with excerpts directly from text]
Aside from the highly localized colonies of Arctic birds found on coastal islands and cliffs, the best breeding areas of a host of birds are to be found on flat, grass-tundra lands in various parts of the Canadian Arctic islands. The best development of tundra is found over horizontally bedded sedimentary rock. As an all-round breeding territory these western and south-central plains of Baffin Island are of a very superior order. The grass-tundra plain bordering Foxe Basin on the western side of the island,

especially, is visited by vast numbers of geese, brant, waders, and Eider Ducks, which either breed locally, or pass on to more northern latitudes.

Soper, J. D. 1946. Ornithological Results of the Baffin Island Expeditions of 1928-1929 and 1930-1931, Together with More Recent Records. ***Auk*** 63:1-24.

Abstract not available [with excerpts directly from text]
In January, 1929, an overland traverse of Foxe Peninsula was run from Andrew Gordon Bay to Nuwata, thence eastward to Ungmaluktuk, Shidawatalik, and Tessikjuak lakes, with a return to Cape Dorset via Andrew Gordon Bay. This was followed by extensive detail work in the Cape Dorset sector. The party then left on the longest journey of the expedition; a third crossing of the Foxe Peninsula interior was made from Andrew Gordon Bay to Bowman Bay, thence the west coast was explored to the mouth of Hantzsch River. There were a few more legs of the trip following this; general climate, geography, and wildlife were noted at each stop. Baffin Island and some of the fauna there are also discussed in this paper.

Stenhouse, I. J. and G. J. Robertson. 2005. Philopatry, Site Tenacity, Mate Fidelity, and Adult Survival in Sabine's Gulls. ***Condor*** 107:416-423.

Abstract taken directly from text
Quantifying the dynamics of populations is fundamental to understanding lifehistory strategies, and essential for population modeling and conservation biology. Few details of the demography and life history of the Sabine's Gull (*Xema sabini*) are known. Uniquely color banded Sabine's Gulls breeding in East Bay, Southampton Island, Nunavut, in the eastern Canadian Arctic, were examined from 1998–2002 to quantify vital rates. Generally, birds banded as chicks first returned to the breeding area in their third year, and the earliest case of first breeding was confirmed at three years of age. Sabine's Gull pairs showed strong tenacity to their breeding site from year to year, with most pairs nesting within approximately 100 m of the previous year's site, regardless of nest success. Individuals also showed strong year-to-year fidelity to their mates. However, birds whose previous partner failed to return, or returned late, were quick to re-mate. On rare occasions, birds were not seen in the study area in a particular year, but seen again in later years, either because they were missed, had dispersed temporarily outside the study area, or did not return to the breeding area in some years. Standard Capture-Mark-Recapture analyses were used to calculate local re-sighting and survival rates. Local annual survival rate of adult Sabine's Gulls was 0.89 6 0.03, similar to annual adult survival estimates recently reported for other small to medium-sized gulls and terns.

Stenhouse, I. J., H. G. Gilchrist and W. A. Montevecchi. 2001. Reproductive Biology of Sabine's Gull in the Canadian Arctic. ***Condor*** 103:98-107.

Abstract taken directly from text
We studied the reproductive biology of Sabine's Gulls (*Xema sabini*) breeding on Southampton Island, in the eastern Canadian Arctic, from May to August in 1998 and 1999, and compared our results to information collected from the same region in 1980. Breeding phenology was 10 days earlier in 1998 than in these other years, and reflects an earlier onset of snowmelt in that year. Nests were dispersed, with a density of 7.6 to 8.7 nests per km^2. Sabine's Gulls exhibited strong inter-annual fidelity to breeding sites. Mean clutch size was lower in 1999 than 1998, and lower in both these years than in 1980. Hatching success was 63% in 1998, but only 21% in 1999 due to increased predation, most likely by arctic fox (*Alopex lagopus*). Adult gulls and chicks abandoned nest-sites within a few hours of the hatching of the last chick and relocated to coastal ponds, where adults continued to attend chicks. In comparisons of the reproductive biology of Sabine's Gull to closely related ''tern-like'' gull species and other ''black-headed'' gulls, Sabine's Gull showed a number of distinct ecological and behavioral differences and represents an ecological outlier within the Laridae.

Stenhouse, I. J., H. G. Gilchrist and W. A. Montevecchi. 2005. Factors affecting nest-site selection of Sabine's Gulls in the eastern Canadian Arctic. ***Canadian Journal of Zoology*** 83:1240-1245.

Abstract taken directly from text
The selection of breeding habitat is of prime importance for individual fitness. Among birds, natural selection should favour the ability to recognize and select habitat suitable for nesting and rearing chicks. This study compares the characteristics of Sabine's Gull, *Xema sabini* (Sabine, 1819), nest sites with random points across a coastal tundra environment on Southampton Island, Nunavut, Canada. The availability of terrestrial invertebrate prey was also examined among habitats. Sabine's Gull nests were nonrandomly distributed in relation to vegetation, substrate, and proximity to water. Gulls nested within approximately 1 km of the coastline and selected sites with the greatest proportions of moss and standing water (i.e., they nested close to the edge of small freshwater ponds near shore). However, there were no detectable differences in characteristics between successful and unsuccessful nests within preferred habitat. The dynamics of terrestrial invertebrate prey communities varied between years, but the volume of invertebrates in Sabine's Gull nesting habitat was intermediate between the most productive habitats and the least productive habitats in both years. However, nest-site selection in Sabine's Gulls may also be influenced by the availability of aquatic invertebrates (not examined in this study) and their proximity to the marine coastline, where chicks are taken to be reared.

Stewart, D. B. and L. M. J. Bernier. 1989. Distribution, Habitat, and Productivity of Tundra Swans on Victoria Island, King William Island, and Southwestern Boothia Peninsula, NWT. ***Arctic*** 42:333-338.

Abstract taken directly from text
Data on tundra swans *(Cygnus columbianus columbianus)* were recorded in the central and eastern Canadian Arctic, south of 77'N latitude, and on Southampton Island during the summers of 1980-85. Swans were seen on Victoria, Royal Geographical Society, King William, Stanley, and Southampton islands and on south-western Melville and Boothia peninsulas. Most swans inhabited low-lying areas that were inundated by the sea following glaciation and are now dotted with shallow tundra ponds. Breeding swans were common in the Minto Inlet, Lady Franklin Point, and Cambridge Bay areas of Victoria Island and on King William Island and south-western Boothia Peninsula. In August, 52-89% of the adults and sub-adults in these areas were seen as potential breeders, and the remainder were in non-kreeding flocks. Between 17 and 33% of the pairs had cygnets, and 10-13% of all swans were cygnets. With brood sizes of 1-3 (1.5 ± 0.7 [X ± SD] to 1.6 ± 0.5), the apparent breeding success was low relative to other northern swan populations. However, these breeding populations are significant and should be considered in management plans for the eastern population of the tundra swan.

Sutton, G. M. and D. F. Parmelee. 1956. On the Loons of Baffin Island. ***Auk*** 73:78-84.

Abstract not available [with excerpts directly from text]
Three species of loons breed on Baffin Island─the Common (*Gavia immer*), the Black-throated (*G. arctica*), and the Red-throated (*G. stellata*). This paper provides a summary of observations of these three loon species in several arctic areas.

Vangilder, L. D., L. M. Smith and R. K. Lawrence. 1986. Nutrient Reserves of Pre-migratory Brant During Spring. ***Auk*** 103:237-241.

Abstract not available [with excerpts directly from text]
Brant (*Branta bernicla*), like other arctic-nesting geese, rely heavily on stored nutrient reserves during reproduction. Brant arrive on the nesting ground with large lipid and protein reserves and metabolize substantial portions of these reserves during egg-laying and incubation. Because of their small body size, however, Brant must rely on exogenous sources of nutrients because they cannot store enough reserves to fast throughout incubation. Spring weather conditions on the arctic nesting grounds have substantial influence on Brant reproductive success.

Wynne-Edwards, V. C. 1952. Zoology of the Baird Expedition (1950) I. The Birds Observed in Central and South-East Baffin Island. ***Auk*** 69:353-391.

Abstract not available [with excerpts directly from text]
The Baird expedition (1950) was based at Clyde, approximately 70^{o} N, on the east coast of Baffin Island. Observations of the habits and reproduction of several bird species were made, including some species of loons, ducks, hawks, and falcons.

2.5.3 Mammals

Angerbjorn, A., M. Tannerfeldt and H. Lundberg. 2001. Geographical and temporal patterns of lemming population dynamics in Fennoscandia. ***Ecography*** 24:298-308.

Abstract taken directly from text
There is a long-lasting debate in ecology on cyclicity, synchrony and time lags of lemming population fluctuations. We have analysed 137 yr of previously published population data on the Norwegian lemming *Lemmus lemmus* in ten geographic regions of Fennoscandia. The dominating pattern was synchronous 4-yr cycles. There was no support for the hypothesis of a north-south gradient in cycle length. However, we found periods of prolonged interruptions in the cyclicity, which were more common in northern areas. We found a high degree of synchrony between regions, with only a weak relationship to distance. The observed pattern in lemming population dynamics was more consistent with effects from extrinsic factors, such as climate, than intrinsic factors, such as dispersal.

Bety, J., G. Gauthier, E. Korpimaki and J.-F. Giroux. 2002. Shared predators and indirect trophic interactions: lemming cycles and arctic-nesting geese. ***Journal of Animal Ecology*** 71:88-98.

Abstract taken directly from text
1) We investigated the hypothesis that cyclic lemming populations indirectly affect arctic-nesting greater snow geese (*Anser caerulescens atlanticus* L.) through the behavioural and numerical responses of shared predators.
2) The study took place on Bylot Island in the Canadian High Arctic during two lemming cycles. We recorded changes in foraging behaviour and activity rate of arctic foxes, parasitic jaegers, glaucous gulls and common ravens in a goose colony during one lemming cycle and we monitored denning activity of foxes for 7 years. We also evaluated the total response of predators (i.e. number of eggs depredated).
3) Arctic foxes were more successful in attacking lemmings than goose nests because predators were constrained by goose nest defence. Predators increased their foraging effort on goose eggs following a lemming decline.
4) Activity rates in the goose colony varied 3·5-fold in arctic foxes and 4·8-fold in parasitic jaegers, and were highest 2 and 3 years after the lemming peak, respectively. The breeding output of arctic foxes appeared to be driven primarily by lemming numbers.
5) Predators consumed 19–88% of the annual goose nesting production and egg predation intensity varied 2·7-fold, being lowest during peak lemming years. Arctic foxes and parasitic jaegers were the key predators generating marked annual variation in egg predation.
6) Our study provides strong support for short-term, positive indirect effects and long-term, negative indirect effects of lemming populations on arctic-nesting geese. The outcome between these opposing indirect effects is probably an apparent competition between rodents and many terrestrial arctic-nesting birds.

Blomqvist, S., N. Holmgren, S. Akesson, A. Hedenstrom and J. Pettersson. 2001. Indirect effects of lemming cycles on sandpiper dynamics: 50 years of counts from southern Sweden. ***Oecologia*** 133:146-158.

Abstract taken directly from text
The bird–lemming hypothesis postulates that breeding success of tundra-nesting geese and waders in Siberia follows the cyclic pattern of lemming populations, as a result of predators switching from lemmings to birds when the lemming population crashes. We present 50 years of data on constant-effort catches of

red knot *Calidris canutus* and curlew sandpiper *C. ferruginea* at an autumn migratory stopover site (Ottenby) at the Baltic Sea, supplemented with literature data on winter censuses of dark-bellied brent goose *Branta b. bernicla* and whitefronted goose *Anser albifrons* in northwestern Europe, and waders in Germany and Southern Africa. Number and proportion of juveniles in these bird populations (both our own and literature data) were compared with an index of predation pressure (calculated from the abundance of lemmings on the Taimyr peninsula), and climate indices for the North Eurasia and the North Atlantic regions. The index of predation pressure correlated significantly with the number of juveniles of red knot and curlew sandpiper, but not with number of adults. Also, this index correlated with the reproductive performance of geese and waders reported in the literature. Fourier analysis revealed a significant deviation from random noise with the maximum spectral density at the period length of 3 years for number of juvenile red knots and curlew sandpipers captured at Ottenby, abundance of lemmings, reproduction in arctic fox *Alopex lagopus*, and reproductive performance in geese on the Siberian tundra. Also, the date of passage at Ottenby for adult red knot and curlew sandpiper showed a spectral density peak at a period length of 3 years, the latter species also showing a peak at a period length of 5–6 years. Passage dates for adult red knot and curlew sandpiper were earlier in years of high predation pressure compared with years of low predation pressure. The fluctuations in reproductive success of the studied Siberian goose and wader species appear to be primarily influenced by biotic factors in the breeding area, rather than by abiotic factors, such as climate oscillations. Annual variations in migratory arctic bird populations may have far reaching effects in habitats along their migration routes and in their wintering areas. We suggest a link between lemming cyclicity in the Northern Hemisphere and predation pressure on Southern Hemisphere benthos, in which the signal is carried between continents by long distance migrating waders.

Northwest Territories Environment and Natural Resources. 2006. ***Caribou Forever- Our Heritage, Our Responsibility: A Barren-ground Caribou Management Strategy for the Northwest Territories 2006-2010***. Environment and Natural Resources, Govt. of the Northwest Territories. 38 pp.

Abstract taken directly from text
The social, cultural and economic value of barren-ground caribou to residents of the Northwest Territories (NWT) is immense. These migratory herds are hunted by Dene, Inuvialuit, Metis and non-aboriginal people from almost all communities on mainland Northwest Territories (NWT). The minimum annual harvest is 11,000 caribou with a minimum economic value of $17 million dollars (includes meat replacement and outfitting). Over the last ten years, the barren-ground caribou herds in the Northwest Territories (NWT) have declined from 40 to 86 percent. Management actions are required to assist declining caribou herds to recover and address the economic hardships resulting from low caribou numbers. The NWT Barren-ground Caribou Management Strategy 2006–2010 supports the Legislative Assembly's vision and goal to care and protect the land, water and wildlife. The Strategy draws on previous management planning initiatives conducted with co-management boards, caribou management boards and NWT communities. The Strategy will not replace herd specific management planning but rather will provide a unifying context for those plans. The five-year NWT Barren-ground Caribou Management Strategy includes principles to guide barren-ground caribou management. The principles indicate that all NWT residents will understand their role and impact on barren-ground caribou and that the GNWT and co-management boards have leadership roles in making decisions on management actions. The Strategy has five key components including 1) engaging partners in management, 2) ensuring information is available for management decisions, 3) managing impacts of human activities, 4) public education and compliance, and 5) addressing hardships from low caribou numbers. Strategies are described under each key component as well as immediate actions. All actions taken over the next five years will have a strategic effect on recovery of caribou herds. To implement the Strategy requires a total investment of $8,773,000 dollars. Of this, the Strategy identifies the current commitment by the Government of the Northwest Territories and the incremental investment required. The major costs in this strategy are associated with the collection of information necessary for sound management decisions. Implementation of the strategy will also require resources from partners who share responsibility for managing caribou herds. These partners include co-management boards, caribou management boards, the Government of Canada and neighbouring jurisdictions.

Clark, K. R. F. 1971. ***Food habits and behaviour of the of the tundra wolf on central Baffin Island***. Ph.D. Thesis, Department of Zoology, University of Toronto, ON.

Abstract taken directly from text
A study of the ecology of the Baffin Island Tundra wolf (*Canis lupus manningi*) was conducted in an 1800 square mile area on central Baffin Island in spring and summer, 1966-1969, in order to further the understanding of the relationships between unexploited populations of this predator and its single large prey species, the caribou (*Rangifer tarandus groenlandicus*). Data on wolf behaviour were gathered primarily by observing wolves at occupied dens, although information on hunting behaviour was gathered throughout the study area. The food habits of the wolves were studied primarily by an examination of hair remains of the prey found in wolf fecal material deposited at den sites and also by an examination of caribou skeletal remains found in the study area.

Crete, M., J.-P. Ouellet and L. Lesage. 2001. Comparative Effects on Plants of Caribou/ Reindeer, Moose and White-Tailed Deer Herbivory. ***Arctic*** 54:407-417.

Abstract taken directly from text
We reviewed the literature reporting negative or positive effects on vegetation of herbivory by caribou/reindeer, moose, and white-tailed deer in light of the hypothesis of exploitation ecosystems (EEH), which predicts that most of the negative impacts will occur in areas where wolves were extirpated. We were able to list 197 plant taxa negatively affected by the three cervid species, as opposed to 24 that benefited from their herbivory. The plant taxa negatively affected by caribou/reindeer (19), moose (37), and white-tailed deer (141) comprised 5%, 9%, and 11% of vascular plants present in their respective ranges. Each cervid affected mostly species eaten during the growing season: lichens and woody species for caribou/reindeer, woody species and aquatics for moose, and herbs and woody species for white-tailed deer. White-tailed deer were the only deer reported to feed on threatened or endangered plants. Studies related to damage caused by caribou/reindeer were scarce and often concerned lichens. Most reports for moose and white-tailed deer came from areas where wolves were absent or rare. Among the three cervids, white-tailed deer might damage the most vegetation because of its smaller size and preference for herbs.

Danks, F. S. and D. R. Klein. 2002. Using GIS to predict potential wildlife habitat: a case study of muskoxen in northern Alaska. ***International Journal of Remote Sensing*** 23:4611-4632.

Abstract taken directly from text
With its versatility and potential in addressing ecological issues, Geographical Information Systems (GIS) were used in a study of wildlife habitat prediction. Habitat determination is a complex problem that requires consideration of a wide variety of factors and their relationships. Assessments of habitat for a large area are not viable without a powerful tool. GIS was appropriate in addressing muskox habitat potential in Alaska. Muskoxen (*Ovibos moschatus*) distribution and habitat selection in northern Alaska remain inadequately documented following heir reintroduction. There is increasing pressure to develop oil, gas and mineral resources in northern Alaska, for example in the National Petroleum Reserve-Alaska (NPR-A), an area facing conflict over its management and use. Muskox location data, satellite-based vegetation maps, digital elevation models (DEMs) and terrain data were incorporated into a maximum likelihood classification to produce a muskox habitat model for a region currently occupied by muskoxen. This model was extrapolated to the NPR-A. Resulting predictive maps showed suitable summer habitat in wetter lower-lying areas and suitable winter habitat in higher, drier more rugged areas. Results suggest that suitable muskox habitat is present in the NPR-A and that GIS may be an effective tool for such an analysis.

Ehrich, D., P. E. Jorde, C. J. Krebs, A. J. Kenney, J. E. Stacy and N. C. Stenseth. 2001. Spatial structure of lemming populations (*Dicrostonyx groenlandicus*) fluctuating in density. ***Molecular Ecology*** 10:481-495.

Abstract taken directly from text

The pattern and scale of the genetic structure of populations provides valuable information for the understanding of the spatial ecology of populations, including the spatial aspects of density fluctuations. In the present paper, the genetic structure of periodically fluctuating lemmings (*Dicrostonyx groenlandicus*) in the Canadian Arctic was analysed using mitochondrial DNA (mtDNA) control region sequences and four nuclear microsatellite loci. Low genetic variability was found in mtDNA, while microsatellite loci were highly variable in all localities, including localities on isolated small islands. For both genetic markers the genetic differentiation was clear among geographical regions but weaker among localities within regions. Such a pattern implies gene flow within regions. Based on theoretical calculations and population census data from a snap-trapping survey, we argue that the observed genetic variability on small islands and the low level of differentiation among these islands cannot be explained without invoking long distance dispersal of lemmings over the sea ice. Such dispersal is unlikely to occur only during population density peaks.

Elmhagen, B., M. Tannerfeldt, P. Verucci and A. Angerbjorn. 2000. The arctic fox (*Alopex lagopus*): an opportunistic specialist. ***Journal of Zoology*** 251:139-149.

Abstract taken directly from text

Reliable and abundant resources are likely to favour specialization, while unpredictable environmental variation should favour a generalist strategy. The rodent population cycles of northern latitudes can be seen as both predictable and unpredictable, depending on the scale in time and space. The arctic fox *Alopex lagopus* is an opportunistic carnivore, but paradoxically, it seems to function as a specialist on fluctuating rodent Arvicolinae populations in most inland areas. We have studied the dietary response of arctic foxes in Sweden during 5 years of varying abundance of Norwegian lemming *Lemmus lemmus*, and how these changes influenced the reproductive success of the foxes. The arctic fox population on mainland Fennoscandia is threatened by extinction and the situation has deteriorated during the 1980s and 1990s because of an absence of lemming peaks. Our results showed that is all years, lemming was the main prey for arctic foxes, with 85% frequency of occurrence in summer faeces (scats). Bird remains (mainly Passeriformes) were present in 34% of the scats, reindeer *Rangifer tarandus* in 21%, voles and shrews in 4% and hares *Lepus timidus* in 2% of the scats. The occurrences of lemming, bird and larger mammal (reindeer and hare) remains in the scats varied significantly between years. Temporal variations within summer seasons and dietary differences between sub-areas, indicated the arctic foxes fed opportunistically on the alternative prey types. Den occupancy rates were positively correlated with lemming population densities during the previous winter, indicating a strong numerical response. We conclude that from a functional aspect, the arctic fox in Sweden is a lemming specialist, since lemming is the main prey and their abundance is the best predictor of arctic fox reproductive success. Other prey are used opportunistically in relation to their availability.

Ferguson, M. A. D., L. Gauthier and F. Messier. 2001. Range shift and winter foraging ecology of a population of Arctic tundra caribou. ***Canadian Journal of Zoology*** 79:746-758.

Abstract taken directly from text

Some researchers have suggested that over periods of several decades, Arctic tundra caribou (*Rangifer tarandus*) may be regulated by density-dependent forage depletion. Winter range shifts could potentially delay such regulation when a population is at or near long-term maximum abundance. In the 1980s, Inuit correctly predicted the mass emigration of caribou from a traditional winter range on Foxe Peninsula (FP) on southern Baffin Island, Nunavut, Canada. Most FP caribou subsequently emigrated to a new winter range on Meta Incognita Peninsula (MIP). To determine if MIP provided emigrating caribou with better foraging habitats, we compared winter forage resources and snow cover at caribou foraging sites, and food selection by caribou on FP and MIP in April 1992. Caribou that remained on FP dug feeding craters in shallower, softer snow than those on MIP did. Biomass of most fruticose lichens was greater within foraging sites on MIP than on FP. Biomass of shrubs, other than *Cassiope tetragona* and *Dryas integrifolia*, was also greater on MIP than on FP. *Dryas integrifolia* was the only plant class that had

higher biomass on FP than on MIP. *Cladina* spp. / *Cladonia* spp., *Sphaerophorus fragilis*, and *Cetraria nivalis* occurred less frequently in the rumens of FP caribou. Proportions of fruticose lichens in rumens of caribou on both peninsulas were similar to those on other overgrazed and High Arctic tundra winter ranges. Caribou on FP showed a higher preference for the shrub *C. tetragona*. Biomasses of plants sensitive to long-term feeding or trampling by caribou (i.e., the five most common fruticose lichens, other shrubs, and plant debris) were consistently lower on FP, which is congruous with Inuit reports that long-term cumulative overgrazing had reduced the supply of important forage plants on FP sites that were accessible to caribou in winter. FP caribou that emigrated to MIP gained access to more abundant, higher quality forage resources than those that remained on FP. Because most FP caribou had emigrated, this South Baffin subpopulation escaped, at least temporarily, the regulating effects of historical cumulative overgrazing.

Ferguson, M. A. D. and F. Messier. 1997. Collection and analysis of traditional ecological knowledge about a population of arctic tundra caribou (Baffin Island). ***Arctic*** 50:17-28.

<u>*Abstract taken directly from text*</u>
Aboriginal peoples want their ecological knowledge used in the management of wildlife populations. To accomplish this, management agencies will need regional summaries of aboriginal knowledge about long-term changes in the distribution and abundance of wildlife populations and ecological factors that influence those changes. Between 1983 and 1994, we developed a method for collecting Inuit knowledge about historical changes in a caribou (*Rangifer tarandus*) population on southern Baffin Island form c. 1900 to 1994. Advice from Inuit allowed us to collect and interpret their oral knowledge in culturally appropriate ways. Local Hunters and Trappers Associations (HTAs) and other Inuit identified potential informants to maximize the spatial and temporal scope of the study. In the final interview protocol, each informant (i) established his biographical map and time line, (ii) described changes in caribou distribution and density during his life, and (iii) discussed ecological factors that may have caused changes in caribou populations. Personal and parental observations of caribou distribution and abundance were reliable and precise. Inuit who had hunted caribou during periods of scarcity provided more extensive information than those hunters who had hunted mainly ringed seals (*Phoca hispida*); nevertheless, seal hunters provided information about coastal areas where caribou densities were insufficient for the needs of caribou hunters. The wording of our questions influenced the reliability of informants' answers; leading questions were especially problematic. We used only information that we considered reliable after analyzing the wording of both questions and answers from translated transcripts. This analysis may have excluded some reliable information because informants tended to understate certainty in their recollections. We tried to retain the accuracy and precision inherent in Inuit oral traditions; comparisons of information from several informants and comparisons with published and archival historical reports indicate that we retained these qualities of Inuit knowledge.

Ferguson, M. A. D., R. G. Williamson and F. Messier. 1998. Inuit Knowledge of Long-term Changes in a Population of Arctic Tundra Caribou. ***Arctic*** 51:201-219.

<u>*Abstract taken directly from text*</u>
Indigenous peoples possess knowledge about wildlife that dates back many generations. Inuit observations of historical changes in a caribou population on southern Baffin Island, collected from 43 elders and active hunters during 1983–95, indicate that caribou were abundant and their distributions extensive in most coastal areas of southern Baffin Island from c.1900–25. Subsequently, caribou distributions contracted and abundance declined, probably reaching an overall low in the 1940s. Beginning in the mid-1950s, distributions and abundance increased gradually, at least until the mid-1980s. Changes in distribution occurred mainly during autumn, as caribou migrated to their wintering areas. Within most wintering areas, increases in caribou abundance followed a process of range expansion, range drift (i.e., expanding on one front while contracting on another), and finally range shift (i.e., mass emigration to a new winter range). During the population decline and low, the caribou often exhibited winter range volatility (i.e., frequent, unpredictable inter-annual range shifts). On the basis of Inuit descriptions of caribou abundance, we estimated that the population as a whole decreased an

average of 9% annually from 1910 to 1940, and then increased about 8% annually from 1940 to 1980. This pattern was largely consistent across southern Baffin Island. As Inuit elders had predicted in 1985, the population essentially abandoned its highest-density wintering area on Foxe Peninsula during the late 1980s, apparently emigrating en masse to a new wintering area on Meta Incognita Peninsula, about 375 km to the southeast. Inuit knowledge suggested that caribou population fluctuations are cyclic, with each full cycle occurring over the lifetime of an elder. Both this study and historical records dating from 1860 support a periodicity of 60–80 years for fluctuations of the South Baffin caribou population. Inuit elders suggested that the abundance of caribou on wintering areas decreases several years after caribou occupy small coastal islands, a phenomenon currently occurring throughout southern Baffin Island, except on Cumberland Peninsula. The Inuit recognize two ecotypes of caribou: migratory upland-lowland caribou and resident mountain-plateau caribou. After migratory caribou from Foxe Peninsula shifted their winter range around 1990, Meta Incognita Peninsula was occupied by both ecotypes. The migratory caribou apparently occupy low elevations, while the resident caribou remain in the mountains, producing two seasonal migratory patterns. Inuit knowledge proved to be temporally and spatially more complete than the written record.

Franklin, S. E., D. R. Peddle, J. A. Dechka and G. B. Stenhouse. 2002. Evidential reasoning with Landsat TM, DEM and GIS data for landcover classification in support of grizzly bear habitat mapping. ***International Journal of Remote Sensing*** 23:4633-4652.

Abstract taken directly from text

Multisource data consisting of satellite imagery, topographic descriptors derived from DEMs, and GIS inventory information have been used with a detailed, field-based landcover classification scheme to support a quantitative analysis of the spatial distribution and concentration of grizzly bear (*Ursus arctos horribilis*) habitat within the Alberta Yellowhead Ecosystem study area. The map is needed to determine if bear movement and habitat use patterns are affected by changing landscape conditions and human activities. We compared a multisource Evidential Reasoning (ER) classification algorithm, capable of handling this large and diverse data set, to a more conventional maximum likelihood decision rule which could only use a subset of the available data. The ER classifier provided an acceptable level of accuracy (ranging to 85% over 21 habitat classes) for a level 3 product, compared to 71% using a maximum likelihood classifier.

Gilg, O., B. Sittler, B. Sabard, A. Hurstel, R. Sane, P. Delattre and I. Hanski. 2006. Functional and numerical responses of four lemming predators in high arctic Greenland. ***Oikos*** 113:193-216.

Abstract taken directly from text

The high-arctic tundra ecosystem has the world's simplest vertebrate predator-prey community, with only four predators preying upon one rodent species, the collared lemming (*Dicrostonyx groenlandicus*). We document the functional and numerical responses of all the four predators in NE Greenland. Using these data, we assess the impact of predation on the dynamics of the collared lemming with a 4 yr cycle and > 100-fold difference between maximum and minimum densities. All predator species feed mostly (>90%) on lemmings when lemming density is >1 ha^{-1}, but the shapes of the predators' responses vary greatly. The snowy owl (*Nyctea scandiaca*) is present and breeds only when lemming densities at snowmelt are >2 ha^{-1}, giving rise to a step-like numerical response. The long-tailed skua (*Stercorarius longicaudus*) has a type III functional response and shifts from alternate food (mainly berries and insects) to lemmings with increasing lemming density. The skua surpasses all the other predators in summer by its total response. The type III functional response of the Arctic fox (*Alopex lagopus*) starts to increase at much lower lemming densities than the responses of the avian predators, but it has only a weak numerical response. Finally, the stoat (*Mustela erminea*) is the most specialized predator and the only one with a clearly delayed numerical response. According to their specific functional and numerical responses, each predator plays a key role at some point of the lemming cycle, but only the stoat has the potential to drive the lemming cycle. Stoat predation is greatly reduced in the winter preceding the lemming peak, and it reaches a maximum in the winter preceding the lowest lemming summer density. Stoat predation appears to maintain low lemming densities for at least two successive years. Our study provides empirical support for the specialist predator hypothesis about small mammal population cycles.

Gilg, O., I. Hanski and B. Sittler. 2003. Cyclic Dynamics in a Simple Vertebrate Predator-Prey Community. ***Science*** 302:866-868.

Abstract taken directly from text
The collared lemming in the high-Arctic tundra in Greenland is preyed upon by four species of predators that show marked differences in the numbers of lemmings each consumes and in the dependence of their dynamics on lemming density. A predator-prey model based on the field-estimated predator responses robustly predicts 4-year periodicity in lemming dynamics, in agreement with long-term empirical data. There is no indication in the field that food or space limits lemming population growth, nor is there need in the model to consider those factors. The cyclic dynamics are driven by a 1-year delay in the numerical response of the stoat and stabilized by strongly density-dependent predation by the arctic fox, the snowy owl, and the long-tailed skua.

Hudson, P. J. and O. N. Bjornstad. 2003. Vole Stranglers and Lemming Cycles. ***Science*** 302:797-798.

Abstract not available [excerpts directly from text]
Some populations of the collared lemming exhibit violent and periodic fluctuations in their numbers, whereas others exhibit no clear statistical pattern. The question of what ecological mechanisms generate these fluctuations is the cause of much controversy. Mathematical models can illustrate how the cyclic fluctuations of collared lemmings are driven by predation by the lemming specialist, the stoat, and then are molded (when lemming populations reach high densities) by three generalist predators: the arctic fox, the snowy owl, and the long-tailed skua. There is a difference between many of the models that attempt to predict lemming populations. The next step is to use experimental manipulation of the rates of lemming predation to test the hypothesis motted by Gilg and colleagues that small mammal populations undergo periodic fluctuations in numbers in response to predation by a specialized predator. Such experimental manipulations will provide a test of the theory and will reveal how to further refine the theoretical model. Sadly, ecologists rarely have the resources to do such large-scale experiments.

Killengreen, S. T., R. A. Ims, N. G. Yoccoz, K. A. Brathen, J.-A. Henden and T. Schott. 2007. Structural characteristics of a low Arctic tundra ecosystem and the retreat of the Arctic fox. ***Biological Conservation*** 135:459-472.

Abstract taken directly from text
We conducted a large-scale, campaign-based survey in Finnmark, northern Norway to evaluate the proposition that declining Arctic fox populations at the southern margin of the Arctic tundra biome result from fundamental changes in the state of the ecosystem due to climatic warming. We utilized the fact that the decline of the Arctic fox in Finnmark has been spatially heterogeneous by contrasting ecosystem state variables between regions and landscape areas (within regions) with and without recent Arctic fox breeding. Within the region of Varanger peninsula, which has the highest number of recorded dens and the most recent breeding records of Arctic fox, we found patterns largely consistent with a previously proposed climate-induced, bottom-up trophic cascade that may exclude the Arctic fox from tundra. Landscape areas surrounding dens without recent Arctic breeding were here more productive than areas with recent breeding in terms of biomass of palatable and climate sensitive plants, the number of insectivorous passerines and predatory skuas. Even the frequency of unspecified fox scats was the highest in landscape areas where arctic fox breeding has ceased, consistent with an invasion of the competitively dominant red fox. The comparisons made at the regional level were not consistent with the results within the Varanger region, possibly due to different causal factors or to deficiencies in Arctic fox monitoring at a large spatial scale. Thus long-term studies and adequate monitoring schemes with a large-scale design needs to be initiated to better elucidate the link between climate, food web dynamics and their relations to Arctic and red foxes.

Krebs, C. J., A. J. Kenney, S. Gilbert, K. Danell, A. Angerbjorn, S. Erlinge, R. G. Bromley, C. Shank and S. Carriere. 2002. Synchrony in lemming and vole populations in the Canadian Arctic. ***Canadian Journal of Zoology*** 80:1323-1333.

Abstract taken directly from text
Population fluctuations may occur in synchrony among several rodent species at a given site, and they may occur in synchrony over large geographical areas. We summarize information on synchrony in lemmings and voles from the Canadian Arctic for the past 20 years. The most detailed available information is from the central Canadian Arctic, where snap-trap samples have been taken annually at several sites for periods of up to 15 years. Geographical synchrony in the same species among different sites was strong, especially for the central and eastern Canadian Arctic. Synchrony among different species at a given site was also generally high. When one species is at high density, densities of all species at that site tend to be high. These results do not easily fit the mobile-predator hypothesis proposed to explain regional synchrony, and are more consistent with the weather hypothesis, which we suggest both entrains synchrony among sites and enforces synchrony among species within a site. We tentatively support the weather hypothesis for geographical synchrony in lemmings, and recommend the establishment of a circumpolar program to monitor lemming cycles and predator movements that would advance our understanding of these large-scale patterns of cyclic synchrony.

Larter, N. C. and J. A. Nagy. 2001. Seasonal and Annual Variability in the Quality of Important Forage Plants on Banks Island, Canadian High Arctic. ***Applied Vegetation Science*** 4:115-128.

Abstract taken directly from text
In vitro acid-pepsin digestibility (IVDMD), crude protein (CP), fibre, lignin, and energy content were measured for a variety of forage plants collected annually from Banks Island over five summers and three winters from 1993-1998. Summer samples were collected during mid-June (start of growing season). Mid-July (peak of growing season), and mid-late August (senescence). Winter samples were collected in early (November), mid- (February). and late- (April/May) winter. Samples, collected in areas of both high and low muskox density, included *Carex aquatilis,* unidentified *Cares, Salix arctica, Dryas integrifolia, Cassiope terragona. Saxlfraga* spp., *A.rtraga1~l.r*spp., *Osytropis* spp., lichen, and grass. Seasonal dynamics in forage quality during the growing season were similar to those reported elsewhere in the arctic and high arctic and were consistent across years. However, there were significant year effects in lignin, fibre, and energy content of forages and the crude protein (CP) content of *C. aquatilis* in winter, indicating annual differences in the quality of forage available to herbivores. The quality of forages on Banks Island was similar between areas subjected to different densities of muskox (ca. 1.6- 1.9 versus 0.3-0.4/km^2) implying that quality was not affected by these grazing intensities. The Banks Island high arctic ecosystem supports an abundance of herbivores. It has been hypothesized that this is because forage quality and/or quantity are superior on Banks Island than elsewhere in the high arctic. Our results regarding forage quality are equivocal. Although the maximum CP content of forages from Banks Island was generally higher than reported elsewhere in the arctic and high arctic, CP content reported elsewhere fell within the inter-annual range reported from Banks Island. Fibre and energy content of forages from Banks Island were similar to slightly lower than elsewhere in the arctic and high arctic. Such comparisons must be considered in light of the inter-annual variability in quality we report.

Manning, T. H. 1943. Notes on the Mammals of South and Central West Baffin Island. ***Journal of Mammalogy*** 24:47-59.

Abstract not available [excerpts directly from text]
Special interest is attached to the fauna of central west Baffin Island owing to the absence of Eskimos on this coast from Bowman Bay northward to a camp some 50 miles north of Piling, a distance of about 300 miles in a straight line. Although it is possible that occasional spring hunting journeys have been made by Iglulik Eskimos nearly, if not quite, to Piling from 1935 on, and although a party of caribou hunting Eskimos from Pangnirtung (on Cumberland Sound, east Baffin Island) visited Taverner Bay in 1938, it is unlikely that the game has been appreciably affected. The north coast of Foxe Peninsula also

has been rarely visited by Eskimos, at least in recent years. The same is true of the Lake Nettilling area, except near its eastern end. In 1937-38, Foxe Peninsula natives camped at the southern end of the lake, but during the winter of 1938-39 caribou were scarce there and the Eskimos moved to Cumberland Sound. Thus this long stretch of coast has been a natural game sanctuary for perhaps a hundred years. Owing to the extreme flatness of the coast, there probably never have been permanent Eskimo camps between Bowman Bay and Taverner Bay; but the numerous rock structures show that the coast between there and Piling once supported a considerable population. When or why the region was deserted cannot be proved, but a failure of the caribou is the most likely reason.

Manseau, M., J. Huot and M. Crete. 1996. Effects of Summer Grazing by Caribou on Composition and Productivity of Vegetation: Community and Landscape Level. ***Journal of Ecology*** 84:503-513.

<u>*Abstract taken directly from text*</u>

1) Changes in demography and studies on physical condition of the Rivihre George caribou *Rangifer tarandus* herd have suggested that its size may be primarily regulated by the amount of forage available on the summer range.
2) We therefore document the impact of grazing and trampling on composition and productivity of two plant communities, the shrub tundra and stands of dwarf birch, within this range. Ungrazed sites were rare, but four previously located small areas were used as control sites.
3) For the shrub tundra, the lichen mat was absent in grazed sites and ground previously occupied by lichens was either bare, covered by fragments of dead lichens and mosses or recolonized by early succession lichen species. Ground cover of shrubs not eaten by caribou was lower in grazed sites than in ungrazed sites, and coverage of graminoids, forage shrubs and forbs did not differ significantly between grazed and ungrazed sites.
4) In stands of dwarf birch grazed by caribou, ground cover and leaf biomass of *Betula glandulosa* was significantly lower than in ungrazed sites.
5) Productivity of forage plant species over the summer range was estimated at 22.5 g m^{-2} $year^{-1}$ in an ungrazed condition compared to 10.3 gm^{-2} $year^{-1}$ when grazed.
6) At the landscape level, caribou have fragmented the distribution of their food resource by reducing biomass of shrub tundra and stands of dwarf birch to a very low level.
7) The serious negative impact of migratory ungulates on plant productivity of their summer range may be explained by characteristics of the vegetation and the high carrying capacity of winter compared to summer ranges. Significant factors related to the vegetation are its low resilience and productivity and the absence of a response of vascular plants following removal of lichens.

Morneau, C. and S. Payette. 2000. Long-term fluctuations of a caribou population revealed by tree-ring data. ***Canadian Journal of Zoology*** 78:1784-1790.

<u>*Abstract taken directly from text*</u>

We used a dendroecological approach that involved examination of debarking lesions (trampling scars) produced by caribou (*Rangifer tarandus*) hooves on surficial roots and low branches of conifers to assess caribou activity in the summer range of the Rivière George caribou herd in north-eastern Quebec-Labrador over the last 100 years. We deduced changes in caribou activity from the age-frequency distributions of trampling scars in three widely spaced (>100 km) old-growth conifer stands in the Rivière George area. We used the fluctuating patterns in age distributions, described by residuals of the log-linear regression, as an index of the number of trampling scars with time. This index indicated that caribou activity at the three sites followed a general decreasing trend from the turn of the last century to around 1950. There were two stages of rapid decline, around 1905–1915 and 1940, separated by a minor increase in the 1920–1930s. A sustained increase occurred from the 1950s to the 1980s. A comparison with survey and historical data for caribou suggested that these fluctuations in this common signal of activity at the three sites resulted mainly from fluctuations in caribou abundance that occurred throughout the 20th century in north-eastern Quebec–Labrador. The increase in caribou activity during the 1920–1930s suggested by the frequency of trampling scars is not reported in the historical record.

Caribou trampling scars on conifers may offer a new opportunity to assess large-scale spatial and temporal population trends of caribou in subarctic and boreal zones.

Morris, D. W., D. L. Davidson and C. J. Krebs. 2000. Measuring the ghost of competition: Insights from density-dependent habitat selection on the co-existence and dynamics of lemmings. ***Evolutionary Ecology Research*** 2:41-67.

Abstract taken directly from text
When interspecific competitors resolve their co-existence by habitat segregation, their competition might, like a ghost, be invisible because the species occupy separate habitats. Population fluctuations should often bring the species into competition in jointly occupied habitats where their competition can be measured by habitat isodars (lines or planes of density where the expected fitness of individuals is the same in all occupied habitats). We tested the theory by calculating isodars for two species of lemmings with distinct habitat preferences. When population densities are high, both habitats are occupied by both species. But as densities decline, habitat isodars suggest that the joint dynamics of each species pass through a region where each occupies a separate habitat (the ghost of competition). The competition was asymmetrical. The density of collared lemmings in their preferred habitat was reduced as the density of brown lemmings increased in the same habitat. But collared lemmings had no direct competitive effect on brown lemmings. The interspecific effect from brown lemmings was comparable to – possibly even in excess of – intraspecific competition for habitat. The asymmetric competition for habitat yields spectacular new kinds of isolegs categorizing habitat competition between co-existing species. Although current evidence implicates competition, the patterns are also consistent with apparent competition driven by specialized predators. Regardless of whether lemming habitat use reflects true or apparent competition, the associated density-dependent differences in habitat preference are likely to have major consequences for the nonstable dynamics of lemmings and non-linear lemming isoclines.

Nellemann, C. 1996. Terrain selection by reindeer in late winter in central Norway. ***Arctic*** 49:339-47.

Abstract taken directly from text
Characteristics of topography, snow, lichen cover, and lichen distribution were compared with habitat use by Snhetta reindeer (*Rangifer tarandus tarandus* L.) in central Norway to investigate the role of terrain structure for habitat use within different lichen health communities. In late winter, density of groups of feeding craters was correlated to indices of terrain ruggedness (TRI) measured at a mesoscale (10-20 m relief), but not to terrain ruggedness measured at a macroscale (30-110 m relief). The use of lichen heaths in rugged terrain (TRI>2.0) was higher than that expected from availability. In rugged terrain, 60-80% of the lichen heaths had less than 40 cm of snow, compared to only 10-30% of the lichen heaths in less rugged areas (TRI < 2.0). Rugged terrain types accounted for only 23% of the lichen heath in the study area, and less than 9% of the total area. Available habitat was thus considerably less than that suggested by overall availability of alpine lichen heath. In late winter, ramhardness of snow exceeded 40 kg, and reindeer cratered mainly where snow was less than 20 cm deep. Reindeer selected narrow (15-25 m broad) and sparsely vegetated ridges with high micro-topographic diversity beyond that suggested from availability. Other ridge types with lichen heath were used less than expected from availability. Terrain ruggedness indices may have the potential for estimating the proportion of lichen heath communities that are available in late winter when snow conditions limit availability of forage.

Olofsson, J., P. E. Hulme, L. Oksanen and O. Suominen. 2004. Importance of large and small mammalian herbivores for the plant community structure in the forest tundra ecotone. ***Oikos*** 106:324-334.

Abstract taken directly from text
Both theoretical arguments and empirical evidence suggests that herbivory in general and mammalian winter herbivory in particular is important in arctic-alpine ecosystems. Although knowledge of the effect of herbivores on specific plants and communities is quite extensive, little is known about the relative impact of large and small vertebrate herbivores and how it might vary among different habitats. To address this

key issue, we established exclosures with two different mesh sizes in forest and nearby tundra at three different sites in four contrasting locations in the forest-tundra ecotone in northernmost Sweden and Norway. Plant community composition was recorded annually in three permanent plots within each exclosure and an unfenced control. Local densities of vertebrate herbivores were estimated in spring and autumn from 1998 to 2002. Reindeer (*Rangifer tarandus*) were the most abundant large vertebrate while Norwegian lemmings (*Lemmus lemmus*) and grey-sided voles (*Clethrionomys rufocanus*) were the most common small vertebrates. The study reveals that voles and lemmings have larger effects on the vegetation than reindeer in both habitats in all four locations, even though densities of reindeer differ between locations and only two locations experienced lemming peaks during the period of the experiment. The relative abundance of five of the fifteen most common species was significantly influenced by voles and lemmings whereas only a single species was significantly influenced by reindeer. Different analyses give contrasting results on the importance of herbivory in forest versus open heathlands. A principal component analyses revealed that herbivory influenced the vegetation more in open heathlands than in forests. However, an importance index of herbivores did not differ between forest and open heathlands. Moreover, none of the plant species responded differently in the two habitats, when herbivores were removed. Our results suggest that intense and localised selective foraging by small mammals may have a more marked effect on vegetation than transient feeding by reindeer.

Olofsson, J., P. E. Hulme, L. Oksanen and O. Suominen. 2005. Effects of mammalian herbivores on revegetation of disturbed areas in forest-tundra ecotone in northern Fennoscandia. ***Landscape Ecology*** 20:351-359.

<u>*Abstract taken directly from text*</u>
Herbivores influence the structure of plant communities in arctic-alpine ecosystems. However, little is known of the effect of herbivores on plant colonisation following disturbance, and on its variability depending on the identity of herbivores and the characteristics of the habitats. To quantify the role of large and small vertebrate herbivores, we established exclosures of two different mesh sizes around disturbed subplots in forest and nearby tundra habitats in four contrasting locations in the forest-tundra ecotone in northernmost Sweden and Norway. The study revealed that herbivores influenced the abundance but not the species composition of regenerating vegetation. Gaps were colonised by the dominant species in the surrounding vegetation. The only exception to this expectation was *Empetrum nigrum*, which failed to colonise gaps even though it dominated undisturbed vegetation. Significant effects of herbivory were only detected when both small and large herbivores were excluded. Herbivores decreased the abundance of three of the most common species *Vaccinium myrtillus*, *Vaccinium vitis idaea*, and *Deschampsia flexuosa*. The effect of herbivory on the abundance of these three species did not differ between habitats and locations. However, the composition of the regenerating vegetation differed between habitats and locations. The disturbance treatment increased the species richness on the scale of plots, habitats, and sites. However, on the scale of whole locations, all species found in disturbed areas were also found in undisturbed areas, suggesting that the natural disturbance regime in arctic landscapes is high enough to sustain colonizing species.

Oosenbrug, S. M. and J. B. Theberge. 1980. Altitudinal Movements and Summer Habitat Preferences of Woodland Caribou in the Kluane Ranges, Yukon Territory. ***Arctic*** 33:59-72.

<u>*Abstract taken directly from text*</u>
The altitudinal movements, preferred topography and plant communities of 150 to 200 woodland caribou *(Rungifer turandus caribou)* were recorded for two summers. Nine subalpine or alpine tundra communities constituting their major summer range were quantitatively described. Caribou calved in shrub communities between 1300 and 1450 m, moving upward as the summer progressed. Stags and associated juveniles preferred higher elevations than did other groupings. Caribou disproportionately chose north-facing slopes of less than 20". They fed in birch-sedge meadow and sedge meadow communities nearly twice as much as expected from the areal extent of the communities, and also disproportionately chose other communities with high sedge components. The presence of sedges was

the predominant vegetational characteristic chosen regardless of elevations, with only minor differences between caribou sex and age groupings.

Roth, J. D. 2003. Variability in marine resources affects arctic fox population dynamics. ***Journal of Animal Ecology*** 72:668-676.

<u>*Abstract taken directly from text*</u>

1) Terrestrial predators in coastal areas are often subsidized by marine foods. In order to determine the potential impact on terrestrial prey, the numerical response of predators to each food source must be determined.
2) In winter, arctic foxes (*Alopex lagopus*) may forage on the frozen Arctic ocean and scavenge carcasses of seals killed by polar bears (*Ursus maritimus*), but the importance of this food source and its effect on the population cycles of arctic foxes and lemmings (their primary prey) are unclear.
3) I estimated the marine component of the late winter diet of arctic foxes near Churchill, Manitoba, using stable-carbon isotope analysis, and compared these estimates to abundance of arctic foxes and collared lemmings (*Dicrostonyx richardsoni*).
4) From 1994 to 1997, fox density varied with lemming abundance, but following a decline, fox abundance began increasing before lemmings. During this increase marine foods were consumed more than in other years, with over two-thirds of food intake from marine sources.
5) Arctic and red fox (*Vulpes vulpes*) harvests in the 1980s to 1990s were correlated with published estimates of polar bear body mass, which varies with seal productivity. However, this relationship disappeared during high lemming years.
6) Thus, variation in marine productivity affects arctic fox abundance, especially when their primary prey are scarce, and this numerical response of arctic foxes to marine resources and lemmings suggests that increased predation by arctic foxes subsidized by seal carrion may delay the recovery of low lemming populations.

Schneider, M. F. 2001. Habitat Loss, Fragmentation and Predator Impact: Spatial Implications for Prey Conservation. ***Journal of Applied Ecology*** 38:720-735.

<u>*Abstract taken directly from text*</u>

1) Because predators threaten the survival of endangered prey in many places, predator management is a widespread conservation tool. At the same time, the effects of predators on their prey are greatly influenced by landscape structure. Therefore, the management of landscapes could be an alternative to predator regulation.
2) A spatially explicit presence/absence model (a stochastic one-layer cellular automaton) was used to investigate two different predator-prey systems that were subject to changes in the number and size of habitat patches in a model landscape.
3) The first scenario included grey-sided voles *Clethrionomys rufocanus*, Norwegian lemmings Lemmus lemmus and small mustelids (stoats *Mustela erminea* and weasels *M. nivalis*) interacting in a tundra landscape. In the second scenario, the effect of habitat perforation by human settlements with subsidized predators (house cats *Felis silvestris catus*) on the dynamics of lemmings (as surrogate for endangered prey) was studied.
4) Both the total area of lemming habitat and the degree of fragmentation were important determinants of the population size and persistence of lemmings. A qualitative change in the effect of fragmentation was observed when the area of lemming habitat decreased from 70% (positive effect) to 50% (negative effect). When lemming habitat covered 50% or less of the landscape, fragmentation had a negative effect on lemming population size and viability, even though habitat area did not decrease.
5) The spatial configuration of settlements as predator sources was important. A few evenly spaced predator sources had less negative effect on lemming populations than the same proportion of predator habitat that was randomly distributed, which in turn had less effect than many evenly spaced patches.
6) Including predator management in the model did not decrease the predators' negative impact on the population size and persistence of the endangered prey when settlements occurred in many small patches.

7) It is concluded that predator management is not a viable strategy to combat the threat to the survival of endangered prey, but that careful planning of landscape pattern could compensate for negative predation effects. The location and size of patches of predator habitat should be optimized in order to minimize the negative effects of predators visiting adjacent areas of natural habitat.

Szor, G., D. Berteaux and G. Gauthier. 2004. ***Arctic and Red Fox Den Ecology in a Changing Ecosystem: Bylot Island, Nunavut***. Poster, Université du Québec à Rimouski and Université Laval.

Abstracts [excerpts directly from text]

Red foxes are invading high arctic ecosystems and could represent an important threat to arctic foxes. A better understanding of the requirements of each species and a monitoring of this community is essential in the context of a warming climate. Objectives of this study were to determine the current status of the fox community on Bylot Island, and establish a monitoring protocol in collaboration with Sirmilik Canada national park, and to be better understand the process leading to den site choice by arctic foxes and identify characteristics selected when choosing a den site. A den survey was conducted in the summer of 2003, and each den found is now visited every summer to identify dens used for reproduction, number of litter and average for each fox species. Out of the 100 identified dens, only 1 has been used by red foxes for reproduction compared to 29 by red foxes. The poster concludes that the abundance of red foxes is low on Bylot Island, but their choice of reproductive dens seems to be similar to that of arctic foxes. Monitoring of the fox community is therefore essential to detect potential impacts on arctic fox populations.

Tesar, C. 2007. What Price the Caribou? ***Northern Perspectives*** 31:1-40. Published by the Canadian Arctic Resources Committee, www.carc.org.

Abstract not available [excerpts directly from text]

The disappearing caribou in the Northwest Territories (NWT) have people anxious. Some herds have declined by thousands, some by hundreds of thousands over the past twenty years. Everywhere in the central Arctic, the trend seems to be the same – fewer caribou. This is not just a matter of concern for people living in that region, especially indigenous people. It is a matter of real hardship, economic, cultural, social and spiritual. In January 2007, the Government of the Northwest Territories brought together about 170 delegates in Inuvik, near the Arctic coast of the Northwest Territories, for a ‘Caribou Summit’, the first gathering of its kind. The indigenous delegates met for two-and-a-half days, together with a few experts, and representatives of other sections of society, including a delegate from CARC. The delegates discussed, listened, and put together strategies that they hope will assist the recovery of the caribou of the caribou herds, and also limit human hardships. These strategies have now gone to the Government of the Northwest Territories, in the hope that they, together with other northern governments and the Canadian Government, can find ways to put them into action.

Canadian Arctic Resources Committee. 2007. Top Twenty Policy Steps for Dealing with Dwindling Caribou. Northern Perspectives. 3 pp.

Abstract not available [excerpts directly from text]

The disappearing caribou in the Northwest Territories (NWT) have people anxious – very anxious. Some herds have declined by thousands, some by hundreds of thousands over the past twenty years. Everywhere in the central Arctic, the trend seems to be the same – fewer caribou. This is not just a matter of concern for people living in that region, especially indigenous people. It is a matter of real hardship, economic, cultural, social and spiritual. The lives of the indigenous peoples of the region have been bound up with caribou for thousands of years. Some believe that in every human heart is a little of the caribou heart, and in every caribou, a little of the human heart. This is not the first time the caribou have declined. Indigenous peoples’ stories and scientific evidence both suggest that caribou herds here hit a low about every thirty years. This is thought to be linked to the effect of climate and caribou populations on lichens, the plants that are the main winter food of the caribou. But things have changed in the Northwest Territories over the past thirty years. There are more people, and more roads. There is new technology being used to help hunters, including tracking of radio-collared caribou that has been posted on the Internet. There are new mines on the barrens, with more planned. Perhaps most importantly, the climate is changing, that changes snow conditions, forest fires, and plant growth. In January 2007, the Government of the Northwest Territories brought together about 170 delegates in Inuvik, near the Arctic coast of the Northwest Territories, for a ‘Caribou Summit’, the first gathering of its kind. The indigenous delegates met for two-and-a-half days, together with a few experts, and representatives of other sections of society, including a delegate from CARC. The delegates discussed, listened, and put together strategies that they hope will assist the recovery of the caribou of the caribou herds, and also limit human hardships. These strategies have now gone to the Government of the Northwest Territories,

Turchin, P., L. Oksanen, P. Ekerholm, T. Oksanen and H. Henttonen. 2000. Are lemmings prey or predators? ***Nature*** 405:562-565.

Abstract taken directly from text

Large oscillations in the populations of Norwegian lemmings have mystified both professional ecologists and lay public[1-3]. Ecologists suspect that these oscillations are driven by a trophic mechanism[4,5]: either an interaction between lemmings and their food supply, or an interaction between lemmings and their predators. If lemming cycles are indeed driven by a trophic interaction, can we tell whether lemmings act as the resource (`prey') or the consumer (`predator')? In trophic interaction models, peaks of resource density generally have a blunt, rounded shape, whereas peaks of consumer density are sharp and angular. Here we have applied several statistical tests to three lemming datasets and contrasted them with comparable data for cyclic voles. We find that vole peaks are blunt, consistent with their cycles being driven by the interaction with predators. In contrast, the shape of lemming peaks is consistent with the hypothesis that lemmings are functional predators, that is, their cycles are driven by their interaction with food plants. Our findings suggest that a single mechanism, such as interaction between rodents and predators, is unlikely to provide the `universal' explanation of all cyclic rodent dynamics.

Walton, L. R., H. D. Cluff, P. C. Paquet and M. A. Ramsay. 2001. Movement Patterns of Barren-Ground Wolves in the Central Canadian Arctic. ***Journal of Mammalogy*** 82:867-876.

Abstract taken directly from text

We collected information on the movement patterns of wolves (*Canis lupus*) captured within a 30,000-km^2 area in the Northwest Territories and western Nunavut. Currently, diamond mining and road construction are occurring in the area used by these migratory wolves for denning. During summers of 1997 and 1998, 23 wolves in 19 different packs were captured and fitted with collar-mounted satellite transmitters. Areas used by these wolves varied seasonally and seemed to correspond to movements of migratory caribou (*Rangifer tarandus*). Annual home-range sizes (95% minimum convex polygon), averaged 63,058 km^2 ± 12,836 SE for males and 44,936 ± 7,564 km^2 for females. Wolves began to restrict movements around a den site on the tundra by late April. They did not depart from their summer ranges until late October, after which they followed caribou to their wintering grounds. Straight-line distances from the most distant location on the winter range to the den site averaged 508 ± 26 km during 1997-1998 and 265 ± 15 km in 1998-1999 ($P < 0.01$). Home range in summer averaged 2,022 ± 659 km^2 for males and 1,130 ± 251 km^2 for females. No difference was detected between sexes or years. All but 2 of 15 wolves returned to <25 km of a previous den, and 2 wolves returned to the same den site. We believe that human activities that disturb or displace denning wolves, or that alter the distribution or timing of caribou movements, will have negative effects on reproductive success of wolves.

Watson, A. 1956. Ecological Notes on the Lemmings *Lemmus trimucronatus* and *Dicrostonyx groenlandicus* in Baffin Island. ***Journal of Animal Ecology*** 25:289-302.

Abstract taken directly from text

During the summer of 1953, the two species of lemmings *Lemmus trimucronatus* and *Dicrostonyx groenlandicus** were common in parts of S. Baffin Island, in eastern Arctic Canada. The following notes were made on the 1953 Baird Expedition which worked from May to September in Cumberland Peninsula on the east side of the island. The central area was at about 67" N in the Penny Highlands which contain the highest mountains of Baffin Island. The biological base was 'Bio. Camp', at 180 m in Owl Valley. The valley floor, here 2-3 km wide, was very flat, banked on either side by steep mountains and ice caps rising to 1500-1800 m. This was the northern section of Pangnirtung Pass, which cuts for 100 km across the mountain belt of the peninsula. Base Camp was situated at its summit at 400 m. The southern part of the Pass, named Weasel Valley, led to a fjord and the settlement of Pangnirtung. Owl Valley was blocked to the west by the Penny Ice Cap (6000 sq. km) rising to 2000 m. To the east, two high passes cut through the mountains to the valleys June and Naksakjua, and from there to Padle Valley. This led to the east coastal fjords around Padloping Island which were visited by sledge in the early summer. There is a brief account of the climate, vegetation and topography of this area in Baird (1953). In Cumberland Peninsula lemmings were common in all the areas visited except on the outer coast around Padloping. They were also abundant at Frobisher Bay (Sutton 1954) and in parts of Banks Island in western Arctic Canada (T. H. Manning, in litt.), and were reported plentiful at Clyde River, in N.E. Baffin.

Wildlife Fact Sheets: Arctic Fox. Undated. Government of Nunavut.

Abstract
This fact sheet gives information on *Alopex lagopus*, or the Arctic Fox, including facts about its appearance, range, habitat, reproduction, survival status, and any management related to this species. Information about its behaviour is also provided.

Wildlife Fact Sheets: Arctic Hare. Undated. Government of Nunavut.

Abstract
This information sheet provides facts about the appearance, food and feeding, behaviour, habitat, range, and status of the Arctic Hare (*Lepus arcticus*).

Wildlife Fact Sheets: Barren Ground Grizzly. Undated. Government of Nunavut.

Abstract
This fact sheet has information about what the grizzly bear (*Ursus arctos*). This includes what it eats, where it is found, reproduction facts, and its survival status.

Wildlife Fact Sheets: Brown Lemming. Undated. Government of Nunavut.

Abstract
Range, reproduction, habitat, appearance, behaviour, and species status information about the brown lemming (*Lemmus trimucronatus*) are summarized in this fact sheet.

Wildlife Fact Sheets: Ermine. Undated. Government of Nunavut.

Abstract
Information on the ermine (*Mustela erminea*) and its appearance, behaviour, range, habitat, food, reproduction, and survival status are found in this fact sheet.

Wildlife Fact Sheets: Grey Wolf. Undated. Government of Nunavut.

Abstract
Arctic wolves (*Canis lupis*) are the topic of this information sheet. General information of where they are found, what they eat, what they look like, how many of them there are, and how they behave are given.

Wildlife Fact Sheets: Ground Squirrel. Undated. Government of Nunavut.

Abstract
This fact sheet provide information on *Spermophilus parryii*, or the arctic ground squirrel, including where it is found, what is eats, when it breeds, and its appearance and behaviour. It also has information of its survival status.

Wildlife Fact Sheets: Least Weasel. Undated. Government of Nunavut.

Abstract
The least weasel (*Mustela nivalis*), and its appearance, behaviour, reproduction, food, habitat, range, and species status, are described in this fact sheet.

Wildlife Fact Sheets: Muskox. Undated. Government of Nunavut.

Abstract
The appearance, range, habitat, behaviour, reproduction, food sources, and species survival status of the muskox (*Ovibos moschatus*) are described in this fact sheet.

Wildlife Fact Sheets: Peary Land Collared Lemming. Undated. Government of Nunavut.

Abstract
The Peary land collared lemming (*Dicrostonyx groenlandicus*) and its feeding, reproductive, behavourial, range, and habitat information are provided in this fact sheet, as well as its species status. There is also a brief section on other lemmings found in parts of Nunavut.

Wildlife Fact Sheets: Polar Bear. Undated. Government of Nunavut.

Abstract
The polar bear (*Ursus maritimus*) is the largest of all bears. Information of this bear, including its species status, management, behaviour, reproduction, feeding, habitat and range, supplied in this literature.

Wildlife Fact Sheets: Red Fox. Undated. Government of Nunavut.

Abstract
The red fox (*Vulpes vulpes*) and its range, behaviour, reproduction, food, habitat, and appearance information, as well as its species status, is in this fact sheet.

Wildlife Fact Sheets: Wolverine. Undated. Government of Nunavut.

Abstract
The range, habitat, behaviour, food, appearance, and reproduction of the wolverine (*Gulo gulo*) are described in this fact sheet. Also, there is some information on the monitoring program of wolverines in parts of Nunavut, and its species survival status.

2.5.4 Habitat Suitability Modelling

Akcakaya, H. R. 2001. Linking population-level risk assessment with landscape and habitat models. ***Science of the Total Environment*** 274:283-291.

Abstract taken directly from text
Ecological risk assessment at the population level often involves predicting the effects of a particular change in the land-use patterns on the viability of native species. A common method of addressing such questions is modeling the meta-population dynamics of the species in the landscape. However, the landscape and, as a result, the spatial structure of the meta-population usually do not remain unchanged,

thus the assessment of viability must incorporate the dynamic nature of the landscape. A new link being developed between a meta-population modeling program (RAMAS) and a landscape dynamics program (LANDIS) will allow the transitional dynamics of the landscape to be incorporated into assessment of viability and threat. This approach combines methods of landscape prediction with those of meta-population simulation. The link between the landscape model and meta-population model is provided by statistical models of habitat suitability for the species in focus.

Bender, L. C., G. J. Roloff and J. B. Haufler. 1996. Evaluating Confidence Intervals for Habitat Suitability Models. ***Wildlife Society Bulletin*** 24:347-352.

Abstract taken directly from text
Implicit in the use of wildlife habitat models is the assumption that different habitat ratings reflect differences in habitat quality. Using a gray squirrel habitat suitability index (HSI) model, we compared 6 different habitats within the Huron-Manistee National Forest, Michigan. We assessed variation in the final HSI scores from variation around model input variables using Monte Carlo simulation (parametric bootstrapping) and nonparametric bootstrapping. In our demonstration, HSI scores as divergent as 0.38 and 0.81 did not differ statistically. Habitat modeling should account for variability in HSI scores, as well as indicators of animal response. Modeling attempts that ignore this variability are unlikely to determine whether faulty relationships are a product of the habitat model or result from habitat or animal variation.

British Columbia Ministry of Environment, Lands and Parks. 1999. ***British Columbia Wildlife Habitat Rating Standards (Version 2.0)***. Prepared by Ministry of Environment, Lands and Parks, Resources Inventory Branch for the Terrestrial Ecosystems Task Force, Resources Inventory Committee. 97 pp.

Abstract taken directly from text
This manual provides the minimum provincial standards required for wildlife habitat assessment data collection and for the development and application of wildlife habitat capability and suitability ratings to ecological mapping at scales from 1:250,000 to 1:20,000. Habitat capability and suitability maps are a planning tool for land management decision making. Capability is defined as the ability of the habitat, under the optimal natural (seral) conditions for a species to provide its life requisites, irrespective of the current condition of the habitat. Suitability is defined as the ability of the habitat in its current condition to provide the life requisites of a species. Ratings indicate the value of a habitat to support a particular wildlife species for a specified habitat use compared to the best habitat in the province (the provincial benchmark). Rating criteria are defined for different map scales and different levels of detail. Three rating schemes are presented to address the variable level of knowledge that exists on the habitat requirements of different wildlife species. The level of detail for describing a species' life requisites and seasons of habitat use have also been defined and standardized. A wildlife habitat capability and suitability assessment project requires development of species-habitat models that are ground-truthed and refined through field sampling. Guidelines for developing a final ratings table are provided and standards for coding and formatting these tables are also identified.

Brooks, R. P. 1997. Improving Habitat Suitability Index Models. ***Wildlife Society Bulletin*** 25:163-167.

Abstract not available [with excerpts directly from text]
The use of Habitat Suitability Index (HSI) models and the associated Habitat Evaluation Procedures (HEP) to assess habitat quality for a spectrum of wildlife species is widespread. They are some of the most influential management tools in use. Despite this, it would appear that no further discussion about the process or refinement of HIS models is needed. Articles on HIS are surprisingly scarce, but this is suspected to not be due to a lack of interest. This paper seeks to remedy the situation by describing a series of stages in HIS development that should be recognized. These stages are: development, calibration, verification, and validation. HIS models should be constructed based on a thorough and critical review of the literature.

Burgman, M. A., D. R. Breininger, B. W. Duncan and S. Ferson. 2001. Setting Reliability Bounds on Habitat Suitability Indices. ***Ecological Applications*** 11:70-78.

Abstract taken directly from text

We expressed quantitative and qualitative uncertainties in suitability index functions as triangular distributions and used the mechanics of fuzzy numbers to solve for the distribution of uncertainty around the habitat suitability indices derived from them. We applied this approach to a habitat model for the Florida Scrub-Jay. The results demonstrate that priorities and decisions associated with management and assessment of ecological systems may be influenced by an explicit consideration of the reliability of the indices.

Clevenger, A. P., J. Wierzchowski, B. Chriszcz and K. Gunson. 2002. GIS-Generated, Expert-Based Models for Identifying Wildlife Habitat Linkages and Planning Mitigation Passages. ***Conservation Biology*** 16:503-514.

Abstract taken directly from text

We developed three black bear (*Ursus americanus*) habitat models in the context of a geographic information system to identify linkage areas across a major transportation corridor. One model was based on empirical habitat data, and the other two (opinion- and literature-based) were based on expert information developed in a multi-criteria decision-making process. We validated the performance of the models with an independent data set. Four classes of highway linkage zones were generated. Class 3 linkages were the most accurate for mapping cross-highway movement. Our tests showed that the model based on expert literature most closely approximated the empirical model, both in results of statistical tests and the description of the class 3 linkages. In addition, the expert literature-based model was consistently more similar to the empirical model than either of two seasonal, expert opinion-based models. Among the expert models, the literature-based model had the strongest correlation with the empirical model. Expert-opinion models were less in agreement with the empirical model. The poor performance of the expert-opinion model may be explained by an overestimation of the importance of riparian habitat by experts compared with the literature. A small portion of the empirical data to test the models was from the pre-berry season and may have affected how well the model predicted linkage areas. Our empirical and expert models represent useful tools for resource and transportation planners charged with determining the location of mitigation passages for wildlife when baseline information is lacking and when time constraints do not allow for data collection before construction.

Carroll C., W. J. Zielinski and R. F. Noss. 1999. Using Presence-Absence Data to Build and Test Spatial Habitat Models for the Fisher in the Klamath Region. U.S.A. ***Conservation Biology*** 13:1344-1359.

Abstract not available [excerpts directly from text]

Forest carnivores such as the fisher (*Martes pennanti*) have frequently been the target of conservation concern because of their association in some regions with older forests and sensitivity to landscape-level habitat alteration. Although the fisher has been extirpated from most of its former range in the western United States, it is still found in northwestern California. Fisher distribution, however, is still poorly known in most of this region where surveys have not been conducted. To predict fisher distribution across the region, we created a multiple logistic regression model using data from 682 previously surveyed locations and a vegetation layer created from satellite imagery. A moving-window function in a geographic information system was used to derive landscape-level indices of canopy closure, tree size class, and percent conifer. The model was validated with new data from 468 survey locations. The correct classification rate of 78.6% with the new data was similar to that achieved with the original data set (80.4%). Whereas several fine-scale habitat attributes were significantly correlated with fisher presence, the multivariate model containing only landscape- and regional-scale variables performed as well as one incorporating fine-scale data, suggesting that habitat selection by fishers may be dominated by factors operating at the home-range scale and above. Fisher distribution was strongly associated with landscapes with high levels of tree canopy closure. Regional gradients such as annual precipitation were also significant. At the plot level, the diameter of hardwoods was greater at sites with fisher detections. A comparison of regional fisher distribution with land-management categories suggests that increased emphasis on the protection of biologically productive, low- to mid-elevation forests is important to ensuring the long-term viability of fisher populations.

Debeljak M., S. Dzeroski, K. Jerina, A. Kobler and M. Adamic. 2001. Habitat suitability modelling for red deer (*Cervus elaphus* L.) in South-central Slovenia with classification trees. ***Ecological Modelling*** 138:321-330.

Abstract taken directly from text
We study and assess the potential habitats of a population of red deer in South-central Slovenia. Using existing data on the deer population spatial distribution and size, as well as data on the landscape and ecological properties (GIS) of the area inhabited by this population, we develop a habitat suitability model by automated data analysis using machine learning of classification trees. We assume that the recorded observations of deer approximate the actual spatial distribution of the deer population reasonably well. The habitat suitability models for individual animals have the form of classification trees. The induced trees are interpreted by domain experts and a generic model is proposed. The generic habitat suitability models can help determine potential unoccupied habitats for the red deer population and develop guidelines for managing the development of the red deer population and its influence on the environment.

Dettmers, R. and J. Bart. 1999. A GIS Modeling Method Applied to Predicting Forest Songbird Habitat. ***Ecological Applications*** 9:152-163.

Abstract taken directly from text
We have developed an approach for using "presence" data to construct habitat models. Presence data are those that indicate locations where the target organism is observed to occur, but that cannot be used to define locations where the organism does not occur. Surveys of highly mobile vertebrates often yield these kinds of data. Models developed through our approach yield predictions of the amount and the spatial distribution of good-quality habitat for the target species. This approach was developed primarily for use in a GIS context; thus, the models are spatially explicit and have the potential to be applied over large areas. Our method consists of two primary steps. In the first step, we identify an optimal range of values for each habitat variable to be used as a predictor in the model. To find these ranges, we employ the concept of maximizing the difference between cumulative distribution functions of (1) the values of a habitat variable at the observed presence locations of the target organism, and (2) the values of that habitat variable for all locations across a study area. In the second step, multivariate models of good habitat are constructed by combining these ranges of values, using the Boolean operators "and" and "or." We use an approach similar to forward stepwise regression to select the best overall model. We demonstrate the use of this method by developing species-specific habitat models for nine forest-breeding songbirds (e.g., Cerulean Warbler, Scarlet Tanager, Wood Thrush) studied in southern Ohio. These models are based on species' microhabitat preferences for moisture and vegetation characteristics that can be predicted primarily through the use of abiotic variables. We use slope, land surface morphology, land surface curvature, water flow accumulation downhill, and an integrated moisture index, in conjunction with a land-cover classification that identifies forest/non-forest, to develop these models. The performance of these models was evaluated with an independent data set. Our tests showed that the models performed better than random at identifying where the birds occurred and provided useful information for predicting the amount and spatial distribution of good habitat for the birds we studied. In addition, we generally found positive correlations between the amount of habitat, as predicted by the models, and the number of territories within a given area. This added component provides the possibility, ultimately, of being able to estimate population sizes. Our models represent useful tools for resource managers who are interested in assessing the impacts of alternative management plans that could alter or remove habitat for these birds.

Glenz C., A. Massolo, D. Kuoen and R. Schlaepfer. 2001. A wolf habitat suitability prediction study in Valais (Switzerland). ***Landscape and Urban Planning*** 55:55-65.

Abstract not available [excerpts directly from text]

In recent years, the European wolf (*Canis lupus*) population has expanded its southern range from the Italian Peninsula to the Maritime Alps (Italy and France) and to Piemonte (Italy); establishing small sub-populations. Hence re-colonisation of the Swiss Alps is now likely to occur. In 1995-1996 the wolf reached the southern part of Switzerland (Canton of Valais) from where he got extinct 150 years ago. Actual conflicts of interests between livestock breeders, local political authorities and nature conservation parties, as well as federal authorities defending the protected status of wolf, require serious management investigations. In order to check wolf habitat suitability of an alpine landscape, like the Valais, subjected to dynamic landscape-ecology processes since the extinction of wolf, we present herein an application of a predictive wolf habitat model, using a stochastic model involving logistic regression. As no data were available in the Canton of Valais, the regression coefficients for the retained variables such as urban area, population density, arable land, minimal altitude, northwest exposure and wild ungulate diversity index, were derived from data collected in the northern Apennine (Northern Italy), where habitat variables were related to data of wolf presence. The selection of the parameters for the Canton of Valais has been performed in respect of their predictive power, as well as their availability and geo-morphological importance for the alpine landscape under consideration. Using the geographic information system (GIS), the simulation pointed out that 19% (1142 km^2) of the total grid surface (5821 km^2) are suitable for wolf presence. Moreover, it reveals that especially areas at lower altitudes (minimum altitude < 800-900 m a.s.l.), due to the high anthropic activity, and areas at high altitudes (minimum altitude > 1800-2000 m a.s.l.), due to the lack of prey and sever geo-morphological conditions, present a reduced habitat suitability. The geomorphological and demographic situation of the alpine area lead to a wolf habitat of a partially fragmented and linear aspect, affecting overall habitat suitability. The strengths of the application is not only the visualization of the present habitat quality of an alpine landscape re-colonised by wolves, but also that it allows to make investigations in order to manage the different conflicts of interest.

Guisan, A. and W. Thuiller. 2005. Predicting species distribution: offering more than simple habitat models. ***Ecology Letters*** 8:993-1009.

Abstract taken directly from text

In the last two decades, interest in species distribution models (SDMs) of plants and animals has grown dramatically. Recent advances in SDMs allow us to potentially forecast anthropogenic effects on patterns of biodiversity at different spatial scales. However, some limitations still preclude the use of SDMs in many theoretical and practical applications. Here, we provide an overview of recent advances in this field, discuss the ecological principles and assumptions underpinning SDMs, and highlight critical limitations and decisions inherent in the construction and evaluation of SDMs. Particular emphasis is given to the use of SDMs for the assessment of climate change impacts and conservation management issues. We suggest new avenues for incorporating species migration, population dynamics, biotic interactions and community ecology into SDMs at multiple spatial scales. Addressing all these issues requires a better integration of SDMs with ecological theory.

Hirzel, A. and A. Guisan. 2002. Which is the optimal sampling strategy for habitat suitability modeling? ***Ecological Modelling*** 157:331-341.

Abstract taken directly from text

Designing an efficient sampling strategy is of crucial importance for habitat suitability modelling. This paper compares four such strategies, namely, ‘random’, ‘regular’, ‘proportional-stratified’ and ‘equal-stratified’ to investigate (1) how they affect prediction accuracy and (2) how sensitive they are to sample size. In order to compare them, a virtual species approach (Ecol. Model. 145 (2001) 111) in a real landscape, based on reliable data, was chosen. The distribution of the virtual species was sampled 300 times using each of the four strategies in four sample sizes. The sampled data were then fed into a GLM to make two types of prediction: (1) habitat suitability and (2) presence/ absence. Comparing the predictions to the known distribution of the virtual species allows model accuracy to be assessed. Habitat suitability predictions were assessed by Pearson’s correlation coefficient and presence/absence

predictions by Cohen's k agreement coefficient. The results show the 'regular' and 'equal-stratified' sampling strategies to be the most accurate and most robust. We propose the following characteristics to improve sample design: (1) increase sample size, (2) prefer systematic to random sampling and (3) include environmental information in the design.

Hirzel, A. H., J. Hausser, D. Chessel and N. Perrin. 2002. Ecological-Niche Factor Analysis: How to Compute Habitat-Suitability Maps without Absence Data. ***Ecology*** 83:2027-2036.

Abstract taken directly from text

We propose a multivariate approach to the study of geographic species distribution which does not require absence data. Building on Hutchinson's concept of the ecological niche, this factor analysis compares, in the multidimensional space of ecological variables, the distribution of the localities where the focal species was observed to a reference set describing the whole study area. The first factor extracted maximizes the marginality of the focal species, defined as the ecological distance between the species optimum and the mean habitat within the reference area. The other factors maximize the specialization of this focal species, defined as the ratio of the ecological variance in mean habitat to that observed for the focal species. Eigenvectors and eigenvalues are readily interpreted and can be used to build habitat-suitability maps. This approach is recommended in situations where absence data are not available (many data banks), unreliable (most cryptic or rare species), or meaningless (invaders). We provide an illustration and validation of the method for the alpine ibex, a species reintroduced in Switzerland which presumably has not yet recolonized its entire range.

Hirzel, A. H. and R. Arlettaz. 2003. Modelling Habitat Suitability for Complex Species Distributions by Environmental-Distance Geometric Mean. ***Environmental Management*** 32:614-623.

Abstract taken directly from text

This paper presents a new habitat suitability modeling method whose main properties are as follows: (1) It is based on the density of observation points in the environmental space, which enables it to fit complex distributions (e.g. non-gaussian, bimodal, asymmetrical, etc.). (2) This density modeled by computing the geometric mean to all observation points, which we show to be a good trade-off between goodness of fit and prediction power. (3) It does not need any absence information, which is generally difficult to collect and of dubious reliability. (4) The environmental space is represented either by an expert-selection of standardized variables or the axes of a factor analysis [in this paper we used the Ecological Niche Factor Analysis (ENFA). We first explain the details of the geometric mean algorithm and then we apply it to the bearded vulture (*Gypaetus barbatus*) habitat in the Swiss Alps. The results are compared to those obtained by the "median algorithm" and tested by jack-knife cross-validation. We also discuss other related algorithms (BIOCLIM, HABITAT, and DOMAIN). All these analyses were implemented into and performed with the ecology-oriented GIS software BIOMAPPER 2.0. The results show the geometric mean to perform better than the median algorithm, as it produces a tighter fit to a bimodal distribution of the bearded vulture in the environmental space. However, the "median algorithm" being quicker, it could be preferred when modeling more usual distribution.

Hirzel, A. H., V. Helfer and F. Metral. 2001. Assessing habitat-suitability models with a virtual species. ***Ecological Modelling*** 145:111-121.

Abstract taken directly from text

This paper compares two habitat-suitability assessing methods, the Ecological Niche Factor Analysis (ENFA) and the Generalised Linear Model (GLM), to see how well they cope with three different scenarios. The main difference between these two analyses is that GLM is based on species presence/absence data while ENFA on presence data only. A virtual species was created and then dispatched in a geographic information system model of a real landscape following three historic scenarios: (1) spreading, (2) at equilibrium, and (3) overabundant species. In each situation, the virtual species was sampled and these simulated data sets were used as input for the ENFA and GLM to reconstruct the habitat suitability model. The results showed that ENFA is very robust to the quality and quantity of the data, giving good results in the three scenarios. GLM was badly affected in the case of the spreading species but produced slightly better results than ENFA when the species was overabundant; at equilibrium, both methods produced equivalent results. The use of a virtual species proved to be a very efficient method, allowing one to fully control the quality of the input data as well as to accurately evaluate the predictive power of both analyses.

Johnson, C. and M. Boyce. 2001. ***A Quantitative Approach for Regional Environmental Assessment: Application of a Habitat-Based Population Viability Analysis to Wildlife of the Canadian Central Arctic***. Canadian Environmental Assessment Agency, Research and Development Program, Ottawa, ON.

<u>*Abstract taken directly from text*</u>
During the environmental assessment process, cumulative effects are an important but challenging consideration. The success of cumulative effects analyses is often limited by difficulties in defining the extent and incremental impacts of temporally and spatially disjointed projects, a lack of large-scale strategic guidance, and few standardized methods. We present a set of quantitative tools, collectively known as a habitat-based population viability analysis (PVA), which can contribute to the development of regional environmental assessments (REA), a planning and evaluation process that can improve current practices for project-specific cumulative effects analyses. Habitat-based PVAs are statistical models that incorporate the deterministic changes associated with habitat alteration or development and longer–term, less predictable stochastic (random) fluctuations in population demographics and environment. The approach has a number of advantages, including the following: It provides spatially explicit input and output; It is quantitative, and thus provides measures of precision and uncertainty; It is based on well-established statistical and ecological theory; and It is general enough to accommodate a wide range of valued ecosystem components. We developed a habitat-based PVA for sensitive and valued wildlife of the Canadian central Arctic. Recent discoveries of diamondiferous kimberlite deposits across the Northwest Territories and Nunavut have led to unprecedented levels of mineral exploration and development. The cumulative effects of such activities and others (recreation, oil and gas, road development, etc.) are now an issue of concern for regulatory agencies, conservationists, wildlife managers, and First Nations. Regional planning initiatives are being developed to guide and monitor the rate of industrial development, but few tools are in place to quantify current and future effects.

Jorgensen, E. E., S. Demarais, S. M. Sell and S. P. Lerich. 1998. Modeling Habitat Suitability for Small Mammals in Chihuahuan Desert Foothills of New Mexico. ***Journal of Wildlife Management*** 62:989 996.

<u>*Abstract taken directly from text*</u>
Desert arroyos make up only 2-4% of the desert landscape but may be unique habitat for some wildlife species. Habitat suitability models for small mammals could indicate habitat condition in these uncommon areas and, through monitoring, provide a tool for arid lands wildlife management. During 1993 and 1994, we modeled habitat associations for 18 species of small mammals in 6 habitats associated with desert foothills in the Sacramento Mountains, New Mexico. Habitat associations of small mammals remained relatively consistent through time, although community abundance decreased 34% from spring 1993 to fall 1994. These habitat associations allowed us to use discriminant analysis to model habitat associations based up011 designation of habitat as capable of supporting "high," "moderate." or "low" relative abundance. The procedure successfully classified 80-93% of habitats as supporting "high," "moderate," or "low" abundance of 13 species of heteromyid and murid rodents. Murid rodents (*Peromyscus*, *Reithrodontomys*, *Neotonza*, *Sigmodon*) were found primarily within arroyos where shrub diversity, canopy cover, and height were greatest cornpared to surrounding habitats. The modeling approach described herein should be useful to managers because stochastic temporal change in the relative abundance of small mammals is effectively removed from consideration.

Kapustka, L. A. 2005. Assessing Ecological Risks at the Landscape Scale: Opportunities and Technical Limitations. ***Ecology and Society*** 10(2):11. [online] URL: http://www.ecologyandsociety.org/vol10/iss2/art11/

Abstract taken directly from text
There is a growing awareness that ecological risk assessments (ERAs) could be improved if they made better use of ecological information. In particular, landscape features that determine the quality of wildlife habitat can have a profound influence on the estimated exposure to stressors incurred by animals when they occupy a particular area. Various approaches to characterizing the quality of habitat for a given species have existed for some time. These approaches fall into three generalized categories: (1) entirely qualitative as in suitable or unsuitable, (2) semiquantitative as in formalized habitat suitability index models, or (3) highly quantitative site-specific characterization of population demographic data such as matrix population models or multiple regression models. Such information can be used to generate spatially explicit estimates of exposure to chemicals or other environmental stressors, e.g., invasive species, physical perturbation, that take into account the magnitude of co-occurrence of the animals and stressors as they forage across a landscape. In this way, greater ecological realism is provided in the ERA and more informed management decisions can be attained.

Kliskey, A. D., E. C. Lofroth, W. A. Thompson, S. Brown and H. Schreier. 1999. Simulating and evaluating alternative resource-use strategies using GIS-based habitat suitability indices. ***Landscape and Urban Planning*** 45:163-175.

Abstract taken directly from text
Geographic information system (GIS) based models were developed for mapping the habitat suitability of pine marten (*Martes americana*) and woodland caribou (*Rangifer tarandus)* using habitat suitability indices (HSI). Habitat suitability was simulated for four timber harvesting strategies. These included an existing harvesting strategy and three alternative strategies targeted specifically at maintenance of wildlife habitat and wilderness protection. The alternative strategy that restricted harvesting from some mature-age stands provided the optimal performance in balancing caribou habitat protection and marten habitat protection when compared using multiple accounts analysis. However, the alternative strategy that maximized caribou habitat retention provided the optimal performance in balancing both wildlife and timber objectives when compared using multiple accounts analysis. The approach demonstrates how the use of HSI models can be extended from simple habitat mapping to scenario testing and, coupled with GIS, can assist in the prediction of the outcomes of alternative resource-use scenarios.

Larson, M. A., W. D. Dijak, F. R. Thompson III and J. J. Millspaugh. 2003. Landscape-level Habitat Suitability Models For Twelve Wildlife Species In Southern Missouri. U.S. Forest Service, ***General Technical Report*** NC-233, North Central Research Station, St. Paul, MN. 51 pp.

Abstract not available [excerpts directly from text]
Geographic information systems (GIS) and abundant landscape-level data, often from remote sensing sources, provide new opportunities for biologists to model and evaluate wildlife habitat quality. Models of habitat quality have not been developed for some species, and many existing models could be improved by incorporating updated knowledge of wildlife–habitat relationships and landscape variables such as the spatial distribution of habitat components. Furthermore, landscape analyses and wildlife population priorities are common features of land management decision processes. We developed GIS-based habitat suitability index (HSI) models for 12 terrestrial vertebrate species that represent a range of potential conservation concerns and have diverse habitat requirements. We developed the models for a large, mostly forested area in southern Missouri and similar landscapes. The models are based primarily on tree species, tree age, and ecological land type—variables available in many GIS and vegetation databases. After describing and justifying the models, we applied them to maps of a study area that contained a wide range of tree ages and forest patch sizes. We believe application of the habitat models in this landscape demonstrated that they satisfactorily predict habitat suitability. Readers can download a

Windows-based software program from the Internet (www.ncrs.fs.fed.us/hsi/) to use in implementing the models in other landscapes.

Lenz, R. and D. Peters. 2006. From data to decisions, Steps to an application-oriented landscape research. ***Ecological Indicators*** 6:250-263.

<u>*Abstract taken directly from text*</u>

Six examples are used to illustrate the potential for application-oriented landscape research in bridging human and natural sciences. The paper therefore examines: (i) uncertainty, (ii) data modelling, (iii) the role of scenarios, (iv) the use of process-oriented and participatory methods, (v) the development of an integrative framework. On the way from ''data to decision'' we start with data uncertainty in spatially explicit data. An assessment of critical loads in Southwest Germany in different spatial scales is exemplified, and landscape research should make these data properties as clear and transparent as possible, e.g. with probability maps. In a next step, data modeling techniques like neural nets in a Geographical Information System (GIS) can improve the availability of maps and therefore spatial data-in our second case study we elaborated a synthetic soil map in the German region Hohenlohe out of various other data like geomorphology and elevation, as well as a reference soil map in an adjacent area. This shows how we can better exploit already existing data with new techniques. The third case study continues with genetic algorithms in order to predict the occurrence of species and habitats (here: heathlands) in the Hohenlohe area in Germany, and hence showing further techniques as well as methods in creating potentials and scenarios. How scenarios can be used to translate options from science to society in order to find a future as well as its implications for a landscape is shown in a next case study. Due to general complexity, we finally suggest to use indicators. On top of that, we developed an Information System to run scenarios for future land use in a municipality, and assess indicator values depending on the envisaged future. The Information System was then used in a participatory process, based in our case on a method from social science, in order to achieve high involvement and acceptance of people for decision making. The final step from data to decision is the development of an integrative framework, which we call Environmental Impact Assessment Multi-level Approach. We conclude that under such a framework it should be easier to bridge gaps between human and natural sciences for an application-oriented landscape research.

Loukmas, J. J. and R. S. Halbrook. 2001. A Test of the Mink Habitat Suitability Index Model for Riverine Systems. ***Wildlife Society Bulletin*** 29:821-826.

<u>*Abstract taken directly from text*</u>

Mink (*Mustela vison*) have been proposed as ecological indicators in aquatic systems, yet little is known about their habitat requirements. The United States Fish and Wildlife Service's mink habitat suitability index (HSI) serves as a model to determine suitable mink habitat. To test this model for riverine systems within the Great Lakes region, we selected 18 streams in the Lake Michigan and Lake Superior basins of Wisconsin for habitat assessment. We randomly divided an 8-km reach of each stream into 10 300-m-long segments, and we measured HSI criteria in each segment. Mink activity, measured using track-board surveys and shoreline searches for mink sign, was assumed to indicate habitat preference and was used as the standard comparative measure to evaluate HSI effectiveness. Correlation analyses determined that HSI values were not associated with degree of mink activity (r=-0.09, P=0.729), indicating that the model is not well suited to predict overall habitat suitability in these areas. The primary deficiency of the model was that it did not give appropriate value to some habitats that potentially support available prey populations. Assessment of mink habitat in the Great Lakes basin should be refined to include additional prey-dependent habitat criteria.

Massolo, A. and A. Meriggi. 1998. Factors affecting habitat occupancy by wolves in northern Apennines (northern Italy): a model of habitat suitability. ***Ecography*** 21:97-107.

Abstract taken directly from text

The expansion of the wolf population all over Europe has posed problems on wolf-man coexistence in those areas where the wolf was not present for a long time. Breeding activities are now threatened by high predation on livestock. We investigated the relationship between wolf and its habitat, in order to evaluate wolf habitat suitability and to predict its presence. The study areas covered 3289 km^2. A 23 km^2 grid was used to identify 143 sample squares. For each sample square 58 habitat variables were measured from land-use (1:25 000), and from topographical maps. Wolf presence (4 classes) was assessed by scat collection, direct observations, snow tracking, wolf-howling, and predation records. Univariate and multivariate statistical analyses were carried out to investigated the influence of habitat features on wolf presence. The habitat suitability model was based on two different equations" a dichotomous logistic regression model, and a polytomous one. The first one discriminated between suitable and unsuitable habitats, and its predictions were confirmed in 93% of grouped cases; the second provided predicted values of wolf presence that were concordant with the observed response levels in 82.5% of contrasts. Both models underlined the importance of three factors in determining wold habitat suitability: wild prey abundance, human presence and forest cover.

McGrath, M. T., S. Destefano, R. A. Riggs, L. L. Irwin and G. J. Roloff. 2003. Spatially Explicit Influences on Northern Goshawk Nesting Habitat in the Interior Pacific Northwest. ***Wildlife Monographs*** 154:1-63.

Abstract taken directly from text

We compared northern goshawk (*Accipiter gentilis atricapillus*) nesting habitat within 1 ha of nest sites and at landscape scales of 10, 30, 60, 83, 120, 150, and 170 ha in 4 study areas east of the Cascade Mountains in Oregon and Washington. Our objective was to describe goshawk nesting habitat at biologically relevant scales and to develop models capable of assessing the effects of forest management alternatives on habitat suitability. We evaluated habitat at 82 active goshawk nests and 95 random sites. Productivity (young fledged per nest) was evaluated at 81 nests. Our ability to discriminate goshawk nest sites from available habitat decreased as landscape scale increased, and different factors influenced goshawks at different scales. The presence and arrangement of forest structural types interacted to influence site suitability for nesting. At the 1-ha scale, the stage of stand development (i.e., stand initiation, stem exclusion, understory re-initiation, old growth), low topographic position, and tree basal area reliably discriminated between nests and random sites. Low topographic position and basal al-ea were more influential than stand structure. At the landscape scale, modeling indicated that conditions at different scales interact to influence selection of habitat for nesting. .4 core area exists surrounding goshawk nests in which stem exclusion and understory re-initiation stands with canopy closure 250% serve as apparent protection against potentially detrimental effects associated with more open forest (e.g., predators and micro-climate). Among several models tested, the model that best discriminated between nests and random sites encompassed 83 ha surrounding the nest and incorporated habitat characteristics from multiple scales nested within that range. We conclude that (1) northern goshawk nesting habitat becomes less distinguishable from the landscape with increasing area, and (2) habitat management based on exclusionary buffers should be re-evaluated in light of the way different habitat factors interact across spatial scales.

Mendoza, G. A. 1997. ***A GIS-Based Multicriteria Approaches to Land Use Suitability Assessment and Allocation***. Seventh Symposium on Systems Analysis in Forest Resources, Department of Natural Resources and Environmental Sciences, University of Illinois, Urbana.

Abstract taken directly from text

Land suitability assessment in a Geographic Information System (GIS) environment is formulated as a multi-criteria decision making (MCDM) problem. Different MCDM approaches are developed to combine factors in a suitability analysis of land for potential land uses. These MCDM approaches are used to develop a generic suitability index. Approaches include both qualitative and quantitative techniques. Results from the MCDM analysis are then linked to a GIS for more detailed spatial analysis. Besides land suitability evaluation, an MCDM framework is also developed for land use allocation. The framework

captures the multi-criteria nature of land suitability analysis and at the same time allocates land by maximizing the overall suitability of a land area.

Mladenoff, D. J., T. A. Sickley and A. P. Wydeven. 1999. Predicting Gray Wolf Landscape Recolonization: Logistic Regression Models vs. New Field Data. ***Ecological Applications*** 9:37-44.

Abstract taken directly from text
Recovery of populations of wolves (*Canis lupus*) and other large, wide-ranging carnivores challenges conservation biologists and resource managers because these species are not highly habitat specific, move long distances, and require large home ranges to establish populations successfully. Often, it will be necessary to maintain viable populations of these species within mixed-use landscapes; even the largest parks and reserves are inadequate in area. Spatially delineating suitable habitat for large carnivores within mixed, managed landscapes is beneficial to assessing recovery potentials and managing animals to minimize human conflicts. Here, we test a predictive spatial model of gray wolf habitat suitability. The model is based on logistic regression analysis of regional landscape variables in the upper Midwest, United States, using radio-telemetry data collected on re-colonizing wolves in northern Wisconsin since 1979. The model was originally derived from wolf packs radio-collared from 1979 to 1992 and a small test data set of seven packs. The model provided a 0.5 probability cut level that best classified the landscape into favorable (road density < 0.45 km/km^2) and unfavorable habitat (road density > 0.45 km/km^2) and was used to map favorable habitat with the northern Great Lake states of Wisconsin, Minnesota, and Michigan. Our purpose here is to provide a better validation test of the model predictions based on data from new packs colonizing northern Wisconsin from 1993 to 1997. In this test, the model correctly classified 18 of 23 newly established packs into favorable areas. We used compositional analysis to assess use of the original habitat probability classes by wolves in relation to habitat class availability. The overall rank of habitat preference classes (P, the percentage favorability from the original model), based on the new packs, was probability class 2 (P = 75-94%) > 3 (P = 50-74%) > 1 (P = 95-100%) > 4 (P = 25-49%) > 5 (P = 10-24%) > 6 (P = 0-9%). As more of the landscape becomes occupied by wolves, classes of lower probability than the 95% class, but above the favorability cut level, are slightly more favored. The 95% class is least abundant on the landscape and is usually associated with larger areas of classes 2 and 3. Wolves may continue to occupy areas of slightly lower habitat probability if adequate population source areas are present to offset the greater mortality in these lower quality areas. The model remains quite robust at predicting areas most likely to be occupied by wolves colonizing new areas based on generally available road network data. The model has also been applied to estimate the amount and spatial configuration of potential habitat in the northeastern United States.

Naugle, D. E., K. F. Higgins, M. E. Estey, R. R. Johnson and S. M. Nusser. 2000. Local and Landscape-Level Factors Influencing Black Tern Habitat Suitability. ***Journal of Wildlife Management*** 64:253-260.

Abstract taken directly from text
Wetlands throughout eastern South Dakota were surveyed (1995-97) for foraging and nesting black terns (*Chlidonias niger*) to evaluate local and landscape factors influencing habitat suitability. We surveyed 834 randomly selected, semi-permanent, and seasonal wetlands that were stratified by physiographic domain, wetland density, and wetland surface area. A discriminant function model was used in a geographic information system (GIS) to classify habitat suitability of all semi-permanent wetlands in eastern South Dakota. We calculated number of suitable, protected wetlands by combining wetlands with easement and fee-title tracts in the GIS. Black terns nested in 7.8% and foraged in an additional 17.9% of semipermanent wetlands. Significant variables in the discriminant function were wetland area, total semipermanent wetland area within the wetland complex, and grassland area in the upland matrix. Black terns were an area-dependent species that occupied large (x = 18.9 ha) wetlands located within high-density wetland complexes. Black terns typically occurred in wetlands within landscapes where <50 % of upland grasslands were tilled. Classification rates were high (76-l00%), indicating that the model identified unsuitable wetlands using wetland area and landscape-level attributes. Characteristics of entire

landscapes must be considered in habitat assessments because wetlands that do not correspond to landscape-scale habitat requirements may not be suitable despite favorable local conditions. Lower correct classification rates (22-78%) for occupied ~onds indicated that suitability also is dependent on local conditions for wetlands which correspond to habitat requirements from a landscape perspective. Suitable black tern nest sites occurred within regenerating or degenerating wetlands where vegetation structure rather than species of vegetation dictated suitability of nest substrates. Wetland acquisition programs have protected 44% of wetlands suitable for black terns. Future wetland acquisitions should maintain the integrity of entire prairie landscapes in additional to attributes of individual wetlands.

Oja, T., K. Alamets and H. Parnamets. 2005. Modelling bird habitat suitability based on landscape parameters at different scales. ***Ecological Indicators*** 5:314-321.

Abstract taken directly from text
Habitat suitability as characterized by the presence of a species and by reproductive success was modelled in relation to different parameters of landscape diversity at different scales. Parameters characterizing landscape pattern were determined for the UTM 10 km × 10 km cells covering the whole of Estonia and were correlated to the distribution of over 30 forest bird species. The landscape parameters include areas of lakes, mires and built-up areas, length of borders between different land cover units and length of selected line elements, share of different kinds of forest and peatland. The bird species are grouped by correlation into three major groups: (a) independent, (b) wetland preferring (with subgroups of those avoiding built-up areas and roads and those not) and (c) built-up area dependent (with subgroups depending on the importance of line elements). For selected predator species, nesting success was related to landscape parameters on a finer scale, using cells of 10 km^2. Land pattern was characterized by total length of line elements (streams, roads, borders, ecotones) and certain areal coverage (forest, mires, fields, built-up areas) within the cell. The impact of variations of food availability was linked to the relation. Possibilities for downscaling and upscaling of relations determined at different scales and areal coverage are discussed.

Osborne, P. E., J. C. Alonso and R. G. Bryant. 2001. Modelling landscape-scale habitat use using GIS and remote sensing: a case study with great bustards. ***Journal of Applied Ecology*** 38:458-471.

Abstract taken directly from text
1) Many species are adversely affected by human activities at large spatial scales and their conservation requires detailed information on distributions. Intensive ground surveys cannot keep pace with the rate of land-use change over large areas and new methods are needed for regional-scale mapping.
2) We present predictive models for great bustards in central Spain based on readily available advanced very high resolution radiometer (AVHRR) satellite imagery combined with mapped features in the form of geographic information system (GIS) data layers. As AVHRR imagery is coarse-grained, we used a 12-month time series to improve the definition of habitat types. The GIS data comprised measures of proximity to features likely to cause disturbance and a digital terrain model to allow for preference for certain topographies.
3) We used logistic regression to model the above data, including an autologistic term to account for spatial autocorrelation. The results from models were combined using Bayesian integration, and model performance was assessed using receiver operating characteristics plots.
4) Sites occupied by bustards had significantly lower densities of roads, buildings, railways and rivers than randomly selected survey points. Bustards also occurred within a narrower range of elevations and at locations with significantly less variable terrain.
5) Logistic regression analysis showed that roads, buildings, rivers and terrain all contributed significantly to the difference between occupied and random sites. The Bayesian integrated probability model showed an excellent agreement with the original census data and predicted suitable areas not presently occupied.
6) The great bustard's distribution is highly fragmented and vacant habitat patches may occur for a variety of reasons, including the species' very strong fidelity to traditional sites through conspecific attraction. This may limit re-colonization of previously occupied sites.

7) We conclude that AVHRR satellite imagery and GIS data sets have potential to map distributions at large spatial scales and could be applied to other species. While models based on imagery alone can provide accurate predictions of bustard habitats at some spatial scales, terrain and human influence are also significant predictors and are needed for finer scale modelling.

Otis, D. L. 1997. Analysis of Habitat Selection Studies with Multiple Patches within Cover Types. ***Journal of Wildlife Management*** 61:1016-1022.

Abstract taken directly from text

Current statistical methods are inadequate for evaluation of the relation between spatial pattern of the landscape and observed patterns of habitat use by individuals or populations. For example, traditional habitat selection analysis methods do not use information about the size and distribution of the several patches of each cover type that may exist within the study area. Statistical tests are presented for hypotheses about disproportional use of cover types and patches within cover types. These tests require that use of individual patches is recorded, as well as the size of individual patches. Different designs are considered in which there are (1)single or multiple samples of use, and (2) equal or unequal habitat availability. Formulas for calculating Type II statistical errors of the tests are presented and Monte Carlo simulation is used to assess the accuracy of the formulas and to check the Type I error rates of the proposed test statistics. With adequate sample sizes, Type II error formulas can be a useful tool for planning of habitat selection studies. An example analysis is presented of a hypothetical study of habitat selection by ring-necked pheasants *(Phasianus colchicus)* in a Midwestern landscape. The proposed tests also represent a contribution toward bringing together concepts of landscape ecology and wildlife habitat selection.

Romero-Calcerrada, R. and S. Luque. 2006. Habitat quality assessment using Weights-of-Evidence based GIS modelling: The case of *Picoides tridactylus* as species indicator of the biodiversity value of the Finnish forest. ***Biological Modelling*** 196:62-76.

Abstract taken directly from text

Biodiversity issues have gained importance in forestry as a result of the increased awareness of forest landscape changes, but still there is much to do before forest management meets reasonable goals for forest protection and renewal of biodiversity. In this work, we focus on boreal forest landscapes, using Finland as a case study, and taking advantage of a valuable database—the National Forest Inventory (NFI). We explore a multi-criteria approach by using a predictive habitat suitability model for three-toed woodpecker (*Picoides tridactylus*) based on Weights-of-Evidence (WofE) and a combination of remote sensing and field data derived from the Multisource Finnish National Forest Inventory (MS-NFI). The WofE model is a quantitative method used for combining evidence to examine the support for a given hypothesis. WofE involves the estimation of a response variable (favourability for certain habitat occurrence) and a set of predictor variables (e.g. GIS layers containing environmental variables).WofE is based on a log-linear form of Bayes' rule and uses the prior probability distribution and the likelihood of the data to generate a posterior probability distribution. Very few examples exist of WofE being used to predict the spatial distribution of species or communities using biophysical descriptors. This work explores WofE as a tool for rapid biodiversity assessment using geo-referenced species information. Since the method is dependent of the indicator species used as a surrogate of biodiversity value it can be applied for assessing biodiversity conditions of both managed and protected areas to help decision-making concerning protection of valuable habitats. Thus, the map of habitat suitability, represented as a range of probabilities of occurrence, offers an objective framework for evaluating the outcomes of different scenarios. Similarly, an objective assessment of habitat suitability provides a rational basis for management decisions incorporating impact on species habitat.

Schadt, S., E. Revilla, T. Wiegand, F. Knauer, P. Kaczensky, U. Breitenmoser, L. Bufka, J. Cerveny, P. Koubek, T. Huber, C. Stanisa and L. Trepl. 2002. Assessing the suitability for the reintroduction of Eurasian lynx. ***Journal of Applied Ecology*** 39:189-203.

Abstract taken directly from text

1) After an absence of almost 100 years, the Eurasian lynx *Lynx lynx* is slowly recovering in Germany along the German–Czech border. Additionally, many reintroduction schemes have been discussed, albeit controversially, for various locations. We present a habitat suitability model for lynx in Germany as a basis for further management and conservation efforts aimed at re-colonization and population development.
2) We developed a statistical habitat model using logistic regression to quantify the factors that describe lynx home ranges in a fragmented landscape. As no data were available for lynx distribution in Germany, we used data from the Swiss Jura Mountains for model development and validated the habitat model with telemetry data from the Czech Republic and Slovenia. We derived several variables describing land use and fragmentation, also introducing variables that described the connectivity of forested and non-forested semi-natural areas on a larger scale than the map resolution.
3) We obtained a model with only one significant variable that described the connectivity of forested and non-forested semi-natural areas on a scale of about 80 km^2. This result is biologically meaningful, reflecting the absence of intensive human land use on the scale of an average female lynx home range. Model testing at a cut-off level of $P > 0{\cdot}5$ correctly classified more than 80% of the Czech and Slovenian telemetry location data of resident lynx. Application of the model to Germany showed that the most suitable habitats for lynx were large-forested low mountain ranges and the large forests in East Germany.
4) Our approach illustrates how information on habitat fragmentation on a large scale can be linked with local data to the potential benefit of lynx conservation in central Europe. Spatially explicit models like ours can form the basis for further assessing the population viability of species of conservation concern in suitable patches.

Schulte, L. A., A. M. Pidgeon and D. J. Mladenoff. 2005. One Hundred Fifty Years of Change in Forest Bird Breeding Habitat: Estimates of Species Distributions. ***Conservation Biology*** 19:1944-1956.

Abstract taken directly from text

Evaluating bird population trends requires baseline data. In North America the earliest population data available are those from the late 1960s. Forest conditions in the northern Great Lake states (U.S.A.), however, have undergone succession since the region was originally cut over around the turn of the twentieth century, and it is expected that bird populations have undergone concomitant change. We propose pre-Euro-American settlement as an alternative baseline for assessing changes in bird populations. We evaluated the amount, quality, and distribution of breeding bird habitat during the mid-1800s and early 1990s for three forest birds: the Pine Warbler (*Dendroica pinus*), Blackburnian Warbler (*D. fusca*), and Black-throated Green Warbler (*D. virens*). We constructed models of bird and habitat relationships based on literature review and regional data sets of bird abundance and applied these models to widely available vegetation data. Original public-land survey records represented historical habitat conditions, and a combination of forest inventory and national land-cover data represented current conditions. We assessed model robustness by comparing current habitat distribution to actual breeding bird locations from the Wisconsin Breeding Bird Atlas. The model showed little change in the overall amount of Pine Warbler habitat, whereas both the Blackburnian Warber and the Black-throated Green Warbler have experienced substantial habitat losses. For the species we examined, habitat quality has degraded since presettlement and the spatial distribution of habitat shifted among ecoregions, with range expansion accompanying forest incursion into previously open habitats or the replacement of native forests with pine plantations. Sources of habitat loss and degradation include loss of conifers and loss of large trees. Using widely available data sources in a habitat suitability model framework, our method provides a long-term analysis of change in bird habitat and a presettlement baseline for assessing current conservation priority.

Sergio, F., L. Marchesi and P. Pedrini. 2004. Integrating individual habitat choices and regional distribution of a biodiversity indicator and top predator. ***Journal of Biogeography*** 32:619-628.

Abstract taken directly from text

Aim: Habitat selection studies have mainly focused on behavioural choices of individuals or on the habitat-related regional distribution of a population, with little integration of the two approaches. This is

despite the fact that traditional biogeography theory sees the geographical distribution of a species as the collective outcome of the adaptive habitat choices of individuals. Here, we integrate individual habitat choices with regional distribution through a bottom-up Geographical Information System (GIS)-based approach, by using a 9-year data set on a large avian predator, the eagle owl (Bubo bubo L.). We further examine the potential population level and biodiversity consequences of this approach. Location The study was conducted in the Trento Region (central-eastern Italian Alps) and in six other areas of the nearby Lombardia Region in the central Alps.

Methods: We used stepwise logistic regression to build a habitat suitability model discriminating between eagle owl territories and an equal number of random locations. The model was applied to the whole Trento region by means of a GIS so as to predict suitable habitat patches. The predicted regional distribution (presence–absence in 10-km grid quadrats) was then compared with the observed one. Furthermore, we compared estimates of biodiversity in quadrats with and without eagle owls, so as to test whether the presence of this top predator may signal macro-areas of high biodiversity.

Results: The logistic habitat suitability model showed that, compared with a random distribution, eagle owls selected low-elevation breeding sites with high availability of prey-rich habitats in their surroundings. Breeding performance increased with the availability of prey-rich habitats, confirming the adaptiveness of the detected habitat choices. We applied the habitat suitability model to the 6200 km^2 study region by means of a GIS and found a close fit between the observed and predicted regional distribution. Furthermore, population abundance was positively related to the availability of habitat defined as suitable by the above analyses. Finally, high biodiversity levels were associated with owl presence and with the amount of suitable owl habitat, demonstrating that modelling habitat suitability of a properly chosen indicator species may provide key conservation information at the wider ecosystem level.

Main conclusions: Our bottom-up modelling approach may increase the conservation-value of habitat selection models, by (1) predicting local and regional distribution, (2) estimating regional population size, (3) stimulating further hypothesis testing, (4) forecasting the population effects of future habitat loss and degradation and (5) aiding in the identification and prioritization of high biodiversity areas.

Store, R. and J. Jokimaki. 2003. A GIS-based multi-scale approach to habitat suitability modeling. ***Ecological Modelling*** 169:1-15.

Abstract taken directly from text

The aim of this study is to develop a method by means of which it is possible to produce geo-referenced ecological information about the habitat requirements of different species. The integrated habitat suitability index approach includes the steps of constructing habitat suitability models, producing data needed in models, evaluating of target areas based on habitat factors, and combining various suitability indices. The method relies on the combined use of empirical evaluation models and models based on expertise in geographical information system (GIS) environment. GIS was used to produce the data needed in the models, and as a platform to execute the models and to present the results of the analysis. Furthermore, multi-criteria evaluation methods (MCEs) provide the technical tools for modeling the expertise and for connecting (standardizing, weighting, and combining) the habitat needs of different species. The main advantages of the method were connected to possibilities to consider the habitat factors on different scales, to combine habitat suitability evaluations for several species and to weight different species in different ways, and to integrate empirical models and expert knowledge. The method is illustrated by a case study in which an integrated habitat suitability map is produced for a group of old-forest species.

Store, R. and J. Kangas. 2001. Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling. ***Landscape and Urban Planning*** 55:79-93.

Abstract taken directly from text

GIS data processing and spatial analysis, together with modern decision analysis techniques, were used in this study to improve habitat suitability evaluation over large areas. Both empirical evaluation models and models based on expert knowledge can be applied to this approach. The habitat requirements of species were described as map layers within GIS so that each map layer represented one criterion. GIS was used as the platform in managing, combining and displaying the criterion data and also as a tool for producing new data, especially by utilizing spatial analysis functions. Criterion standardization, weighting and combining were accomplished by means of multi-criteria evaluation (MCE) methods, the theoretical background being based on the multi-attribute utility theory (MAUT). By using continuous priority and sub-priority functions in the evaluation, no classification of continuous attributes was needed and also non-linear relationships between habitat suitability and the attributes could be considered. Sensitivity analysis was applied to consider the temporal factor in the analysis and to find out the effect of different criteria weights on the spatial pattern of the suitability index. Changing the weights of permanent factors such as soil properties define the habitat potential, which is important to take into consideration; e.g. in forest management planning and species conservation. The method is illustrated by a case study in which habitat suitability maps were produced for an old-forest polypore, *Skeletocutis odora*.

Tikkanen, O.-P., T. Heinonen, J. Kouki and J. Matero. 2007. Habitat suitability models of saproxylic red-listed boreal forest species in long-term matrix management: Cost-effective measures for multi-species conservation. ***Biological Conservation*** 140:359-372.

Abstract taken directly from text

Understanding of how a large landscape or network of conservation areas and habitats of red-listed species change in time is an important topic when addressing the temporal interplay between protected areas and matrix. We developed models of habitat suitability indices (HSI) for saproxylic red-listed invertebrate and fungal species, accounting for roughly 70% of all red-listed boreal forest species of the study area in eastern Finland. By using a forestry planning program that incorporates various optimisation methods we analysed trade-offs between timber production and amount of habitats of saproxylic red-listed species within a 60-year period. We also produced production possibility frontiers that show how to increase quality of the matrix with least costs. Moreover, we analysed how habitat suitability criteria used in optimisations affect the area of different habitat quality classes. Our analysis shows that by adopting HSI models in long-term matrix management, it is possible to increase habitats for several red-listed species without substantial losses in timber production. The increase in habitat area is achieved mainly by decreasing the area that is thinned compared to intensive timber production plan. In the long term, this seems to be a novel cost-effective method to increase the quality of the matrix for red-listed saproxylic species. However, the selected optimisation method and the criteria or specification of the management objective for red-listed forest species have a strong effect on results when HIS models are used in conservation planning. Therefore any practical application must be performed with great care.

Turner, M. G., G. J. Arthaud, R. T. Engstrom, S. J. Hejl, J. Liu, S. Loeb and K. McKelvey. 1995. Usefulness of Spatially Explicit Population Models in Land Management. ***Ecological Applications*** 5:12-16.

Abstract taken directly from text

Land managers need new tools, such as spatial models, to aid them in their decision-making processes because managing for biodiversity, water quality, or natural disturbance is challenging, and landscapes are complex and dynamic. Spatially explicit population models are helpful to managers because these models consider both species-habitat relationships and the arrangement of habitats in space and time. The visualizations that typically accompany spatially explicit models also permit managers to "see" the effects of alternative management strategies on populations of interest. However, the expense entailed in developing the data bases required for spatially explicit models may limit widespread implementation. In addition, many of the models are developed for one or a few species, and dealing with multiple species in a landscape remains a significant challenge. To be most useful to land managers, spatially explicit population models should be user friendly, easily portable, operate on spatial and temporal scales

appropriate to management decisions, and use input and output variables that can be measured affordably.

Vincenzi, S., G. Caramori, R. Rossi and G. A. De Leo. 2006. A GIS-based habitat suitability model for commercial yield estimation of *Tapes philippinarum* in a Mediterranean coastal lagoon (Sacca di Goro, Italy). ***Ecological Modelling*** 193:90-104.

Abstract taken directly from text
Habitat suitability models have been extensively used by conservation planners to estimate the likelihood of occurrence and abundance of threatened wildlife species in terrestrial ecosystems, but they have been rarely applied to aquatic environment. In this study a GIS-based habitat suitability (HS) model has been developed to identify suitable sites for Manila clam (*Tapes philippinarum*) farming in the Sacca di Goro lagoon and to estimate the expected commercial yield. Habitat suitability and the assessment of potential yield for each specific site of the lagoon are derived on the basis of information on six exogenous parameters, namely sediment type, dissolved oxygen, salinity, hydrodynamism, water depth and chlorophyll "a". For each of them, a parameter-specific non-linear suitability function has been used to transform parameter values into a quality index normalized between zero (i.e., habitat non suitable to clam rearing) and 1 (habitat best suitable with respect to that specific parameter). Habitat suitability of a specific site within the lagoon is then computed as a weighted geometric mean of the quality indices corresponding to the six measured parameters. Weight has been set according to expert knowledge. Finally, a scaling function derived from field observations is used to transform HS values into estimates of annual potential yield (kgm^{-2} year^{-1}). The model has been applied to the Sacca di Goro lagoon where data on actual yield and the main biogeochemical and hydrodynamic parameters have been gathered in 15 sampling sites. These point data have been interpolated by Kriging so as to derive full maps of each biochemical parameter for the whole lagoon. The HS model has been then applied to derive the thematic maps of suitable sites for clam rearing and the corresponding expected yield. In order to assess the sensitivity of model predictions to errors in weights estimation, we performed a MonteCarlo analysis considering three different assumptions on ranges of variation of weights values. The model has proved to provide managers with sound estimates on yield potential of the different sites of Goro lagoon where *T. philippinarum* is commercially exploited. We thus claim that this reasonably rapid and cost-effective approach poses the basis for a fair partition of harvesting concessions among competitive users and for a remarkable improvement of transparency in the decision-making process.

Vogiatzakis, I. N. 2003. ***GIS-based Modelling and Ecology: A Review of Tools and Methods***. Geographical Paper No. 170, Department of Geography, The University of Reading, UK. 34 pp.

Abstract taken directly from text
The rapid development of computers and associated software during the last thirty years has led to the expansion (emergence) of Geographical Information Systems (GIS). Geographical information systems (GIS) are computer-based systems designed specifically to facilitate the digital storage, retrieval, and analysis of spatially-referenced environmental data. Coupled with ecological modelling, GIS can provide significantly increased opportunities for detailed environmental resource inventory and analysis and show considerate promise for extensive use in nature conservation. The paper introduces these two concepts and discusses the role of GIS-based modelling in nature conservation focusing on the predictive models for species occurrence, plant community occurrence and habitat suitability. The importance of Digital Elevation Models and their derived properties in these ecological studies is explained. Emphasis is placed on empirical or inductive modelling based on field observations. The generic steps of empirical modelling are described and demonstrated by a case study in Lefka Ori, Crete, Greece. Tools such as fuzzy mapping and geostatistics have a potential role to play in improving the level of information and therefore in the understanding of species and plant community distribution.

SECTION 3.0 - REMOTE SENSING AND VEGETATION MAPPING

British Columbia Ministry of Environment. 1998. ***Field Manual for Describing Terrestrial Ecosystems***. Prepared by the Ecosystems Working Group, Terrestrial Ecosystems Task Force, Resources Inventory Committee, Ministry of Environment, Victoria, B.C. 231 pp.

Abstract taken directly from text

This report describes British Columbia standards for ecosystem mapping at scales of 1:5000 to 1:50 000. The information here has been developed for, and approved by, the Resources Inventory Committee (RIC), a provincial committee responsible for developing inventory standards for the province. These mapping standards use a three-level classification hierarchy of ecological units, including ecoregion units and biogeoclimatic units at broader levels, and site units and vegetation developmental stages (combined as ecosystem units) at a more detailed scale. Ecoregion classification is hierarchical, with five levels of generalization; the lowest level, ecosection, is used here. Biogeoclimatic classification includes four levels, including zone, subzone, variant, and phase. Ecoregion and biogeoclimatic units are broad-level delineations derived from provincial maps. Within these broader units, site-level polygons describe ecosystem units composed of site series, site modifiers, and structural stages. At the first stage of ecosystem mapping, ecosystem units are delineated on aerial photographs following a bioterrain approach. To draw and label polygons, the mapper considers vegetation, topographic, and terrain (surficial geology) features. Site, vegetation and terrain attributes are recorded in a polygon database, and final map completed. The polygons are digitized and compiled in a geographic information system, and stored in a provincial database. Outlined here are the standards established for ecosystem unit characterization, symbology, sampling, mapping procedures, interpretations and legends. Core data attributes to be collected for all ecosystem mapping projects in British Columbia are also described, in addition to other attributes that are recommended in order to support interpretations for various land management activities.

Blasi, C., M. L. Carranza, R. Frondoni and L. Rosati. 2000. Ecosystem Classification and Mapping: A Proposal for Italian Landscapes. ***Applied Vegetation Science*** 3:233-242.

Abstract taken directly from text

This paper deals with the development of a hierarchical land classification for describing and mapping landscapes at different scales. After a brief overview of the theoretical background, an integrative framework is proposed which incorporates different hierarchical levels from plant sociology as diagnostic attributes. The feasibility of this proposal has been tested in different sample landscapes in central Italy. This system has a potential for applications to Italian landscapes from national to local scales, because it is based on solid theory and on information which is generally available in Italy.

Bredenkamp, G., M. Chytry, H. S. Fischer, Z. Neuhauslova and E. van der Maarel. 1998. Vegetation Mapping: Theory, Methods and Case Studies: Introduction. ***Applied Vegetation Science*** 1:162-164.

Abstract taken directly from text

This Special Feature on Vegetation mapping results from a session on 'Vegetation mapping: scales in space and time and hierarchical vegetation classification' during the 40th Symposium of the International Association for Vegetation Science in Ceske Budejovice, Czech Republic. Sub-sessions were devoted to theoretical approaches, remote sensing, predictive mapping of vegetation, and Applications. In total 22 lectures were presented and some scores of posters demonstrated. We received 18 manuscripts based on these presentations, of which 12 were accepted for this Special Feature. Three papers deal with Potential Natural Vegetation and related concepts; they represent the sub-session on Theory. Six papers describe various methodological aspects of vegetation mapping; they are concerned with remote sensing and hierarchical vegetation classification, keywords referring to the title of the symposium session; in a way they are also case studies. The final three papers are case studies in a stricter sense, but also contain methodological aspects.

Brook, R. K. and N. C. Kenkel. 2002. A multivariate approach to vegetation mapping of Manitoba's Hudson Bay Lowlands. ***International Journal of Remote Sensing*** 23:4761-4776.

Abstract taken directly from text

The Hudson Bay Lowlands of Manitoba contain a wide range of vegetation types that reflect local variations in climate, geological history, permafrost, fire, wildlife grazing and human use. This study, in Wapusk National Park and the Cape Churchill Wildlife Management Area, uses a Landsat-5 TM image mosaic to examine landscape-level vegetation classes. Field data from 600 sites were first classified into 14 vegetation classes and three un-vegetated classes. Principal component analysis was used to examine the spectral properties of these classes and identify outliers. Multiple discriminant analysis was then applied to determine the statistical significance of the vegetation classes in spectral space. Finally, redundancy analysis was used to determine the amount of vegetation variance explained by the spectral reflectance data. We advocate this adaptive learning approach to vegetation mapping, by which the researcher employs an iterative strategy to carefully examine the relationship between ground and spectral data. This approach is labour intensive, but has the advantage of producing vegetation classes that are spectrally separable, decreasing the likelihood of errors in classification caused by overlap between classes.

Calef, M. P., A. D. McGuire, H. E. Epstein, T. S. Rupp and H. H. Shugart. 2005. Analysis of vegetation distribution in Interior Alaska and sensitivity to climate change using a logistic regression approach. ***Journal of Biogeography*** 32:863-878.

Abstract taken directly from text

Aim: To understand drivers of vegetation type distribution and sensitivity to
climate change.
Location: Interior Alaska.
Methods: A logistic regression model was developed that predicts the potential equilibrium distribution of four major vegetation types: tundra, deciduous forest, black spruce forest and white spruce forest based on elevation, aspect, slope, drainage type, fire interval, average growing season temperature and total growing season precipitation. The model was run in three consecutive steps. The hierarchical logistic regression model was used to evaluate how scenarios of changes in temperature, precipitation and fire interval may influence the distribution of the four major vegetation types found in this region. *Results:* At the first step, tundra was distinguished from forest, which was mostly driven by elevation, precipitation and south to north aspect. At the second step, forest was separated into deciduous and spruce forest, a distinction that was primarily driven by fire interval and elevation. At the third step, the identification of black vs. white spruce was driven mainly by fire interval and elevation. The model was verified for Interior Alaska, the region used to develop the model, where it predicted vegetation distribution among the steps with an accuracy of 60–83%. When the model was independently validated for north-west Canada, it predicted vegetation distribution among the steps with an accuracy of 53–85%. Black spruce remains the dominant vegetation type under all scenarios, potentially expanding most under warming coupled with increasing fire interval. White spruce is clearly limited by moisture once average growing season temperatures exceeded a critical limit (+2 C). Deciduous forests expand their range the most when any two of the following scenarios are combined: decreasing fire interval, warming and increasing precipitation. Tundra can be replaced by forest under warming but expands under precipitation increase.
Main conclusion: The model analyses agree with current knowledge of the responses of vegetation types to climate change and provide further insight into drivers of vegetation change.

Carolinian Canada. Undated. ***Data Collection Standards for the Inventory of Natural Heritage Components for an EIS***. Report, London, ON. 12 pp.

Abstract taken directly from text

A natural area is characterized by natural features and by ecological functions, and these are inter-connected. They form the basis for assessing the effects of a proposed development on an area and its adjacent lands. Establishment of "significance" (as in "significant woodland" in the Provincial Policy Statement) may be less clear until comparative evaluations are undertaken. Data from Ontario indicates that in landscapes with less than 30% natural cover all natural heritage features are important to regional biodiversity and watershed function. Comparative evaluations require extensive knowledge of regional ecosystems. Similar comparisons will be more difficult in isolated studies such as a site-specific EIS unless regional information is available. Watershed and sub-basin studies establish a good baseline of information from which comparative evaluations can be made. The intention of data collection standards is to ensure that all new information collected for various studies, including EISs, uses a similar approach and format so that it may be entered into regional databases and compared with existing information. The size of the study area should not affect the ability to make comparative evaluations. The initial consultation between the proponent and the Technical Review Team will establish whether a principle for development is acceptable, or unacceptable because of the high probability of negative impacts on natural heritage features. The Technical Review Team will make recommendations on the level of effort required to address the potential for impacts, and the specific elements of study that will be required for the EIS. The specific elements required for the EIS will be selected from a detailed list. Not all elements will need to be studied for all EIS's.

Chytry, M. and L. Tichy. 1998. Phenological Mapping in a Topographically Complex Landscape by Combining Field Survey with an Irradiation Model. ***Applied Vegetation Science*** 1:225-232.

<u>*Abstract taken directly from text*</u>
A phenological map has been prepared for the PodyjiI/Thayatal National Park, located on the border between the Czech Republic and Austria. The area is characterized by V-shaped river valleys deeply incised into a gently undulating landscape. Five stages of phenological development were defined, based upon phenological spectra of plant communities in late April; 96 sites, more or less regularly spaced over the area, were assigned to one of these stags using field observations of these spectra. Potential direct solar irradiation was calculated from a digital elevation model for a 25 m x 25 m grid extending over the study area. A method was developed for interpolation of phenological observations by weighted regression of phenology on the irradiation model. This interpolation enables the prediction of the local stage of phenological development across the study area without levelling out phenological patterns dependent upon small-scale topographic variation. Spring phenological events appear to be more advanced in the valleys (except for steep north-facing slopes) than in the adjacent landscape. Possible climatic processes underlying this pattern are discussed with emphasis on temperature inversions in the river valleys. Cold-air-drainage inversions reported from the valleys are probably too infrequent and of too short duration to delay plant phenology. The combined effects of advanced phenology and the increased risk of spring frost injury due to these inversions in the valleys may be an explanation for local distributional patterns of flora and vegetation.

Dormann, C. F. 2007. Effects of incorporating spatial autocorrelation into the analysis of species distribution data. ***Global Ecology and Biogeography*** 16:129-138.

<u>*Abstract taken directly from text*</u>

Aim: Spatial autocorrelation (SAC) in data, i.e. the higher similarity of closer samples, is a common phenomenon in ecology. SAC is starting to be considered in the analysis of species distribution data, and over the last 10 years several studies have incorporated SAC into statistical models (here termed 'spatial models'). Here, I address the question of whether incorporating SAC affects estimates of model coefficients and inference from statistical models.

Methods: Review ecological studies that compare spatial and non-spatial models.

Results: In all cases coefficient estimates for environmental correlates of species distributions were affected by SAC, leading to a mis-estimation of on average c. 25%. Model fit was also improved by incorporating SAC.

Main conclusions: These biased estimates and incorrect model specifications have implications for predicting species occurrences under changing environmental conditions. Spatial models are therefore required to estimate correctly the effects of environmental drivers on species present distributions, for a statistically unbiased identification of the drivers of distribution, and hence for more accurate forecasts of future distributions.

Environmental Systems Research Institute, National Center for Geographic Information and Analysis, and The Nature Conservancy. 1994. ***Accuracy Assessment Procedures***. NBS/NPS Vegetation Mapping Program, Prepared for United States Department of Interior, National Biological survey and National Park Service.

Abstract taken directly from text
The aim of the National Park Service/National Biological Survey (NPS/NBS) Vegetation Mapping Project is to map 237 Inventory and Monitoring Park units using a single, standard vegetation classification. The primary data to be utilized for the vegetation mapping is aerial photography combined with ancillary field data. The final output product will be a digital map of the vegetation. An essential part of this ambitious mapping project will be an accuracy assessment of the final database. Accuracy assessment is important because estimates of thematic and positional errors in the data will allow users of the data to assess data suitability for a particular application. At the same time, data producers will be able to learn more about the nature of errors in the data and improve the mapping process. Accuracy requirements for the NPS/NBS Vegetation Mapping Project specify an 80% accuracy for each vegetation class that is mapped. In terms of positional accuracy, the data are expected to meet National Map Accuracy Standards (NMAS). At a minimum, accuracy assessment procedures should be able to determine, with sufficient precision, whether the vegetation map meets these requirements. The objectives of this report are to provide the theoretical framework for accuracy assessment and to make initial recommendations as well as alternative procedures for accuracy assessment of the NPS/NBS Vegetation Mapping Project.

Felinks, B., M. Pilarski and G. Wiegleb. 1998. Vegetation Survey in the Former Brown Coal Mining Area of Eastern Germany by Integrating Remote Sensing and Ground-Based Methods. ***Applied Vegetation Science*** 1:233-240.

Abstract taken directly from text
In the former brown coal mining area of eastern Germany, now scheduled as a nature conservation area, an analysis of the spatial distribution of vegetation was considered as an important tool in landscape planning. Therefore a comprehensive vegetation survey by means of satellite imagery (Landsat-TM), airborne imagery (CASI), and ground-based methods, notably habitat mapping and vegetation sampling was carried out. With respect to the scales of resolution the classification results of the four methods are, to a certain degree, comparable. Differences in the outcome can be ascribed to the fact that methods of low resolution result in a discrete array of polygons whereas methods of high resolution depict a mosaic structure with an underlying, continuously changing gradient. Provided that the biological meaning of the remote sensing classification is known, a shift from single vegetation patterns to the landscape scale will be possible. Neither satellite nor airborne imagery is restricted to the purpose of mapping but may also serve for vegetation classification itself.

Fensham, R. J., R. J. Fairfax and J. E. Holman. 2002. Quantitative assessment of vegetation structural attributes from aerial photography. ***International Journal of Remote Sensing*** 23:2293-2317.

Abstract taken directly from text
Cover of vegetation understorey and overstorey was determined from aerial photography at 1:25 000 and 1:40 000 scales by a grid sampling technique. Models were developed relating values of aerial cover to field cover as determined by intensive field measurement. The influence of photo-scale, photo colour, the angle of the image, shadow, the hiatus between aerial and field sampling, crown width, crown height, proportion of dead trees, drought prior to aerial sampling, land type, previously cleared vegetation and

incline on explanatory models was also examined. The only variables that could be clearly interpreted as influencing the models were vegetation height, photo-scale and land type. Only the latter two variables are useful for predictive models. The smaller the scale of photography the greater the exaggeration of the aerial image of tree crowns. This probable result of photo graininess would be most significant when tree crowns are small, an inverse surrogate of tree height. Two-phase models were developed for predicting basal area and biomass from aerial cover. In most instances models were successful for predicting overstorey and understorey cover and for predicting total basal area and biomass. The technique offers a powerful and cost-effective method of assessing vegetation change over long time periods in a way that no other technique can duplicate.

Gould, W. A., M. Raynolds and D. A. Walker. 2003. Vegetation, plant biomass, and net primary productivity patterns in the Canadian Arctic. ***Journal of Geophysical Research*** 108:8167.

Abstract taken directly from text

We have developed maps of dominant vegetation types, plant functional types, percent vegetation cover, aboveground plant biomass, and above and belowground annual net primary productivity for Canada north of the northern limit of trees. The area mapped covers 2.5 million km^2 including glaciers. Ice-free land covers 2.3 million km^2 and represents 42% of all ice-free land in the Circumpolar Arctic. The maps combine information on climate, soils, geology, hydrology, remotely sensed vegetation classifications, previous vegetation studies, and regional expertise to define polygons drawn using photo-interpretation of a 1:4,000,000 scale advanced very high resolution radiometer (AVHRR) color infrared image basemap. Polygons are linked to vegetation description, associated properties, and descriptive literature through a series of lookup tables in a graphic information systems (GIS) database developed as a component of the Circumpolar Arctic Vegetation Map (CAVM) project. Polygons are classified into 20 landcover types including 17 vegetation types. Half of the region is sparsely vegetated (<50% vegetation cover), primarily in the High Arctic (bioclimatic subzones A–C). Whereas most (86%) of the estimated aboveground plant biomass (1.5×10^{15} g) and 87% of the estimated above and belowground annual net primary productivity (2.28×10^{14} g yr^{-1}) are concentrated in the Low Arctic (subzones D and E). The maps present more explicit spatial patterns of vegetation and ecosystem attributes than have been previously available, the GIS database is useful in summarizing ecosystem properties and can be easily updated and integrated into circumpolar mapping efforts, and the derived estimates fall within the range of current published estimates.

Gould, W. A., S. Edlund, S. Zoltai, M. Raynolds, D. A. Walker and H. Maier. 2003. Canadian Arctic vegetation mapping. ***International Journal of Remote Sensing*** 23:4597-5609.

Abstract taken directly from text

During the next few decades the Arctic is expected to experience unprecedented changes in climate and resource development. All of these will potentially affect land use and vegetation cover. There is a need for a comprehensive and consistent circumpolar map of arctic vegetation that will be useful for modelling vegetation change in the circumpolar region. The Canadian arctic vegetation map is part of the Circumpolar Arctic Vegetation Mapping project (CAVM) which was initiated to fulfil this need. The CAVM is an effort by an international group of arctic vegetation scientists to create a map and GIS database of circumpolar vegetation at the 1:7 500 000 scale. The Canadian vegetation map and ultimate circumpolar map will be useful for the study of arctic vegetation, modelling vegetation change at the continental and circumpolar scale, interpreting patterns of wildlife distribution and migration, land management, and educational purposes. The mapping effort combines information on soils, bedrock and surficial geology, hydrology, remotely-sensed vegetation characteristics, previous vegetation studies and regional expertise of mapping scientists. Map units are drawn using photo-interpretation of a 1:4 000 000 scale AHVRR false colour infrared image basemap. Mapped polygons represent homogeneous landscape terrain units (e.g. hills, plains, plateaus, mountains and valleys). A GIS database contains ancillary information for each polygon and vegetation is defined through a series of lookup tables with information on dominant climatic, parent material chemistry and topographic characteristics. We present the mapping methods, a vegetation map of the Canadian Arctic, and ancillary maps developed in the mapping process. Twenty

land cover classes are presented on the map, including 17 vegetation classes that are defined by dominant physiognomy (growth form), dominant moisture regime, characteristic plant communities and characteristic degree of vegetation cover. Ancillary data presented include the AVHRR CIR basemap and landscape unit polygons, a maximum NDVI image, bioclimatic and elevation zones, and a map of parent material pH.

Halounov, L. Undated. ***Textural classification of B&W aerial photos for the forest classification***. Remote Sensing Laboratory, Faculty of Civil Engineering, CTU Prague, Czech Republic.

Abstract taken directly from text
The Ministry of agriculture of the Czech Republic has defined a pilot project to summarize possible information that can be automatically evaluated from black and white aerial photos. This information should serve as input data into the large forest database or as signal data for forest state management organizations. These data were derived in traditional and modern ways. The traditional one used well-known principles of image processing as image distraction and \ of these B&W aerial photos. The textural classification as another way used results of the detailed object oriented classification. The methodology was tested in another project defining the geodynamical model of land. The result of the project is a methodology to delineate forest areas, to distinguish deciduous and coniferous forest, to detect new deforestation and new large illegal dumpings and erosional rills from two different time level aerial photos. These tasks also include uninsured forest area detection. It means to determine six year-old forest (and younger).

Hope, A. S., J. S. Kimball and D. A. Stow. 1993. The relationship between tussock tundra spectral reflectance properties and biomass and vegetation composition. ***International Journal of Remote Sensing*** 14:1861-1974.

Abstract taken directly from text
Frequent cloud cover and logistical constraints hamper biophysical remote sensing studies in arctic locations, resulting in a general lack of information regarding relationships between biophysical quantities and the spectral reflectance of arctic vegetation communities. An experiment was conducted on the north slope of Alaska to characterize relationships between the spectral reflectance of three tussock tundra communities (moist tussock, dry heath and water track) and the above ground biomass and vegetation composition of each community. Hand-held radiometric and ground reference data were collected three times during the 1989 growing season. The normalized difference vegetation index (NDVI) was regressed on above ground photosynthetic and non-photosynthetic biomass quantities and individual blue, green red and near-infrared spectral reflectances and the NDVI were regressed on vegetation cover type fractions. Up to 51 per cent of the variance in the NDVI was explained by the amount of photosynthetic biomass in the moist tussock and dry heath communities while no significant relationship was established between the NDVI and non-photosynthetic biomass. Vegetation cover types had a substantial effect on the observed spectral reflectances and NDVI of each of the three communities. A secondary objective of the study was to determine whether the ratio of photosynthetic to non-photosynthetic biomass could be determined using simple point quadrat estimates of these fractions. No substantial relationship was established between the harvested and point quadrat estimates of the biomass fractions.

Kamada, M. and T. Okabe. 1998. Vegetation Mapping with the Aid of Low-Altitude Aerial Photography. ***Applied Vegetation Science*** 1:211-218.

Abstract taken directly from text
A technique for fine-scale vegetation mapping with the aid of low-altitude aerial photography was developed. The procedure is as follows: 1) The site is divided into a lattice pattern - in case the site is too large to fit into a single photograph with satisfactory resolution. The coordinates of every lattice point are surveyed to be used as control points for geometric correction. A photograph of each block of the lattice is taken using a remote-controlled camera system lifted by a captive helium balloon. 2) The vegetation is classified on the basis of a phytosociological survey. 3) The shapes and locations of vegetation patches

appearing in the photographs are entered into a computer, using a digitizer. A geometric correction is carried out through coordinate transformation referring to the coordinates of the control points and subsequently a draft vegetation map is produced. Finally, discrepancies are corrected and the map is coloured to produce the final version of the vegetation map. This technique was applied to vegetation mapping at a bar, 500 m wide and 2 km long, in the river Yoshino in Shikoku, Japan. A fine-scale vegetation map was obtained and used to analyse the influence of plants on geomorphic processes and community-specific hydrogeomorphic conditions on the bar.

Lawrence, R. L. and W. J. Ripple. 1998. Comparisons among Vegetation Indices and Bandwise Regression in a Highly Disturbed, Heterogeneous Landscape: Moutn St. Helens, Washington. ***Remote Sensing of Environment*** 64:91-102.

<u>*Abstract taken directly from text*</u>
Spectral vegetation indices have been used extensively to predict ecological variables, such as percent vegetation cover, above-ground biomass, and leaf-area index. We examined the use of various vegetation indices and multiple linear regression using raw spectral bands for predicting vegetation cover in a landscape characterized by high variability in vegetation cover and soil properties. We were able to improve the explanatory value of several vegetation indices by using regression fitting techniques including log transformations and polynomial regressions. We expected soil-adjusted indices to perform better than non-adjusted indices. However, soil-adjusted vegetation indices based on a ratio of red and near-infrared bands explained 55-65% of the variability in vegetation cover, while two non-adjusted indices each explained 70%. An index using six spectral bands explained 40%. The best multiple regression model used the red and near-infrared bands and explained 75% of the variability in vegetation cover. Among the soil-adjusted indices, and index which used a computed soil line performed best. Ratio-based vegetation indices were less sensitive to shadow influences, but this influence was outweighed by the advantages of multiple regression against original bands.

Lux, A. and F. A. Bemmerlein-Lux. 1998. Two Vegetation Maps of the Same Island: Floristic Units versus Structural Units. ***Applied Vegetation Science*** 1:201-210.

<u>*Abstract taken directly from text*</u>
This paper presents a comparison of two alternative methods to describe and map vegetation: on the basis of plant species and growth forms, respectively. A stratified random sampling was taken from spontaneous vegetation in 1989 on the volcanic island of Pantelleria (near Sicily, Italy). Cartographic and other comparisons of the results from classification and ordination analysis suggest that the major differences were associated with differences in the time scale of the underlying processes. Species results (leading to floristic vegetation units) were representative of longer-term processes, growth-form results (leading to structural vegetation units) with shorter-term processes. Further implications of these results are discussed.

Michaelsen, J., D. S. Schimel, M. A. Friedl, F. W. Davis and R. C. Dubayah. 1994. Regression Tree Analysis of Satellite and Terrain Data to Guide Vegetation Sampling and Surveys. ***Journal of Vegetation Science*** 5:673-686.

<u>*Abstract taken directly from text*</u>
Monitoring of regional vegetation and surface biophysical properties is tightly constrained by both the quantity and quality of ground data. Stratified sampling is often used to increase sampling efficiency, but its effectiveness hinges on appropriate classification of the land surface. A good classification must be sufficiently detailed to include the important sources of spatial variability, but at the same time it should be as parsimonious as possible to conserve scarce and expensive degrees of freedom in ground data. As part of the First ISLSCP (International Satellite Land Surface Climatology Program) Field Experiment (FIFE), we used Regression Tree Analysis to derive an ecological classification of a tall grass prairie landscape. The classification is derived from digital terrain, land use, and land cover data and is based on their association with spectral vegetation indices calculated from single-date and multi-temporal satellite

imagery. The regression tree analysis produced a site stratification that is similar to the *a priori* scheme actually used in FIFE, but is simpler and considerably more effective in reducing sample variance in surface measurements of variables such as biomass, soil moisture and Bowen Ratio. More generally, regression tree analysis is a useful technique for identifying and estimating complex hierarchical relationships in multivariate data sets.

Nilsen, L., A. Elvebakk, T. Brossard and D. Joly. 1999. Mapping and analyzing arctic vegetation: evaluating a method coupling numerical classification of vegetation data with SPOT satellite data in a probability model. ***International Journal of Remote Sensing*** 20:2947-2977.

Abstract taken directly from text
Vegetation and environmental data were collected at 266 sampling points distributed in a regular manner along transects covering the Broggerhalvoya peninsula, on the north-western coast of Spitsbergen. Transects with sampling points were drawn in advance on aerial photographs. The analysis of releves and collection of ground data along transects represent an efficient, representative and precise way of sampling. The vegetation data were classified and 19 plant communities distinguished. The plant communities were subjected to detrended correspondence analysis (DCA). Among the recorded variables, moisture is the one with the highest correlation along axes one and two, and reflects a coincidental moisture and vegetation cover gradient. The vegetation component responsible for this positive correlation is the bryophytes. Likewise, the TWINSPAN classification confirms this gradient in a dendrogram reflecting the hierarchical structure of the plant communities. Plant communities constitute the base of a statistical model that links the communities and the SPOT satellite data. The model then classifies and maps plant communities by means of satellite data, covering the entire Broggerhalvoya peninsula. Satellite data and environmental data were analysed regarding their ability to distinguish the plant communities in a discriminant function analysis (DFA). The results of the DFA indicate that it may be reasonable to include all the information from the different satellite channels when using satellite data for vegetation classification purposes. Among the satellite data the panchromatic channel is the one adding the most unique information to the power of the model in separating plant communities. The classification of satellite data using the probability model indicates that plant communities with less than 30%vegetation cover could be classified with the same degree of confidence or better, as compared with plant communities with more than 30%vegetation cover. The overall percentage of correctly classified releves increased by 13% when using probability level two instead of level one (57.8 to 71.1%). The probability classification model makes it possible to experiment with different probability levels to improve the fit between the vegetation and satellite data classification.

O'Neill, R. V., K. H. Riitters, J. D. Wickham and K. B. Jones. 1999. Landscape Pattern Metrics and Regional Assessment. ***Ecosystem Health*** 5:225-233.

Abstract taken directly from text
The combination of remote imagery data, geographic information systems software, and landscape ecology theory provides a unique basis for monitoring and assessing large-scale ecological systems. The unique feature of the work has been the need to develop and interpret quantitative measures of spatial pattern - the landscape indices. This article reviews what is known about the statistical properties of these pattern metrics and suggests some additional metrics based on island biogeography, percolation theory, hierarchy theory, and economic geography. Assessment applications of this approach have required interpreting the pattern metrics in terms of specific environmental endpoints, such as wildlife and water quality, and research into how to represent synergistic effects of many overlapping sources of stress.

Raynolds, M. K., D. A. Walker and H. A. Maier. 2005. Plant community-level mapping of arctic Alaska based on the Circumpolar Arctic Vegetation Map. ***Phytocoenologia*** 35:821-848.

Abstract taken directly from text
A plant community-level map of arctic Alaska was derived in a hierarchical fashion from the Circumpolar Arctic Vegetation Map (CAVM). The new map has 33 units described for Alaska, an increase from the

original 13 units shown on the CAVM. The polygons of the new map refer through the legend to the appropriate dominant plant community described in a table. The table includes eighty-five plant community descriptions used in creating the Alaska portion of the CAVM, including dominant and characteristic plant species that define the community, literature citations for the descriptions and published plant community names. Researchers can use the literature citations to find more complete species lists, habitat descriptions and plot locations. The map is an important tool for research and management at the regional level. A 1:4,000,000 version of the map is available from the authors.

Raynolds, M. K., D. A. Walker and H. A. Maier. 2006. NDVI patterns and phytomass distribution in the circumpolar Arctic. ***Remote Sensing of Environment*** 102:271-281.

Abstract taken directly from text
The Circumpolar Arctic Vegetation Map (CAVM) was used to analyze the distribution of NDVI and phytomass in the Arctic, providing data for understanding arctic vegetation patterns, assessing change, and calibrating models. The dominant trend in the analysis of Normalized Difference Vegetation Index (NDVI) was a decrease from south to north, correlating with bio-climate subzones and vegetation units. NDVI also decreased at higher elevations and with higher substrate pH. In the coldest bio-climate subzone, increased elevation was not correlated with decreased NDVI. In the warmest tundra bio-climate subzone, especially in Alaska, NDVI did not decrease with the first several hundred meters of elevation. NDVI in this subzone varied more by region than by elevation or substrate chemistry, and was lowest in recently glaciated areas such as the Canadian Shield. Phytomass (above-ground plant biomass) was calculated from NDVI using a relationship derived from ground clip-harvest data. Phytomass for the tundra bioclimate subzone was estimated at 2.5×10^{12} kg, with most of this in the warmest subzone, at the lowest elevations, and on acidic substrates.

Stockwell, D. and A. T. Peterson. 2003. Comparison of resolution of methods used in mapping biodiversity patterns from point-occurrence data. ***Ecological Indicators*** 3:213-221.

Abstract taken directly from text
This paper examines three methods of mapping of biodiversity using point-occurrence data for the birds of Mexico: aggregation of species occurrence records, vegetation surrogate, and individual species models. We compare the approaches from the perspective of achieving potential gains in spatial resolution with existing data. We found that mapping the diversity of Mexican birds using individual species models yielded results 400-fold more finely resolved, quantifiable errors, and greater flexibility for many applications. We show that the aggregation and surrogate methods are susceptible to tradeoffs between bias and resolution that can only be ameliorated thorough more intensive sampling. A theoretical error model and an empirical demonstration shows that higher spatial resolution in the individual species approach can be achieved by controlling the modeling approach by reducing bias and decreasing random error. The method is particularly applicable for large-scale biodiversity mapping, where intensive ground survey data are lacking.

Tanser, F. and A. R. Palmer. 2000. Vegetation Mapping of the Great Fish River Basin, South Africa: Integrating Spatial and Multi-Spectral Remote Sensing Techniques. ***Applied Vegetation Science*** 3:197-203.

Abstract taken directly from text
We present a remote sensing based vegetation mapping technique well suited to a heterogeneous, semi-arid environment. 10 structural vegetation classes were identified and described on the ground. Using Landsat-TM from two different seasons and a combination of three conventional classification techniques (including a multi-temporal classification) we were unsuccessful in delineating all of the desired vegetation classes. We then employed a simple textural classification index, known as the Moving Standard Deviation Index (MSDI), that has been used to map degradation status. MSDI measures spatial variations in the landscape and is calculated by passing a 3 x 3 standard deviation filter across the Landsat-TM red band. High MSDI values are associated with degraded or disturbed rangelands whilst low MSDI values

are associated with undisturbed rangeland. A combination of two conventional multi-spectral techniques and MSDI were used to produce a final vegetation classification at an accuracy of 84 %. MSDI successfully discriminated between two contrasting vegetation types of identical spectral properties and significantly strengthened the accuracy of the classification. We recommend the use of a textural index such as MSDI to supplement conventional vegetation classification techniques in heterogeneous, semi-arid or arid environments.

The Nature Conservancy. 1996. ***Methodology for Assessing the Utility of Existing Data for Vegetation Mapping***. Prepared for the U.S. Department of Interior, Biological Resources Division and National Park Service, NBS/NPS Vegetation Mapping Program.

Abstract not available [excerpts directly from text]
Vegetation data can be gathered for different purposes, each of which can employ varying methodologies. The purposes and methodologies for data collection for other vegetation studies are often not compatible with the standards that have been developed for the purpose of standardized mapping across all National Parks. Some of the data sets may be useful for the characterization of a vegetation type, but not for the assignment of a classification attributes to map polygons. Other data sets may require significant effort to locate and convert to a compatible form such that its use would not be cost effective. Data also varies in its intrinsic quality and the amount of information it carries; some data may be useful, but only minimally so, or with low confidence. A decision about the utility of a given data set may therefore involve a cost/benefit analysis, and this analysis may be affected by consideration of other available data sets. In order to be useful for a vegetation mapping project a data set must, at a minimum, represent existing vegetation and contain enough structural and compositional information to place the sample within the standard national vegetation classification framework (The Nature Conservancy Ecology Working Group 1997). Vegetation samples meeting these minimum criteria can be used to refine the vegetation classification, document the variation in vegetation types, and to develop park specific vegetation characterizations. To aid in polygon attribution or map accuracy assessment, the vegetation samples must, in addition to the minimum criteria, be geographically referenced with sufficient accuracy for vegetation mapping. The methodology outlined below requires that the data assessor become familiar with key data quality factors which affect the utility of data in various applications. This assessment requires unrestricted access to each data set. Each data set will need to be assessed for each data quality factor, as described below. The assessment will be used to determine the potential value of each data set for the purposes of the vegetation mapping project.

The Nature Conservancy and Environmental Systems Research Institute. 1994. ***Field Methods for Vegetation Mapping***. Prepared for the U.S. Department of Interior, Biological Resources Division and National Park Service, NBS/NPS Vegetation Mapping Program.

Abstract taken directly from text
The objective of the National Biological Survey/National Park Service (NBS/NPS) Vegetation Mapping Program is to develop a uniform hierarchical vegetation classification standard and methodology on a Service-wide basis and, using that classification standard and methodology, generate vegetation maps for most of the park units under NPS management. This program is in response to the National Park Service's Natural Resources Inventory and Monitoring Guideline (NPS-75) issued in 1992. The vegetation data are to be automated in a GIS-compatible format, which will provide great flexibility in map design and production, data analysis, data management, and maintenance activities. The use of a standard national vegetation classification scheme and mapping protocols will facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information will support a wide variety of resource assessment, park management, and planning concerns. They will provide a structure for framing and answering critical scientific questions about vegetation types and their relationship to environmental processes across the landscape. They will provide a consistent means for the inventory and monitoring of plant communities and they will support "ecosystem management" by providing a consistent basis for the characterization of the biological components of different ecosystem

units. The first step toward the implementation of the mapping program includes the development and documentation of standards and protocols. This is being initiated in three studies: (1) a proposed National Vegetation Classification Standard, (2) Field Methodologies, and (3) Accuracy Assessment Procedures. This document is the result of the second study. The fundamental purpose of this study is to review the scientific basis for vegetation sampling and to propose a standardized field methodology that will serve the objectives of this project. The planning process and field methods that will be used to sample and accurately map the National Vegetation Classification units across all parks are described. The National Vegetation Classification System is the result of synthesizing a great body of earlier scientific effort as well as twenty years of field data collection and scientific analyses by The Nature Conservancy (TNC) and Natural Heritage Program scientists. Confidence levels are assigned to each community type to identify the quantity and the quality of information available. The classification is rigorously reviewed and updated as new data become available.

The Nature Conservancy and Environmental Systems Research Institute. 1994. ***Standardized National Vegetation Classification System***. Prepared for the U.S. Department of Interior, Biological Resources Division and National Park Service, NBS/NPS Vegetation Mapping Program.

Abstract taken directly from text

The objective of the National Biological Survey/National Park Service (NBS/NPS) Vegetation Mapping Program is to develop a uniform hierarchical vegetation classification standard and methodology on a Service-wide basis and, using that classification standard and methodology, to generate vegetation maps for most of the park units under NPS management. This Program is in response to the National Park Service's Natural Resources Inventory and Monitoring Guideline (NPS-75) issued in 1992. The vegetation data are to be automated, in a GIS-compatible format, which will provide great flexibility in map design and production, data analysis, data management, and maintenance activities. Deliverable products will include a digital file of vegetation maps, digital metadata files, textual descriptions and keys to the vegetation classes, hard-copy maps, and map accuracy verification reports. The use of a standard national vegetation classification scheme and mapping protocols will facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information will support a wide variety of resource assessment, park management, and planning concerns. They will provide a structure for framing and answering critical scientific questions about vegetation types and their relationship to environmental processes across the landscape. They will provide a consistent means for the inventory and monitoring of plant communities and, they will support "ecosystem management" by providing a consistent basis for the characterization of the biological components of different ecosystem units.

U.S. Fish & Wildlife Service. 2006. ***Spatial Inventory and Monitoring on National Wildlife Refuges. Southwest Region, National Wildlife Refuge System***. Technical Manual, NWR Remote Sensing Lab, Division of Planning. 162 pp.

Abstract not available [excerpts directly from text]

Spatial inventory and monitoring of vegetation, land cover and wildlife habitat on National Wildlife Refuges (NWR) plays an important role in the management of our natural resources. Within the Southwest Region (R2) the NWR Remote Sensing Lab has been tasked with developing spatial habitat inventory and monitoring methods and producing these data for all NWRs throughout the region. This document describes the sampling, field data collection, remote sensing (RS) and geographic information system (GIS) applications, methods and tools used to complete this process. The methods described in this document may be applied to vegetation/landcover/habitat mapping, historical land use and change detection analysis. It is important to note that this document goes into some detail outlining the methods used to generate spatial vegetation and habitat inventory and monitoring. It is written under the assumption that staff using these protocols have a developed background in field data collection, general landscape ecology, remote sensing sciences and GIS applications.

van Etten, E. J. B. 1998. Mapping Vegetation in an Arid, Mountainous Region of Western Australia. ***Applied Vegetation Science*** 1:189-200.

Abstract taken directly from text

Predictive mapping of vegetation using models linking vegetation units to mapped environmental variables has been advocated for remote areas. In this study, three different types of model were employed (within a GIS) to produce vegetation maps of the Hamersley Ranges region of Western Australia. The models were: (1) decision trees; (2) statistical models; and (3) heuristic/conceptual models. Maps were produced for three different levels of a floristic classification, i.e. 16 communities in two community groups with eight subgroups. All models satisfactorily established relationships between the vegetation units and available predictor variables, except where the number of sites of a particular unit was small. The different models often made similar predictions, especially for more widespread vegetation units. Map accuracy (as determined by field testing of maps) improved with increasing level of abstraction, with plant community maps ca. 50 % correct, subgroup maps ca. 60 % correct and group maps 90 % correct. Map inaccuracies were due to several factors, including low sample numbers producing unrepresentative models, poor resolution of and errors in available maps of predictor variables, and available predictor variables not being able to differentiate between certain vegetation units, particularly at the plant community level. Of these factors, poor resolution of maps was seen as the most critical. One type of model could not be recommended over another; however the choice of model will be largely dependent on the nature of the data set and the type of map coverage required.

Vogt, P., K. H. Riitters, M. Iwanowski, C. Estreguil, J. Kozak and P. Soille. 2007. Mapping landscape corridors. ***Ecological Indicators*** 7:481-488.

Abstract taken directly from text

Corridors are important geographic features for biological conservation and biodiversity assessment. The identification and mapping of corridors is usually based on visual interpretations of movement patterns (functional corridors) or habitat maps (structural corridors). We present a method for automated corridor mapping with morphological image processing, and demonstrate the approach with a forest map derived from satellite imagery of northern Slovakia. We show how the approach can be used to differentiate between relatively narrow ('line') and wide ('strip') structural corridors by mapping corridors at multiple scales of observation, and indicate how to map functional corridors with maps of observed or simulated organism movement. An application to environmental reporting is demonstrated by assessing structural forest corridors in relation to forest types in northern Slovakia.

Walker, D. A. 1999. An integrated vegetation mapping approach for northern Alaska (1:4M scale). ***International Journal of Remote Sensing*** 20:2895-2920.

Abstract taken directly from text

A six-step integrated vegetation mapping approach is described for making a small-scale (1:4 million) map of northern Alaska. The method uses two primary maps: (1) a Phytogeographic subzones and Floristic subprovinces Map (PFM) adjusted to Advanced Very High Resolution Radiometer false colour infrared (AVHRRCIR) imagery, and (2) an Integrated Vegetation-Complex Map (IVCM). The IVCM map-polygon boundaries are guided by information from a variety of remote-sensing data (AVHRR imagery, maximum greenness maps and classified images) and hard-copy source maps (surficial geology, bedrock geology, soils, percentage water cover). The map-polygon boundaries are integrated so that they conform to terrain features that are interpretable on the AVHRR CIR. The PFM and IVCM are overlaid in a geographic information system(GIS), and a series of derived maps is created through the use of look-up tables. Northern Alaska is a prototype area for the Circumpolar Arctic Vegetation Mapping (CAVM) project, which has a goal of producing a new vegetation map of the region north of the arctic tree line by the year 2001. The method could be modified and adapted to any region of the Arctic based on locally available information.

Walker, D. A., C. Bay, F. J. A. Daniels, E. Einarsson, A. Elvebakk, B. E. Johansen, A. Kapitsa, S. S. Kholod, D. F. Murray, S. S. Talbot, B. A. Yurtsev and S. C. Zoltai. 1995. Toward a New Arctic Vegetation Map: A Review of Existing Maps. ***Journal of Vegetation Science*** 6:427-436.

Abstract taken directly from text
A circumpolar arctic vegetation map and series of derived products are needed for a variety of current issues including resource development, studies of arctic biota and biodiversity, arctic land-atmosphere, ice, ocean and human interactions, land-use planning, and education. A new map would provide a common legend and language for the ecosystems of the arctic region. It would also be a key component of circumpolar geographic information systems (GIS). At the Circumpolar Arctic Vegetation Mapping Workshop held in St. Petersburg, Russia, 21-25 March 1994, 51 participants from all the circumpolar countries reviewed the status of mapping north of the arctic treeline, and developed an approach to formatting a series of new maps. 15 papers by regional experts described the status of arctic vegetation mapping in each of the circumpolar countries.

Walker, D. A., M. K. Raynolds, F. J. A. Daniels, E. Einarsson, A. Elvebakk, W. A. Gould, A. E. Katenin, S. S. Kholod, C. J. Markon, E. S. Melnikov, N. G. Moskalenko, S. S. Talbot, B. A. Yurtsev and other members of the CAVM Team. 2005. The Circumpolar Arctic vegetation map. ***Journal of Vegetation Science*** 16:267-282.

Abstract taken directly from text
Question: What are the major vegetation units in the Arctic, what is their composition, and how are they distributed among major bio-climate subzones and countries?
Location: The Arctic tundra region, north of the tree line.
Methods: A photo-interpretive approach was used to delineate the vegetation onto an Advanced Very High Resolution Radiometer (AVHRR) base image. Mapping experts within nine Arctic regions prepared draft maps using geographic information technology (ArcInfo) of their portion of the Arctic, and these were later synthesized to make the final map. Area analysis of the map was done according to bio-climate subzones, and country. The integrated mapping procedures resulted in other maps of vegetation, topography, soils, landscapes, lake cover, substrate pH, and above-ground biomass.
Results: The final map was published at 1:7 500 000 scale map. Within the Arctic (total area = 7.11×10^6 km^2), about 5.05×10^6 km^2 is vegetated. The remainder is ice covered. The map legend generally portrays the zonal vegetation within each map polygon. About 26% of the vegetated area is erect shrublands, 18% peaty graminoid tundras, 13% mountain complexes, 12% barrens, 11% mineral graminoid tundras, 11% prostrate-shrub tundras, and 7% wetlands. Canada has by far the most terrain in the High Arctic mostly associated with abundant barren types and prostrate dwarf-shrub tundra, whereas Russia has the largest area in the Low Arctic, predominantly low-shrub tundra.
Conclusions: The CAVM is the first vegetation map of an entire global biome at a comparable resolution. The consistent treatment of the vegetation across the circumpolar Arctic, abundant ancillary material, and digital database should promote the application to numerous land-use, and climate-change applications and will make updating the map relatively easy.

Walker, D. A., W. A. Gould, H. A. Maier and M. K. Raynolds. 2002. The Circumpolar Arctic Vegetation Map: AVHRR-derived base maps, environmental controls, and integrated mapping procedures. ***International Journal of Remote Sensing*** 23:4551-4570.

Abstract taken directly from text
A new false-colour-infrared image derived from biweekly 1993 and 1995 Advanced Very High Resolution Radiometer (AVHRR) data provides a snow-free and cloud-free base image for the interpretation of vegetation as part of a 1:7.5 M-scale Circumpolar Arctic Vegetation Map (CAVM). A maximum-NDVI (Normalized DiVerence Vegetation Index) image prepared from the same data provides a circumpolar view of vegetation green-biomass density across the Arctic. This paper describes the remote sensing products, the environmental factors that control the principal vegetation patterns at this small scale, and the integrated geographic information-system (GIS) methods used in making the CAVM.

Yang, X. 2007. Integrated use of remote sensing and geographic information systems in riparian vegetation delineation mapping. ***International Journal of Remote Sensing*** 28:353-370.

<u>*Abstract taken directly from text*</u>

This paper presents a pilot study on riparian vegetation delineation and mapping using remote sensing and geographic information systems (GIS) in the Hunter Region, Australia. The aim of the study was to develop appropriate and repeatable assessment and mapping techniques to quantify the extent of riparian vegetation within the region. Ortho-rectified digital aerial photographs, SPOT-4 multispectral (XS) and Landsat-7 ETM+ images were tested to delineate the riparian vegetation and to develop a quantifiable and repeatable method of mapping the extent of that vegetation. Image processing techniques such as parallelepiped classification, tasselled cap transformation, and vegetation index clustering were used in an attempt to delineate riparian vegetation from remotely sensed images. Specific GIS analysis techniques were used for riparian zone buffering and segmentation, vegetation cover estimation, and mapping. Specific GIS scripts were developed for those processes so that they were automatic, fast, and repeatable. Various vegetation indices (VI) were evaluated and compared for their ability to discriminate riparian vegetation and its extent. The riparian vegetation was assessed and mapped at designed segmental interval (e.g. 1 km) with polygon and lineal representations. The classification accuracy was assessed against field observation and air photo interpretation (API). The overall accuracy of the photo-based classification was about 81%, SPOT-4 63%, and Landsat-7 ETM+ 53%. Statistic analysis shows that there is little agreement between photo-based classification and that from satellite imagery.

SECTION 4.0 - <u>ECOLOGICAL INDICATORS</u>

Andreasen, J. K., R. V. O'Neill, R. Noss and N. C. Slosser. 2001. Considerations for the development of a terrestrial index of ecological integrity. ***Ecological Indicators*** 1:21-35.

<u>*Abstract taken directly from text*</u>

Ecological systems are composed of complex biological and physical components that are difficult to understand and to measure. However, effective management actions and policy decisions require information on the status, condition, and trends of ecosystems. Multiple levels of information are needed to make effective decisions and the ideal indicators for measuring ecosystem integrity will incorporate information from multiple dimensions of the ecosystem. A terrestrial index of ecological integrity would be a useful tool for ecosystem managers and decision makers. The ideal requirements of the terrestrial index of ecosystem integrity (TIEI) are that it be comprehensive and multi-scale, grounded in natural history, relevant and helpful, able to integrate concerns from aquatic and terrestrial ecology, and that it be flexible and measurable. The objective of this research is to investigate if an index, or indices, could be developed that would summarize the condition of ecosystems so that changes can be tracked over time and this information utilized as a tool to support environmental decision making.

Barrera-Roldan, A. and A. Saldivar-Valdes. 2002. Proposal and application of a Sustainable Development Index. ***Ecological Indicators*** 2:251-256.

<u>*Abstract taken directly from text*</u>

This work shows the methodology used to design a Sustainable Development Index (SDI), and its application to a region within the Coatzacoalcos river basin. This region is one of the more highly industrialized zones in Mexico, and is located in the State of Veracruz, about 800 km southeast of Mexico City. The SDI was formed within the framework of the driving forces, state, and response (DSR) philosophy. Within this framework we have included an indicator about environmental accounting in order to determine the monetary value of losses due to depletion and deterioration of natural resources. At the same time we use the Multi-Attribute Decision Theory methodology along with 21 indicators; most of them were designed and calculated specifically for this work. The indicators represent the environmental, economic, and social characteristics of the region. The utility functions that were designed for grading the

region in each attribute used international and national parameters of performance. The SDI was applied to seven municipalities. The Figure of Merit obtained by each municipality served to rank them in terms of their closeness to a Sustainable Development. The results of the analysis also identified and prioritized the most urgent problems that need to be solved in order to obtain an improvement in the development of the municipalities in accordance to sustainability and resource management criteria.

Bastin, G. N., J. A. Ludwig, R. W. Eager, V. H. Chewings and A. C. Liedloff. 2002. Indicators of landscape function: comparing patchiness metrics using remotely-sensed data from rangelands. ***Ecological Indicators*** 1:247-260.

<u>*Abstract taken directly from text*</u>
In arid and semi-arid rangeland regions, landscapes that trap and retain resources, such as rain water, soil particles, and organic matter, provide more favorable habitats for vegetation and fauna, and are considered more functional than landscapes that lose, or leak, these essential resources. The cover and arrangement of perennial vegetation patches is an important indicator of whether landscapes retain or leak resources. Patchiness attributes, as descriptors of resource retention potential in landscapes, can be obtained from remotely-sensed imagery, such as aerial videography and high-resolution satellites where this imagery has been classified into perennial vegetation patch and open inter-patch pixels. In this paper, we compare four landscape patchiness metrics on their ability to indicate how well landscapes potentially function to retain resources. Landscape patch attributes (e.g. patch cover and spacing) and on-ground inspection of soil and vegetation attributes were used to rate and rank four sites relative to their potential to retain resources. A directional leakiness index (DLI) that is highly sensitive to patch cover, shape, and configuration correctly and adequately ranked sites in the same order as our field ratings. The lacunarity index also correctly ranked sites, but showed little separation amongst sites with reduced potential to retain resources. The weighted mean patch size (WMPS) index and proximity index failed to correctly rank sites. The directional leakiness and lacunarity indices can be calculated for any remotely-sensed imagery that is of sufficient resolution to measure landscape patchiness at scales where processes of resource conservation are operating. For example, imagery of 0.2–1m pixel sizes from arid and semi-arid rangelands can be classified into flow-obstructing patches and open non-obstructing inter-patches. Such classified imagery and leakiness or lacunarity indicators can then be used to monitor changes in the resource retention potential of these landscapes. However, the applicability of these indicators for monitoring more humid vegetation types, and for assessing larger landscape areas (i.e. at coarser scales), needs to be evaluated.

Belaoussoff, S. and P. G. Kevan. 2001. Toward an Ecological Approach for the Assessment of Ecosystem Health. ***Ecosystem Health*** 4:4-8.

<u>*Abstract taken directly from text*</u>
Many ecologists express difficulty with the concept of ecosystem health. Ecosystem health must have definable and objective norms that allow for rigorous hypothesis testing for it to be acceptable to those ecologists. On step toward objective measurement of ecosystem health is to characterize ecosystem health by diversity-abundance relationships. The log-normal relationship between diversity and abundance characterizes taxocenes (i.e., taxonomically related groups that have similar ecological functions). Under conditions of stress, the patterns of diversity and abundance often change and are no longer log-normal, this change in patterns has been show for some, but not all, marine and terrestrial taxocenes tested. The interdisciplinary possibilities for using log-normality, and deviation for it, as a measure of natural and anthropogenic ecosystem health are discussed. The interdisciplinarity of ecosystem health is illustrated with an example of blueberry pollinator decline caused by insecticide spraying in New Brunswick, Canada, and related economic and human health costs.

Bertollo, P. 1998. Assessing Ecosystem Health in Governed Landscapes: A Framework for Developing Core Indicators. ***Ecosystem Health*** 4:33-51.

Knight Piésold
CONSULTING

Abstract taken directly from text

This article describes the development of a framework for selecting a core set of indicators suitable for an integrated ecosystem health assessment of a governed landscape. Integrated assessments are those that consider a combination of biophysical, socioeconomic, and human health considerations. Highly governed landscapes are cultural landscapes that are strictly controlled by humans to the extent that they would revert to an entirely different form were it not for continued human intervention. One example of such a landscape, which serves as the setting for this investigation, is the former wetlands of the northeastern Italian coastal zone, which have been subject to widespread land reclamation and coastal development over the past century. The science of ecosystem health has been chosen as the frame of reference because "health" is not judged by the degree of "naturalness" but instead on the ability of the ecosystem to maintain and renew itself. The framework consists of first reviewing literature and methods related to ecological and environmental monitoring, state-of-the-environment reporting, landscape ecology, and sustainability. This is followed by the definition of indicator guidelines that are designed to assist in the evaluation and selection of potential indicators. A core set of indicators are then presented based on a conceptual framework devised for this purpose. Indicators are classed as abiotic, biotic, and cultural, and selected according to the ecological districts comprising the study area. The ultimate goal is their application to an ecological monitoring and assessment program within a governed landscape such as the northeastern Italian costal zone. Given such a commitment, the normal process of core indicator refinement can then proceed, based on such actions as further consultations with interested stakeholders and evaluation of methodological and practical constraints to their actual application.

Bremner, J., S. I. Rogers and C. L. J. Frid. 2006. Methods for describing ecological functioning of marine benthic assemblages using biological traits analysis (BTA). ***Ecological Indicators*** 6:609-622.

Abstract taken directly from text

Biological traits analysis (BTA) is a method recently proposed for describing ecological functioning of marine benthic assemblages. It incorporates information on species' distributions and the biological characteristics they exhibit, to produce a summary of the biological trait composition of assemblages. The approach provides a link between species, environments and ecosystem processes, and is potentially useful for the investigation of anthropogenic impacts on ecological functioning. As part of the development of BTA for application to marine systems, two aspects of the approach were investigated here: (1) the comparative applicability of three analytical tools proposed for conducting BTA and (2) the sensitivity of the approach to the number and type of traits selected for analysis. The three tools, fuzzy correspondence analysis (FCA), co-inertia analysis (CoI) and non-metric multidimensional scaling (nmMDS) portrayed trait composition of benthic assemblages in similar ways, however nmMDS had less power to discriminate between assemblages with varying trait composition than FCA or CoI. For the thirteen biological traits considered, the number of traits selected for analysis affected the ability of BTA to describe relationships between assemblages, more so than the identity of the traits themselves. Ultimately, selection of biological traits for inclusion in BTA will be based on a trade-off between their efficacy for describing variability in ecological functioning and the time and effort required to gather information on the biological characteristics of the taxa studied. The choice of analytical tool is a balance between the power of the tool to describe changes in trait composition and the ease with which results can be interpreted. nmMDS is appropriate for providing a general picture of functioning in marine assemblages, whereas FCA and CoI have greater power to detect the effects of human impacts, but are more difficult to interpret. Including as many traits as possible will lead to the most useful description of ecological functioning, as will select traits sensitive to anthropogenic impacts or closely linked to important ecosystem processes.

Bouyer, J., Y. Sana, Y. Samandoulgou, J. Cesar, L. Guerrini, C. Kabore-Zoungrana and D. Dulieu. 2007. Identification of ecological indicators for monitoring ecosystem health in the trans-boundary W Regional park: A pilot study. ***Biological Conservation*** 138:73-88.

Abstract taken directly from text

The sustainable management of the W Regional park and its peripheral areas is based on a trade-off between conservation and the generation of economic income for local populations. This work is a pilot study for the identification of ecological indicators to monitor ecosystem health in Sudanian Savannah ecosystems. Ecological indicators are needed to warrant the efficiency of the protection measures, particularly in the mosaic landscape of the peripheral areas. Two insect families (Coleoptera: Scarabaeidae (Cetoniinae) and Lepidoptera: Nymphalidae) were trapped along transects crossing landuse units submitted to various human presses (none, hunting, traditional and intensive crops, grazing) in two countries (Burkina Faso and Benin). Plant species richness was found to be correlated with the abundance of four fruit-feeding insect species and with the fruit-feeding butterfly species richness, but not with the Cetoniinae species richness. The abundance of Nymphalidae species generally dropped with human activities, but that of the Cetoniinae species followed the intermediate disturbance theory. The likely impact of the various management practises on the general ecosystem health is discussed, as is the potential value of fruit-feeding insects as bio-indicators and the points that still need to be clarified.

Carignan, V. and M.-A. Villard. 2003. Selecting Indicator Species to Monitor Ecological Integrity: A Review. ***Environmental Monitoring and Assessment*** 78:45-61.

Abstract taken directly from text

We review critical issues that must be considered when selecting indicator species for a monitoring program that aims to maintain or restore ecological integrity. First, we examine the pros and cons of different management approaches on which a conservation program can be based and conclude that ecosystem management is most appropriate. We then identify potential indicators of ecological integrity at various levels of the ecosystem, with a particular emphasis on the species level. We conclude that, although the use of indicator species remains contentious, it can be useful if (1) many species representing various taxa and life histories are included in the monitoring program, (2) their selection is primarily based on a sound quantitative database from the focal region, and (3) caution is applied when interpreting their population trends to distinguish actual signals from variations that may be unrelated to the deterioration of ecological integrity. Finally, we present and discuss different methods that have been used to select indicator species.

Caughlan, L. and K. L. Oakley. 2001. Cost considerations for long-term ecological monitoring. ***Ecological Indicators*** 1:123-134.

Abstract taken directly from text

For an ecological monitoring program to be successful over the long-term, the perceived benefits of the information must justify the cost. Financial limitations will always restrict the scope of a monitoring program, hence the program’s focus must be carefully prioritized. Clearly identifying the costs and benefits of a program will assist in this prioritization process, but this is easier said than done. Frequently, the true costs of monitoring are not recognized and are, therefore, underestimated. Benefits are rarely evaluated, because they are difficult to quantify. The intent of this review is to assist the designers and managers of long-term ecological monitoring programs by providing a general framework for building and operating a cost-effective program. Previous considerations of monitoring costs have focused on sampling design optimization. We present cost considerations of monitoring in a broader context. We explore monitoring costs, including both budgetary costs, what dollars are spent on, and economic costs, which include opportunity costs. Often, the largest portion of a monitoring program budget is spent on data collection, and other, critical aspects of the program, such as scientific oversight, training, data management, quality assurance, and reporting, are neglected. Recognizing and budgeting for all program costs is therefore a key factor in a program’s longevity. The close relationship between statistical issues and cost is discussed, highlighting the importance of sampling design, replication and power, and comparing the costs of alternative designs through pilot studies and simulation modeling. A monitoring program development process that includes explicit checkpoints for considering costs is presented. The first checkpoint occurs during the setting of objectives and during sampling design optimization. The last

checkpoint occurs once the basic shape of the program is known, and the costs and benefits, or alternatively the cost-effectiveness, of each program element can be evaluated. Moving into the implementation phase without careful evaluation of costs and benefits is risky because if costs are later found to exceed benefits, the program will fail. The costs of development, which can be quite high, will have been largely wasted. Realistic expectations of costs and benefits will help ensure that monitoring programs survive the early, turbulent stages of development and the challenges posed by fluctuating budgets during implementation.

Chong, G. W. and T. J. Stohlgren. 2007. Species-area curves indicate the importance of habitats' contributions to regional biodiversity. ***Ecological Indicators*** 7:387-395.

Abstract taken directly from text

We examined species–area curves, species composition and similarity (Jaccard's coefficients), and species richness in 17 vegetation types to develop a composite index of a vegetation type's contribution to regional species richness. We collected data from 1 to 1000 m^2 scales in 147 nested plots in Rocky Mountain National Park, Colorado, USA to compare three species–area curve models' abilities to estimate the number of species observed in each vegetation type. The log(species)–log(area) curve had the largest adjusted coefficients of determination (r^2 values) in 12 of the 17 types, followed by the species–log(area) curve with five of the highest values. When the slopes of the curves were corrected for species overlap among plots with Jaccard's coefficients, the species–log(area) curves estimated values closest to those observed. We combined information from species–area curves and measures of heterogeneity with information on the area covered by each vegetation type and found that the types making the greatest contributions to regional biodiversity covered the smallest areas. This approach may provide an accurate and relatively rapid way to rank hotspots of plant diversity within regions of interest.

Cousins, S. A. O. and R. Lindborg. 2004. Assessing changes in plant distribution patterns─indicator species versus plant functional types. ***Ecological Indicators*** 4:17-27.

Abstract taken directly from text

To meet conservation goals it is necessary to assess vegetation status and to be able to monitor effects of management and environmental change. In northern Europe grazed grasslands are one of the most threatened habitat in the rural landscape and thus in focus for conservation plans. At present managers use species indicator list to assess past and present management status of grassland and succession stages in particular, as well as effects of the environment. However, these indicators have rarely been scientifically tested. In this study we discuss if plant functional traits may be a key to select suitable indicator species for monitoring land-use change in Swedish rural landscape. The suitability of two possible monitoring tools: (i) plant species selected from functional traits (PFTs) and (ii) indicator species commonly used today to assess grassland management status, were tested along two gradients, a succession gradient and a wetness gradient. We found no association between successional change and plant functional traits, but a response in plant functional traits was found along the wetness gradient. However, the more common "non-scientific" indicator species responded fairly well to the varying gradient categories along both gradients. We believe that there is a need to further validate the ecological mechanisms behind the present-day indicators and to place them in a geographical context.

Dale, V. H. and S. C. Beyeler. 2001. Challenges in the development and use of ecological indicators. ***Ecological Indicators*** 1:3-10.

Abstract taken directly from text

Ecological indicators can be used to assess the condition of the environment, to provide an early warning signal of changes in the environment, or to diagnose the cause of an environmental problem. Ideally the suite of indicators should represent key information about structure, function, and composition of the ecological system. Three concerns hamper the use of ecological indicators as a resource management tool. (1) Monitoring programs often depend on a small number of indicators and fail to consider the full complexity of the ecological system. (2) Choice of ecological indicators is confounded in management programs that have vague long-term goals and objectives. (3) Management and monitoring programs often lack scientific rigor because of their failure to use a defined protocol for identifying ecological indicators. Thus, ecological indicators need to capture the complexities of the ecosystem yet remain simple enough to be easily and routinely monitored. Ecological indicators should meet the following criteria: be easily measured, be sensitive to stresses on the system, respond to stress in a predictable manner, be anticipatory, predict changes that can be averted by management actions, be integrative, have a known response to disturbances, anthropogenic stresses, and changes over time, and have low variability in response. The challenge is to derive a manageable set of indicators that together meet these criteria.

DiBari, J. N. 2003. Scaling exponents and rank-size distributions as indicators of landscape character and change. ***Ecological Indicators*** 3:275-284.

Abstract taken directly from text

I used a rank-size distribution model and its associated scaling exponents to describe the organization of Yellowstone National Park before and after the 1988 fire season using the statistical distribution of patch sizes. Rank-size distributions indicate the relative effect of patch size on landscape structure, and whether the size of patches differs from what is expected from the model. Scaling exponents describe the distribution and magnitude of change in patch size, and may indicate the effect of fire on ecological processes including succession and resource distribution. The results of my analysis suggest that fires during the 1988 fire-season substantially affected the distribution of patch size in Yellowstone National Park, where large patches have a disproportionate effect on landscape character. For example, patches ≥100 ha occupy a majority of the area even though they represent a minority number of patches in the landscape. Additionally, rank-size distributions indicate fractal properties existed over several orders of magnitude, signifying that processes acting at one level of the landscape hierarchy may be acting similarly at other levels of the hierarchy. This has implications for linking the scaling properties of patch size with other scale-based phenomena including allometry. Finally, the distribution of patch sizes in conjunction with fire-return interval may be useful in assessing the likelihood of landscape-level disturbances.

Dierssen, K. 2006. Indicating botanical diversity─Structural and functional aspects based on case studies from Northern Germany. ***Ecological Indicators*** 6:94-103.

Abstract taken directly from text

Richness in species should be appropriately measured in samples of a standard size. Standard plot sizes of 400 m^2 were recommended in order to compare the a-diversity between different ecosystem types. For the application of diversity aspects in landscape management, further attributes of the species composition should be considered. The state of the regional and phytocoenological species pool and the relationship between autochthonous and allochthonous species may help to describe the importance and potential risks of biological invasions. Life strategy types reflect the interactions between species trade-offs and environmental constraints. The species preferences for different hemerobic steps may be used as indicators of human impacts especially in agricultural and urban landscapes and ecological indication values for different site qualities. These attributes in combination may help to characterize ecosystem properties and to develop scenarios for succession processes. Biodiversity in its different aspects can only be successfully sustained, if the multitude of biological interactions with the human way of life in and subsiding on ecosystems are considered. The approach of the convention of biodiversity (CBD) based on the 'Malawi Principles' focus on the functional relationships and processes within ecosystems and propagates the use of adaptive management practices at scales appropriate for the issues being addressed. The principles take into account the need for integrative cooperation. A regional application of these principles is necessary for sustainable landscape planning.

Diffendorfer, J. E., G. M. Fleming, J. M. Duggan, R. E. Chapman, M. E. Rahn, M. J. Mitrovich and R. N. Fisher. 2007. Developing terrestrial, multi-taxon indices of biological integrity: An example from coastal safe scrub. ***Biological Conservation*** 140:130-141.

<u>*Abstract taken directly from text*</u>

We screened 351 species or genera for their response to disturbance in coastal sage scrub (CSS) to develop a 15-metric, 5-taxon Index of Biological Integrity (IBI).We collected data on ants, birds, herpetofauna, small mammals, and plants for two years on 46 sites established across a gradient of disturbance in three reserves. The gradient spanned relatively intact CSS with thick stands of shrubs, to former CSS stands type-converted to exotic grasses. ANOVAs and clustering analyses indicated the IBI could distinguish four levels of disturbance in CSS. General measures of community structure, such as richness, did not show changes across the gradient for most taxa, and responses of taxa across the gradient were varied and rarely correlated. However, turnover in species or genera across the gradient was common across all taxa as shrub-obligate life forms were replaced by those favoring grassy or disturbed habitats. Our data indicate index-based approaches based on data collected across disturbance gradients may outperform more traditional community level metrics when responses to anthropogenic influences are complex and vary across species.

Fanelli, G., P. Tescarollo and A. Testi. 2006. Ecological indicators applied to urban and suburban floras. ***Ecological Indicators*** 6:444-457.

<u>*Abstract taken directly from text*</u>

Among the many approaches to ecological indicators, ecological indicators derived from the floristic composition of a site (i.e. Raunkiaer's forms spectrum or the percentage of different geographical distribution types-chorotypes) are well established in botanical and ecological literature. Nonetheless their relationship with other indicators, such as Ellenberg's ecological indicators, or the Grime model [Grime, J.P., 2002. Plant Strategies, Vegetation Processes and Ecosystem Properties. Wiley, Chichester] and the Hemeroby index [Kowarik, I., 1990. Some responses of flora and vegetation to urbanization in Central Europe. In: Sukopp, H., Hejny, S., Kowarik, I. (Eds.), Urban Ecology. Plants and plant communities in urban environments. SPB Academic Publishing, The Hague] is still poorly explored. We concentrated on an urban ecosystem because such areas, due to their high degree of artificialization, are particularly well suited for studying the interaction of anthropical disturbance with other processes of the ecosystems. This paper attempts to select a small indicator frameset of many already proposed indicators which best express the variability of the sites studied. A floristic-ecological investigation has been carried out in 10 urban sites, of which 6 were archeological, located in the centre of Rome and 4 suburban, semi-natural, in the NE of the town. Ecological indicators have been calculated on this data set. The Pearson correlation test was then applied to verify whether the indicators were independent, while stepwise regression analysis was done to evaluate the statistical weight of each eco-indicator. Disturbance and temperature are the main factors shaping the composition of the sites studied. They are largely interacting and are well expressed with the help of a small subset of the initial set of 19 indicators, namely, by indicators related to life forms and to the geographical distribution of species: Therophytes/Hemicryptophytes, Mediterranean/large distribution, Eurasiatic/ large distribution, Mediterranean/Eurasiatic species. The information provided by Ellenberg's indicators values and Grime's life strategies are largely summarized by these chorological indicators.

Franzle, O. 2006. Complex bioindication and environmental stress assessment. ***Ecological Indicators*** 3:114-136.

<u>*Abstract taken directly from text*</u>

The indicative quality of bio-indicators, ranging from organelles, organs or single organisms to complex ecosystems, depends on inherent ecophysiological properties, population dynamics, and stress reactions with regard to physical and chemical changes in site conditions as described in Section 2 of the present contribution. Section 3 provides a systematic review of both typology and rational selection of bio-indicators on the species, population, biocenotic, and ecosystem levels. It is to show that the primary task of bio-indicators is the general determination of physiological effects in the sense of strain reactions rather than the direct measurement of environmental concentrations of stressors. Thus, in early recognition perspective the lack of specificity has the advantage of a broad-based caveat, inducive to subsequent systematic search for quantitative causal inter-relationships. A further advantage of bio-monitoring is its comparatively low cost on the one hand and the integrative recording character on the other. Contrary to these positive aspects of bio-indicator use there is, however, an essential deficiency resulting from the highly variable susceptibility of the test species exposed to stressors, which leads to difficulties in comparing specific effect data. In view of such problems, the possibilities of fuzzy logic approaches for evaluative data interpretation and inter- and intraspecific comparison purposes are emphasized. Active and passive bio-monitoring approaches on the basis of single-species reactions yield spatially valid data only on condition the underlying sampling networks are implemented in compliance with geostatistical requirements or the corresponding test methodologies of variogram analysis and kriging procedures, respectively. Analogously, also the selection of complex bio-indicators such as biocenoses or ecosystems must be based on rigid criteria of spatial and temporal representativeness. The last section then is a critical comparative appraisal of the problems encountered in bio-monitoring, which leads to a set of suggestions for improving both the technical practicability and the data quality of bio-monitoring approaches.

Gray, A. N. and D. L. Azuma. 2005. Repeatability and implementation of a forest vegetation indicator. ***Ecological Indicators*** 5:57-71.

<u>*Abstract taken directly from text*</u>
The composition, diversity, and structure of vascular plants are important indicators of forest health. Changes in species diversity, structural diversity, and the abundance of non-native species are common national concerns, and are part of the international criteria for assessing sustainability of forestry practices. The vegetation indicator for the national Forest Inventory and Analysis (FIA) Program, USA, was designed to assess these issues. The objectives of this study were to: (1) assess the repeatability and practicality of the vegetation field techniques using independent measurements of 48 plots by two botanists and (2) examine the interpretation of forest health indicators from 2 years of data collected on 110 plots in the state of Oregon. Plant identification was similar for both botanists, with 80% of all plant species on the plot being identified to species, and another 14% identified to the genus level; the greatest problems were in dry forest types where plants had senesced by July. Agreement among botanists for species identification was 71% at the subplot level and 67% at the quadrat level, with many differences caused by plants being identified as closely related species, usually in the same genus. As a result, agreement between botanists on species richness and the abundance of non-native species was high, with correlation coefficients of 0.94 and 0.98, respectively. Quadrats detected only 20% of the species found from the subplot search, on average. Although botanists differed in their speed, 22% of subplot searches were completed within 15 min and 71% were completed within 30 min. Dramatic differences in patterns of plant diversity were found across the ecological regions of Oregon, with high plot richness and the highest species turnover among plots found in the Blue Mountains. Abundance of non-native species varied from 15% of the species in juniper (Juniperus occidentalis Hook.) stands to 1% in high-elevation conifer stands. The proportion of cover made up of non-native species was highest in juniper and Ponderosa pine (Pinus ponderosa P. & C. Lawson) forest types. Numbers of non-native species on a plot increased with the number of native species, but the relationship was weak (R2 = 0.09). Results suggest that the vegetation indicator provides a robust and valuable tool for assessing forest health.

Johnson, G. D. and G. P. Patil. 1999. Quantitative Multiresolution Characterization of Landscape Patterns for Assessing the Status of Ecosystem Health in Watershed Management Areas. ***Ecosystem Health*** 4:177-187.

<u>*Abstract taken directly from text*</u>
Landscape ecology is a field that has grown from realizing that maintenance of ecological resources requires management at several spatial and temporal scales, including landsape-level ecosystems as whole units of study and management. The subsequent need for characterizing landscape structure has led to a variety of measurements for assessing different aspects of spatial patterns; however, most of these measurements are known to depend on both the spatial extent of a specified landscape and the measurement grain. Therefore, measurements that incorporate a range of scales would be most

informative. In response, this article introduces a new method for obtaining a multi-resolution characterization of land cover fragmentation patterns within a fixed geographic extent. The method applies the concept of conditional entropy as one moves from larger "parent" land cover pixels to smaller "child" pixels that are hierarchically nested within the parents pixels. When applied over a range of resolutions, one obtains a "conditional entropy profile." The conceptual and methodological development of conditional entropy profiles is presented, followed by current and future directions for evaluating and applying this methodology.

Jorgensen, S. E. 2006. Application of holistic thermodynamic indicators. ***Ecological Indicators*** 6:24-29.

Abstract taken directly from text
The paper proposes to use eco-exergy, specific eco-exergy = eco-exergy/biomass and ecological buffer capacities as ecological indicators for ecosystem development and health. After definitions of these three concepts, it is shown that the attributes for ecosystem development proposed by von Bertalanffy and E.P. Odum and six descriptors of ecosystem health proposed by Costanza are covered by three types of ecosystem growth forms: growth of biomass, network and information. As it has been shown that eco-exergy increases with all three growth forms, eco-exergy seems a good candidate for a holistic indicator of ecosystem development and health. By supplementing eco-exergy with specific eco-exergy and buffer capacity, we obtain also direct indication of the level of information, respectively, the resistance of the ecosystem to perturbations.

Lausch, A. and F. Herzog. 2002. Applicability of landscape metrics for the monitoring of landscape change: issues of scale, resolution and interpretability. ***Ecological Indicators*** 2:3-15.

Abstract taken directly from text
In most parts of the world, land-use/land cover can be considered an interface between natural conditions and anthropogenic influence. Indicators are being sought which reflect landscape conditions, pressures and related societal responses. Landscape metrics, which are based on the number, size, shape and arrangement of patches of different land-use/land cover types, are used-together with areal statistics-to quantify landscape structure and composition. The applicability of landscape metrics for landscape monitoring has been investigated in a 700 km^2 test region in eastern Germany, where open cast coal mining has caused far reaching land-use changes in the course of this century. Time series of maps (1912–2020) have been elaborated from various data sources (topographic maps, aerial photography, satellite images, prospective planning material). Landscape metrics have been calculated for the entire test region and for ecologically defined sub-regions at the landscape, class and patch level. The results are presented and methodological issues are addressed, namely the impact of scale, spatial and temporal resolution on the interpretability of landscape metrics. Critical issues are: 1) the application of remote sensing methods, which is a pre-requisite for the area-wide monitoring of land-use change; 2) standardised data processing techniques, which are vital for the spatial and temporal comparability of results; 3) the selection of a manageable set of indicators which embraces the structural properties of landscapes; 4) the choice of appropriate spatial units which allow for an integration of landscape indicators (which tend to relate to cross-border phenomena) and socio-economic indicators (which are usually available for administrative entities or areas). These issues are discussed in relation to the application of landscape indices in environmental monitoring.

Lindenmayer, D. B., C. R. Margules and D. B. Botkin. 2000. Indicators of Biodiversity for Ecologically Sustainable Forest Management. ***Conservation Biology*** 14:941-950.

Abstract taken directly from text
The conservation of biological diversity has become one of the important goals for managing forests in an ecologically sustainable way. Ecologists and forest resource managers need measures to judge the success or failure of management regimes designed to sustain biological diversity. The relationships between potential indicator species and total biodiversity are not well established. Carefully designed

studies are required to test relationships between the presence and abundance of potential indicator species and other taxa and the maintenance of critical ecosystem processes in forests. Other indicators of biological diversity in forests, in addition or as alternatives to indicator species, include what we call structure-based indicators. These are stand-level and landscape-level (spatial) features of forests such as stand structural complexity and plant species composition, connectivity, and heterogeneity. Although the adoption of practises to sustain (or recreate) key characteristics of forst ecosystems appears intuitively sensible and broadly consistent with current knowledge, information is lacking to determine whether such stand- and landscape-level features of forests will serve as successful indices of (and help conserve) biodiversity. Givenour limited knowledge of both indicator species and structure-based indicators, we advocate the following four approaches to enhance biodiversity conservation in forests: (1) establish biodiversity priority areas (e.g., reserves) managed primarily for the conservation of biological diversity; (2) within production forests, apply structure-based indicators including structural complexity, connectivity, and heterogeneity; (3) using multiple conservation strategies at multiple spatial scales, spread out risk in wood production forests; and (4) adopt an adaptive management approach to test the validity of structure-based indices of biological diversity by treating management practices as experiments. These approaches would aim to provide new knowledge to managers and improve the effectiveness of current management strategies.

Loh, J. and D. Harmon. 2005. A global index of biocultural diversity. ***Ecological Indicators*** 5:231-241.

Abstract taken directly from text
The relationships between biological and cultural diversity are drawing increasing attention from scholars. Analyses of these relationships are beginning to crystallize around the concept of biocultural diversity, the total variety exhibited by the world's natural and cultural systems. Here, we present the first global measure of biocultural diversity, using a country-level index. The index is calculated using three methods: an unadjusted richness measure, one adjusted for land area, and one adjusted for the size of the human population. The adjusted measures are derived from the differences between observed and expected diversity values. Expected diversity was calculated using the species–area relationship. The index identifies three areas of exceptional biocultural diversity: the Amazon Basin, Central Africa, and Indomalaysia/Melanesia.

Ludwig, J. A., N. Hindley and G. Barnett. 2003. Indicators for monitoring minesite rehabilitation: trends on waste-rock dumps, northern Australia. ***Ecological Indicators*** 3:143-153.

Abstract taken directly from text
Minesite rehabilitation needs to be monitored with easily measured indicators so that trends can be plotted and assessed over time to address closure criteria. Our aim was to evaluate two traditional vegetation indicators used in woodlands and forests (tree composition and size), and two new landscape surface indicators (integrity of rip-lines and a nutrient cycling index), as well as a new habitat complexity index. We measured these five indicators on rehabilitated waste-rock dumps of differing ages on two mines in northern Australia, and compared these measures to those for nearby natural savannas. Our results confirm that tree composition and size were useful traditional indicators of vegetation development on rehabilitation because trends were towards that expected for nearby savannas. Surface roughness, as indicated by rip-lines, was also a useful indicator of the potential for a landscape to retain resources because these rip-lines persisted until vegetation was well established to assume this role. As this vegetation developed, soil surface condition, as indicated by a nutrient cycling index, also progressed towards values found on nearby natural savannas. A habitat complexity index suggested that older rehabilitation sites were developing the structural features needed by fauna. Although our findings need to be confirmed for other mines and for older sites, they do suggest that these five ecological indicators are useful for monitoring mine site rehabilitation.

Malkina-Pykh, I. G. M. 2002. Integrated assessment models and response function models: pros and cons for sustainable development indices design. ***Ecological Indicators*** 2:93-108.

Abstract taken directly from text
Systems constituting sustainable development (SD) concepts are complex systems. A systems analysis approach, with models as a primary tool, is the most appropriate way to investigate SD phenomena in general and its complex systems in particular. Indicators and indices as a communication tool between scientists and decision-makers should be linked to SD models. This article presents the general analysis of the systems approach and model approaches for the development of SD indicators and indices. Integrated assessment models (with TARGET 1.0 as an example) and response function models were examined from the point of their applicability for SD indicators and indices design. It is shown that we should create SD models, which will allow researchers to obtain indices as the direct output of the models. The model of ecosystem pesticide contamination (PESTMOD) is given as an example of the successful application of the model for the development of ecosystem's resilience index (ERI).

Mander, U., F. Muller and T. Wrbka. 2005. Functional and structural landscape indicators: Upscaling and downscaling problems. ***Ecological Indicators*** 5:267-272.

Abstract taken directly from text
Evaluation of nature is an inseparable part of the process of environmental planning, management and decision-making. In the last decades its importance has reached a global level. At local and regional levels, landscape assessment for planning and decision making processes is a key issue pertaining to sustainable landscape management. Various indicator models for evaluating performance functions of landscapes are widely used in landscape planning and management. However, due to the large variety of landscape functions and possible indicators it is not easy for end-users of the landscape assessment to identify the optimal solutions. One of the well-known conceptual frameworks for ecological/environmental indicators is the driving forces (Drivers): Pressures, State, Impact, Responses (DPSIR) approach, which treats the environmental management process as a feedback loop controlling a cycle consisting of these five stages. Taking the DPSIR approach as conceptual background, w consider landscape indicators as a system of structural and functional parameters that can be used to evaluate landscape pressures, states and responses

Manoliadis, O. G. 2002. Development of ecological indicators - a methodological framework using compromise programming. ***Ecological Indicators*** 2:169-176.

Abstract taken directly from text
Ecological assessments often rely on indicators to evaluate environmental conditions. An ecological indicator integrates discrete pieces of information representing condition of resources, magnitude of stresses, exposure of biological components to stress and related impacts and consequences. This paper describes our efforts to develop an ecological indicator based on information routinely collected during irrigation systems operation from projects in Greece. Compromise programming is used for the development of ecological indicators. The indicators can be used for decision making in order to evaluate different irrigation policies for irrigation water management when the water is limited. The results of the alternative policies are compared and conclusions for the application of the methodology are drawn. The study indicated that ecological indicators could be incorporated to select alternatives concerning water delivery. Conclusively, the methodology can be incorporated in ecological assessment and program studies.
Mendoza, G. A. and R. Prabhu. 2003. Fuzzy methods for assessing criteria and indicators of sustainable forest management. ***Ecological Indicators*** 3:227-236.

Abstract taken directly from text
This paper describes the general concepts, meaning, and definitions of sustainability and proposes the use of soft methodologies, particularly fuzzy set theory, for its assessment. Criteria and indicators (C&I) are described as instruments to assess forest sustainability. Basic elements and concepts of fuzzy sets are described, including membership functions and their interpretations in the context of sustainable forest management. Moreover, fuzzy operators that can combine the operational concepts of

sustainability, namely criteria and indicators are described. A simple illustrative example is described to demonstrate the application of these methodologies.

Miller, S. J. and D. H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. ***Ecological Indicators*** 6:313-326.

Abstract taken directly from text

The floristic quality assessment index (FQAI) is an evaluation procedure that uses measures of ecological conservatism (expressed numerically as a coefficient of conservatism or C value) and richness of the native plant community to derive a score (I) that is an estimate of habitat quality. We evaluated the ability of the FQAI to indicate the level of anthropogenic disturbance in headwater wetlands in the Ridge and Valley physiographic province of central Pennsylvania. I scores were highly correlated with disturbance, with scores generally decreasing with increasing levels of disturbance. However, we found that I did not equally characterize sites with differing species richness. I scores were higher for sites with greater intrinsic native species, regardless of other influences on floristic quality. To eliminate sensitivity to species richness, we evaluated sites using mean conservatism values (C) and a variant of the I' score (adjusted FQAI, hereafter cited as I') that considered both the contribution of non-native species and the intrinsic low species richness of high quality forested wetlands. C values were more highly correlated with disturbance than I scores; however, site assessments based on C values alone were misleading. I' scores were also more highly correlated with disturbance than I scores and were robust to differences in native species richness. Therefore, we offer I' as an improved formulation of the index that, in addition to serving as a useful condition assessment tool, addresses two problematic issues that have plagued the FQAI since its conception: the overwhelming influence of the species richness multiplier and the role of non-native species in floristic assessment.

Miller, S. J., D. H. Wardrop, W. M. Mahaney and R. P. Brooks. 2006. A plant-based index of biological integrity (IBI) for headwater wetlands in central Pennsylvania. ***Ecological Indicators*** 6:290-312.

Abstract taken directly from text

Vascular plants are quickly emerging as one of the best indicators of human-mediated disturbances in the environment. We developed a plant-based index of biological integrity (IBI) to evaluate headwater wetland condition in response to anthropogenic disturbances in the Ridge and Valley Physiographic Province of central Pennsylvania. To construct the IBI, we evaluated 50 attributes of the plant community, including species richness, diversity, and evenness. Disturbance was quantified for each site using information on surrounding land use, buffer characteristics, and an assessment of potential site stressors. Ecological dose–response curves were then plotted to evaluate the relationship between each attribute and the disturbance score. Eight attributes showed a consistent and strong response to disturbance and were selected as metrics: adjusted FQAI, % cover of tolerant plant species, % annual species, % non-native species, % invasive species, % trees, % vascular cryptogams, and % cover of *Phalaris arundinacea*. All metrics were highly and significantly correlated ($P < 0.001$) with disturbance as were IBI scores. To test the IBI, we used data from 47 sites collected as part of the Juniata Wetland Monitoring Project. The metrics and IBI scores for this data set were also significantly correlated with disturbance. Although, to date, very few plant-based IBIs are in use, studies from Minnesota, Massachusetts, and Ohio, as well as our study in Pennsylvania demonstrate the efficacy of plant community measures in assessing the overall condition of wetlands.

Moffatt, S. F. and S. M. McLachlan. 2004. Understorey indicators of disturbance for riparian forests along an urban-rural gradient in Manitoba. ***Ecological Indicators*** 4:1-16.

Abstract taken directly from text

Extensive agricultural and urban development has contributed to the decline of riparian forests across North America. An urban–rural gradient was used to identify species- and guild-level indicators of riparian forest degradation in southern Manitoba. Twenty-five sites were categorized according to urban, suburban, high-intensity rural, low-intensity rural, and relatively high quality reference land use.

Generalists, which frequented all land use types, dominated (69%) the understorey community, whereas opportunistic (15%) and vulnerable (16%) species were relatively less common. Opportunistic species, which characterized city sites, tended to be exotic, woody and annual, and effective dispersers (i.e., endozoochores). In contrast, vulnerable species, which characterized non-city sites, tended to be native, perennial, and ineffective dispersers (i.e., barochores or anemochores). Indicators of disturbed forests were opportunistic and positively associated with disturbance measures including connectivity and cover of garbage, and negatively correlated with native and overall diversity. They included exotics *Solanum dulcamara*, *Rhamnus cathartica*, and *Lonicera tartarica*. In contrast, indicators of high-integrity forest were vulnerable, often excluded from urban sites and were negatively associated with disturbance measures and positively correlated with native and overall diversity. They included natives *Rubus idaeus*, *Carex* spp., and *Galium triflorum*. Our results suggest that opportunistic and vulnerable species, and their associated guilds, can be used as effective indicators of disturbance and forest integrity and to identify forest patches that warrant further protection or restoration.

Muller, F. 2005. Indicating ecosystem and landscape organisation. ***Ecological Indicators*** 5:280-294.

<u>*Abstract taken directly from text*</u>
This paper presents a brief outline of the theoretical and conceptual fundamentals for the derivation of an ecosystem oriented indicator system to demonstrate the state of ecological entities on a holistic basis. There are two branches of argumentation: on a normative level, the sustainability principle is interpreted from an anthropocentric point-of-view; sustainability in this context means to provide ecosystem services on a broad scale and a long-term basis, including the attempt to avoid unspecific ecological risks. A second line-of-argumentation bases on the principles of ecosystem analysis and the theory of ecological orientation. Consequently, the aspired indicandum is the self-organising capacity of ecosystems, and the indicator sets represents an aggregate of structural and functional ecosystem features in a developing environment. The indicator set is demonstrated by one case study from the Bornhoeved Lakes ecosystem research project.

Muller, F. and R. Lenz. 2006. Ecological indicators: Theoretical fundamentals of consistent applications in environmental management. ***Ecological Indicators*** 6:1-5.

<u>*Abstract not available [excerpts directly from text]*</u>
Ecosystem theory and environmental practice have been separated by many factors and frontiers, although both sides could benefit from a closer linkage and a better communication. Practitioners often do not follow the deep analyses of theoretical fundamentals, although they feel the need of underpinning their concepts and approaches by theories. On the other hand, scientists are not primarily interested in applications, but in falsifying or quantifying their hypotheses. Hence, there is a permanent need to “update” or improve assessment processes and applications in environmental management by reviewing and interpreting theoretical fundamentals. In 2003, scientists from Australia, the USA and a number of European countries discussed development in the area of ecological indicators and indications.

Niemi, G. J., J. M. Hanowshi, A. R. Lima, T. Nicholls and N. Weiland. 1997. A Critical Analysis on the Use of Indicator Species in Management. ***Journal of Wildlife Management*** 61:1240-1252.

<u>*Abstract taken directly from text*</u>
We examined the habitat distributions of management indicator and sensitive species (MIS), as defined by the U.S. Forest Service within the Chequamegon National Forest (CNF) of northern Wisconsin and whether other bird species were positively associated with these MIS. We addressed these associations with 2 relatively large databases, annual breeding bird counts of 92 line transect segments gathered from 1986 to 1992 and counts of 122 “Forest Stands” gathered in 1992-1993. Of 25 MIS identified by the CNF, only 7 species were abundant enough for analyses. The other species were either too rare within the CNF or the censusing methods were not compatible with their life history. Only 2 of the MIS had nonrandom distributions associated with specific habitat types and warranted consideration as indicators. The yellow-bellied flycatcher (*Empidonax flaviventris*) was found primarily in lowland coniferous habitats,

while the pine warbler (*Dendroica pinus*) was found primarily in upland coniferous habitats especially pine. Although many positive species associations were found for most of the MIS, many inconsistencies among the 2 datasets also were identified. Most species responded to habitat attributes that satisfy their needs for survival and these autecological responses likely led to inconsistent patterns of species associations for most of the MIS. The lack of consistent patterns among most MIS casts doubt on the ability to use a few species as indicators for the well-being of many other species, especially for those that are uncommon and difficult to monitor. Developing more comprehensive techniques that improve habitat classifications and combine monitoring of trends in habitat and birds within those habitats likely will prove more fruitful than focusing on a few "representative" species.

Niemi, G. J. and M. E. McDonald. 2004. Application of Ecological Indicators. ***Annual Review of Ecology, Evolution and Systematics*** 35:89-111.

Abstract taken directly from text
Ecological indicators have widespread appeal to scientists, environmental managers, and the general public. Indicators have long been used to detect changes in nature, but the scientific maturation in indicator development primarily has occurred in the past 40 years. Currently, indicators are mainly used to assess the condition of the environment, as early-warning signals of ecological problems, and as barometers for trends in ecological resources. Use of ecological indicators requires clearly stated objectives; the recognition of spatial and temporal scales; assessments of statistical variability, precision, and accuracy; linkages with specific stressors; and coupling with economic and social indicators. Legislatively mandated use of ecological indicators occurs in many countries worldwide and is included in international accords. As scientific advancements and innovation in the development and use of ecological indicators continue through applications of molecular biology, computer technology such as geographic information systems, data management such as bioinformatics, and remote sensing, our ability to apply ecological indicators to detect signals of environmental change will be substantially enhanced.

O'Connell, T. J., J. A. Bishop and R. P. Brooks. 2007. Sub-sampling data from the North American Breeding Bird Survey for application to the Bird Community Index, an indicator of ecological condition. ***Ecological Indicators*** 7:679-691.

Abstract taken directly from text
We examined the use of data from the North American Breeding Bird Survey (BBS) for assessments of ecological condition using an avian community-based indicator, the Bird Community Index (BCI). In previous research, the BCI was developed and applied to a random sample of sites in the Mid-Atlantic Highlands. The goal of providing national scale assessments with bird community indicators hinges on a demonstration that existing monitoring programs, like the BBS, can be tapped as source data for the indicators. Our goal was to compare a BBS-based assessment of the Mid-Atlantic Highlands to our original assessment based on random sampling locations. We sub-sampled three iterations of BBS route data from the study area to account for spatial and temporal scale differences between 40 km BBS routes and the original 1 km transects sampled to develop the BCI. All three iterations of BBS subsamples provided lower overall assessments of ecological condition for the Mid-Atlantic Highlands relative to our original research. Land cover analysis, however, revealed that BBS routes sampled land cover types in proportion to their actual prevalence in the region. Thus, we conclude that BBS data are appropriate as source data for broad scale ecological assessments with indicators such as the BCI. For numerous analytical and logistical reasons, we recommend 10-stop subsamples of BBS data as the preferred scale at which to apply bird community indicators of ecological condition.

Oliver, I. 2002. An expert panel-based approach to the assessment of vegetation condition within the context of biodiversity conservation Stage 1: the identification of condition indicators. ***Ecological Indicators*** 2:223-237.

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Abstract taken directly from text
Vegetation condition assessment has recently become a major priority for Australian agencies and organisations responsible for integrated natural resource management. However, despite widespread acknowledgement of the importance of vegetation condition, there is little agreement as to how assessments should be conducted. This paper documents the process and results generated by the initial phases of a study designed to develop a repeatable and defensible approach to site-based assessment of vegetation condition within the context of species-level biodiversity conservation. The approach uses site-based indicator data to quantify the capacity of existing areas of vegetation to provide habitat and resources for indigenous plants and animals. The study makes use of the Delphi approach for structuring an e-mail-based group communication process dedicated to the identification of potential site-based indicators of condition. Through an iterative process involving 47 Australian experts, the study identified 62 potential indicators of vegetation condition. The indicators were equally representative of compositional (21), structural (20), and functional (21) attributes of biodiversity [Conserv. Biol. 4 (1990) 355]. The indicators reported here will, in later stages of the study, be prioritised for importance and feasibility and the resultant prioritised sub-set will then be incorporated into a site-based approach to vegetation condition assessment. This approach and the indicators reported may assist other Government agencies or groups tackling the specific task of vegetation condition assessment, or more generally, planning to use expert panels in natural resource management applications.

Olsen, A. R., J. Sedransk, D. Edwards, C. A. Gotway, W. Liggett, S. Rathbun, K. H. Reckhow and L. J. Young. 1999. Statistical Issues for Monitoring Ecological and Natural Resources in the United States. ***Environmental Monitoring and Assessment*** 54:1-45.

Abstract taken directly from text
The United States funds a number of national monitoring programs to measure the status and trends of ecological and natural resources. Each of these programs has a unique focus; the scientific objectives are different as are the sample designs. However, individuals and committees, all well aware of the cost of ecological monitoring, have called for more effective monitoring programs. The objective of this paper is to summarize existing programs' statistical designs and discuss potential alternatives for improvement in national monitoring. Can we improve the current situation by providing an overall framework for the design or analysis of data from these disparate surveys? First, the paper summarizes the objectives of these surveys, compares and contrasts their survey designs as currently implemented, and determines what variables they collect. Through this process we identify commonalities and issues that impact our ability to combine information across one or more of the surveys. Three potential alternatives are presented, leading to comprehensive monitoring in the United States.

O'Neill, R. V., J. R. Krummel, R. H. Gardner, G. Sugihara, B. Jackson, D. L. DeAngelis, B. T. Milne, M. G. Turner, B. Zygmunt, S. W. Christensen, V. H. Dale and R. L. Graham. 1988. Indices of landscape pattern. ***Landscape Ecology*** 1:153-162.

Abstract taken directly from text
Landscape ecology deals with the patterning of ecosystems in space. Methods are needed to quantify aspects of spatial pattern that can be correlated with ecological processes. The present paper develops three indices of pattern derived from information theory and fractal geometry. Using digitized maps, the indices are calculated for 94 quadrangles covering most of the eastern United States. The indices are shown to be reasonably independent of each other and to capture major features of landscape pattern. One of the indices, the fractal dimension, is shown to be correlated with the degree of human manipulation of the landscape.

Orfanidis, S., P. Panayotidis and N. Stamatis. 2003. An insight to the ecological evaluation index (EEI). ***Ecological Indicators*** 3:27-33.

Abstract taken directly from text
The ecological evaluation index (EEI) was designed to estimate the ecological status of transitional and coastal waters. Marine benthic macrophytes (seaweeds, seagrasses) were used as bioindicators of ecosystem shifts due to anthropogenic stress, from the pristine state with late-successional species (high ecological status class (ESC)) to the degraded state with opportunistic species (bad ESC). The relation of EEI to function and to resilience of the marine ecosystem, and its possibility for comparing and ranking at local, national and international levels are some of its main management implications.

Padoa-Schioppa, E., M. Baietto, R. Massa and L. Bottoni. 2006. Bird communities as bioindicators: The focal species concept in agricultural landscapes. ***Ecological Indicators*** 6:83-93.

Abstract taken directly from text
The use of bioindicators as a tool in conservation and landscape ecology projects is becoming more widespread. We suggest objective criteria for selecting suitable focal species to identify important semi-natural elements in agricultural landscapes and provide quality indications at two different spatial scales. At a broad scale, focal species can indicate overall landscape quality, and species abundance data allow an environment suitability map to be drawn. At a local scale, focal species abundances can be related to structural characteristics of landscape elements, thus, providing valuable indications of the most effective locations for restoration projects.

Papadimitriou, F. 2002. Modelling indicators and indices of landscape complexity: an approach using G.I.S. ***Ecological Indicators*** 2:17-25.

Abstract taken directly from text
The study of complex environmental systems steadily gains momentum in the domain of environmental sciences. The complexity of landscapes, however, still lacks a proper definition, as well as a straightforward method for its calculation. The assessment of landscape complexity is indeed a difficult undertaking and research results hitherto published in the scientific literature demonstrate that several problems arise when the structural (quantitative) and the functional (qualitative) aspects of landscapes are considered to assess their complexity. With this paper, a straightforward method is proposed for deriving indicators of landscape complexity. This method relies on the identification of three key indicators which are necessary to describe landscape complexity: diversity, fractality and function. Three rules are given for applying these indicators to the study of landscape complexity. These three indicators are subsequently used to derive an index of structural and an index of functional landscape complexity (IS and IF, respectively). Example calculations of landscape complexity are given, based on a model landscape. Using a G.I.S., it is demonstrated that a distinction should be made between the concept “complexity of landscape change” and the concept “change in the landscape complexity”. The usefulness of G.I.S. for studying landscape structural complexity is significant for calculating IS and IF indices, albeit restricted by their limited topological capabilities for handling boundary calculations between adjacent land units.

Patil, G. P., R. P. Brooks, W. L. Myers, D. J. Rapport and C. Taillie. 2001. Ecosystem Health and Its Measurement at Landscape Scale: Toward the Next Generation of Quantitative Assessments. ***Ecosystem Health*** 7:307-316.

Abstract taken directly from text
The purpose of this paper is twofold: (A) to describe the challenges of reporting on changes in ecosystem health at landscape scales, and (B) to review the statistical and mathematical techniques that allow the derivation of landscape health assessments from a variety of data consisting of remote sensing imagery, demographic and socioeconomic censuses, natural resource surveys, long-term ecological research, and other geospatial information that is site specific. We draw upon seven innovative and integrative concepts and tools that together will provide the next generation of ecosystem health assessments at regional scales. The first is the concept of ecosystem health, which integrates across the social, natural, physical, and health sciences to provide the basis for comprehensive assessments of regional environments. The

second consists of innovative stochastic techniques for representing human disturbance and ecosystem response in landscapes, and the corresponding statistical tools for analyzing them. The third constitutes representation of spatial biocomplexity in landscapes through application of echelon analysis assessment. The fourth concerns combination techniques of upper-echelon-based spatial scan statistic to detect, delineate, and prioritize critical study areas for evaluating and prioritizing causal factors and effects. The fifth involves the capability of comparing and prioritizing a collection of entities in light of multiple criteria, using poset mathematics of partial order with rank frequency statistics, to provide multicriterion decision support. The sixth lies in extending data mining and visualization techniques to determine associations between geospatial patterns and ecosystem degradation at landscape scales. The seventh encompasses comprehensive studied conducted on different types of regional ecosystems. Our focus is to show how the integration of recent advances in quantitative techniques and tools with facilitate the evaluation of ecosystem health and its measurement at a variety of landscape scales. The challenge is to characterize, evaluate, and validate linkages between socioeconomic drivers, biogeochemical indicators, multiscale landscape pattern metrics, and quality of human life indicators. Initial applications of these quantitative techniques and tools have been with respect to regions in the eastern United States, including the U.S. Atlantic Slope and mid-Atlantic region.

Patil, G. P. and W. L. Myers. 1999. Environmental and Ecological Health Assessment of Landscapes and Watersheds with Remote Sensing Data. ***Ecosystem Health*** 5:221-224.

Abstract not available [excerpts directly from text]
In this special issue of *Ecosystem Health*, we focus on the new generation of techniques and analyses that permit broad-scale, geographically based assessments of ecological conditions. These techniques, including important recent advances in applications of GIS and remote sensing imagery, will, we believe, prove invaluable for advance in ecosystem health. Evolution of NASA's remote sensing programs in concert with international counterparts has now laid solid groundwork for a greatly expanded role of remote sensing in the monitoring of ecosystem health. Resolution, frequency of coverage, cost, and procurement are not the only concerns with respect to use of remotely sensed data seldom constitute a complete information source for ecosystem analysis. Improvements in these respects will not necessarily translate to substantially improved monitoring and assessment unless we learn better ways of incorporating pixelized spectral data into multitiered analysis that integrates intensive site studies, distributed sample plots, and various partial coverages from remote sensors at different resolutions and different times. Contributions to this special issue explore and illustrate several of the ways in which remotely sensed data can be mobilized for environmental and ecological assessment of landscapes and watersheds.

Pearman, P. B. and D. Weber. 2007. Common species determine richness patterns in biodiversity indicator taxa. ***Biological Conservation*** 138:109-119.

Abstract taken directly from text
Identification of spatial patterns of species diversity is a central problem in conservation biology, with the patterns having implications for the design of biodiversity monitoring programs. Nonetheless, there are few field data with which to examine whether variation in species richness represents consistent correlations among taxa in the richness of rare or common species, or the relative importance of common and rare species in establishing trends in species richness within taxa. We used field data on three higher taxa (birds, butterflies, vascular plants) to examine the correlation of species richness among taxa and the contribution of rare and common species to these correlations. We used graphical analysis to compare the contributions to spatial variation in species richness by widely-distributed ('common') and sparsely-distributed ('rare') species. The data came from the Swiss Biodiversity Monitoring Program, which is national in scope and based on a randomly located, regular sampling grid of 1 km^2 cells, a scale relevant to real-world monitoring and management. We found that the correlation of species richness between groups of rare and common species varies among higher taxa, with butterflies exhibiting the highest levels of correlation. Species richness of common species is consistently positively correlated among these three taxa, but in no case exceeded 0.69. Spatial patterns of species richness are

determined mainly by common species, in agreement with coarse resolution studies, but the contribution of rare species to variation in species richness varies within the study area in accordance with elevation. Our analyses suggest that spatial patterns in species richness can be described by sampling widely distributed species alone. Butterflies differ from the other two taxa in that the richness of red-listed species and other rare species is correlated with overall butterfly species richness. Monitoring of butterfly species richness may provide information on rare butterflies and on species richness of other taxa as well.

Peng, C., J. Liu, Q. Dang, X. Zhou and M. Apps. 2002. Developing carbon-based ecological indicators to monitor sustainability of Ontario's forests. ***Ecological Indicators*** 1:235-246.

Abstract taken directly from text

With 2% of the world's forests and 17% of Canada's forested land, Ontario plays a major role in maintaining Canada's forests and managing them sustainably. Ontario is developing a set of criteria and indicators of sustainable forest management (SFM) to aid in conservation and sustainable management of its temperate and boreal (BO) forests. The criteria and indicators are intended to provide a framework for describing and assessing processes of SFM at a regional scale; and to improve the information available to the public and decision-makers. This paper describes three ecological indicators, evaluated using a carbon (C) budget model, a forest inventory database, and disturbance records to assess long-term sustainability of Ontario's forest ecosystems based on the environmental conditions of the past 70 years. Results suggest that total net primary productivity (NPP) of Ontario's forest ecosystems increased from 1925 to 1975 and then decreased between 1975 and 1990; Ontario's forest ecosystems acted as a C sink between 1920 and 1980, and a C source from 1981 to 1990, mainly due to decreased average forest age and NPP caused by increased ecosystem disturbance (e.g. fire, insect and disease infestations, harvesting) since 1975. Current estimates from this analysis suggest that there is significant potential for Ontario's forests to function as C sinks by reducing ecosystem disturbances and increasing growth and storage of C in the young forests throughout the province.

Popp, J., D. Hoag and D. E. Hyatt. 2001. Sustainability indices with multiple objectives. ***Ecological Indicators*** 1:37-47.

Abstract taken directly from text

One of the many debates about sustainability centers on how a natural resource stock (e.g. a forest) generates flows of desired human services (such as lumber and recreation). Should resources be sustained as they currently exist or should the services that they provide be sustained? This is a difficult question to address since there is very little quantitative information available. The purpose of this study was to address this question by using information from an empirical study that was able to look at sustainability when there is one output and extend that framework to a multi-objective setting. We then discuss the framework by using a multi-objective resource, the Neuse River in North Carolina. We identified several concepts from the single objective study, including that there are at least three important types of resource stocks, two types of goals, substitutes for natural resources, and a need to consider uncertainty and reversibility. An index of resource quality was used in a production model, which also allowed substitution of manufactured inputs to achieve the sustainability objective over long periods of time. The relationship between resource quality, manufactured inputs and output over time proved critical to meeting sustainability definitions and varied from one resource to another. When we expanded the framework, we found that constructing indices for one resource output might reveal that it is positively or negatively correlated to another output. For example, an index for drinking water might be made better through an indicator that is a positive, or negative, input into another index such as fishability. Sustainability should consider what is being sustained - i.e. stock, flow or something else, and be inclusive enough to account for multiple services, lest governments will under fund conservation (when services are positively correlated) or waste money by competing one objective against another (when they are negatively correlated) - addressing one objective through some policy requires more money in another government program to fix a problem that the first program caused. It should also be dynamic to allow for changes in relationships over time.

Purtauf, T., C. Thies, K. Ekschmitt, V. Wolters and J. Dauber. 2005. Scaling properties of multivariate landscape structure. ***Ecological Indicators*** 5:295-304.

Abstract taken directly from text
Analyses of landscape context is essential for understanding how ecological patterns and processes relate to space. This requires that we quantify variation patterns of different landscape parameters, which may change relative to one another at different spatial scales. Here, we analyzed how statistical relationships of land-use composition parameters changed as a function of extent in 20 real agricultural landscapes. Furthermore, we tested the generality of these scaling relations in numerical simulations using 300 artificial landscapes. We analyzed proportions of artificial habitat types at different extent and compared these patterns with three dominant habitat types in real landscapes (forest, arable land and grassland) at four spatial scales (quadrats of 1–4 km). Both real and simulated landscapes showed that variance of landscape parameters (data differentiation) decreased and their correlations (data consistency) increased as scale increased, thereby suggesting general scaling laws. The potential statistical impact of these scaling relationships is revealed in simultaneous analyses of variation of (local) site parameters of 20 arable fields and their surrounding landscape context. At small and medium extent (quadrats of 1–3 km), variability of local site parameters (e.g. fertilization, pH-value) was high relative to those of landscape parameters. In contrast, at large extent (quadrats of 4 km) variability of landscape parameters was greater than that of site parameters indicating a fundamental shift in the relationship between these sets of parameters at different scales. Hence, it is clear that there is a high risk of artefactual correlations in hierarchical multi-scale landscape analyses when ecological data are related to the landscape context. Accordingly, there is a necessity for multi-scale analyses in landscape ecology to accurately evaluate the relative importance of landscape context at different spatial scales.

Pykh, Y. A. 2002. Lyapunov functions as a measure of biodiversity: theoretical background. ***Ecological Indicators*** 2:123-133.

Abstract taken directly from text
The concept of indicators (measure) of biological diversity is rather recent. Indicators of biological diversity are biased strongly towards species and away from the ecosystem as a whole, and that further progress towards generalized indicators of biological diversity poses substantial difficulties. An indicator may be a species, a structure, a process or some other feature of biological system, the occurrence of which insures the maintenance or restoration of the most important aspects of biodiversity for that system. A biological community consists of a collection of species and the underlying food web, i.e. the network of interactions by which consumers exploit and compete for available resources. The classical Lotka-Volterra model has been altered in many ways to model food webs more realistically. The dynamics of the web is mathematically described as a set of coupled non-linear ordinary differential equations. This makes application of the theory of non-linear dynamics systems possible. Commonly used models for food chains have been studied intensively using in particularly method of Lyapunov functions. In this report I introduce fitness-like and entropy-like Lyapunov functions as a basis for biodiversity study.

Rapport, D. J. and A. Singh. 2006. An EcoHealth-based framework for State of Environment Reporting. ***Ecological Indicators*** 6:409-428.

Abstract taken directly from text
Transformation in human-dominated ecosystems results from cumulative impacts of human activity. A comprehensive system for State of Environment Reporting (SOER) must take into account indicators of stress on ecosystems, indicators of the state of the system (i.e., ecosystem structure and function), and indicators of social response (policy interventions). The Pressure–State–Response (PSR) model for State of Environment Reporting developed by Statistics Canada in the mid 1970s incorporated these elements. By adopting an ecosystem perspective, it represented a significant advance from the then prevailing engineering-based approaches, with their focus on contaminants in air, water and land. The PSR model, however, has its own inherent limitations: its focus on isolating ‘‘pressures’’, ‘‘states’’, and ‘‘responses’’

tends to provide a static representation of the environment, ignoring the significant dynamic processes that comprise the interactions between these components. The PSR model also lacks a 'bottom line' that would provide the policy community and the public with an overall assessment of environmental trends. These limitations can be overcome by adopting an ecosystem health approach, which allows for a determination of the overall viability of environments and for the identification of the collective pressures from human activity that threaten that viability. An ecosystem health approach also allows for a more explicit connection between the state of the environment and human well-being. In this paper, we trace the evolution of SOER and provide some of the building blocks for overcoming its present limitations.

Riitters, K. H. 2005. Downscaling indicators of forest habitat structure from national assessments. ***Ecological Indicators*** 5:273-279.

<u>*Abstract taken directly from text*</u>
Downscaling is an important problem because consistent large-area assessments of forest habitat structure, while feasible, are only feasible when using relatively coarse data and indicators. Techniques are needed to enable more detailed and local interpretations of the national statistics. Using the results of national assessments from land-cover maps, this paper demonstrates downscaling in the spatial domain, and in the domain of the habitat model. A moving window device was used to measure structure (habitat amount and connectivity), and those indicators were then analyzed and combined with other information in various ways to illustrate downscaling.

Singh, R. K., H. R. Murty, S. K. Gupta and A. K. Dikshit. 2007. Development of composite sustainability performance index for steel industry. ***Ecological Indicators*** 7:565-588.

<u>*Abstract taken directly from text*</u>
The steel companies are becoming increasingly aware about the sustainability challenges. In order to become a responsible corporate citizen, the industry has responded to these challenges through adoption of pillars of sustainability. The industry has made the beginning with identification of sustainability indicators. The indicators have been developed specifically for steel industry. Generally, it is quite difficult to evaluate the performance of company on the basis of large number of sustainability indicators. Integration of key sustainability indicators is quite essential for decision-making. Composite indicators are an innovative approach to evaluate sustainable performance. This paper presents a method for development of composite sustainability performance index (CSPI) that addresses the sustainable performance of steel industries along all the three pillars of sustainability—economic, environmental and societal. Organizational governance and technical aspects have also been considered fourth and fifth dimensions of sustainability. The objective of this paper is to introduce sustainability and to present a conceptual decision model, using analytical hierarchy process (AHP) to assist in evaluating the impact of an organization's sustainability performance. AHP has been used to determine the weights at various levels. Sub-indices have been evaluated and aggregated to form CSPI. The effectiveness of the proposed model is evaluated in a case study for a major steel company in India.

Spangenberg, J. H. 2002. Environmental space and the prism of sustainability: frameworks for indicators measuring sustainable development. ***Ecological Indicators*** 2:295-309.

<u>*Abstract taken directly from text*</u>
The notion of Environmental Space refers to external criteria regarding resources available for human consumption. On the one hand, it has been demonstrated that the reduction of energy consumption, material flows and land use would significantly contribute to reducing the main stresses for the European environment. On the other hand, the concept defines a socially motivated minimum of resource availability, permitting to lead a dignified life in the respective society. Environmental space is a tool for exploring sustainable development benchmarks on a sound scientific basis, and it is helpful to derive indicators of sustainable development for different applications on the macro as well as on the micro level. However, the environmental space concept expresses no preference regarding the structure of the economic system, as long as the environmental and social benchmarks are respected, nor does it

suggest specific economic sustainability indicators. Since in 1995, the CSD formally introduced the institutional dimension as the fourth dimension of sustainable development, sustainable development can be described by referring to four dimensions and their six inter-linkages. Using the Prism of Sustainability, the concept—although rather complex—can easily be communicated and used as a tool for gathering public support for sustainability policies. The prism simplifies matters by structuring them, but avoids the oversimplification inherent to aggregate indices. At the macro level, the environmental space and the prism of sustainability have been applied to international, regional and national indicator development. At the micro level, systems of indicators for households, companies and local communities have been developed. The indicators have also been used in dynamic modeling, demonstrating their capability to assess the sustainability of different policy strategies.

Stockwell, D. and A. T. Peterson. 2003. Comparison of resolution of methods used in mapping biodiversity patterns from point-occurrence data. ***Ecological Indicators*** 3:213-221.

Abstract taken directly from text

This paper examines three methods of mapping of biodiversity using point-occurrence data for the birds of Mexico: aggregation of species occurrence records, vegetation surrogate, and individual species models. We compare the approaches from the perspective of achieving potential gains in spatial resolution with existing data. We found that mapping the diversity of Mexican birds using individual species models yielded results 400-fold more finely resolved, quantifiable errors, and greater flexibility for many applications. We show that the aggregation and surrogate methods are susceptible to tradeoffs between bias and resolution that can only be ameliorated thorough more intensive sampling. A theoretical error model and an empirical demonstration shows that higher spatial resolution in the individual species approach can be achieved by controlling the modeling approach by reducing bias and decreasing random error. The method is particularly applicable for large-scale biodiversity mapping, where intensive ground survey data are lacking.

Tegler, B. 1999. ***Selecting Core Variables For Tracking Ecosystem Change At EMAN Sites***. Geomatics International Inc, prepared for Environment Canada, Ecological Monitoring and Assessment Network, Burlington, ON. 28 pp.

Abstract taken directly from text

This project evaluated existing ecological monitoring variables from a variety of sources to select a suite of about twenty-five core variables suitable for monitoring at the Ecological Monitoring and Network's Ecological Science Cooperative (ESC) sites located across Canada. The intention is to acquire relevant and consistent data on ecosystem change that can be compared for national trends. Existing monitoring variables were evaluated in two steps. In the first step three primary criteria were used to pre-screen 1770 preliminary variables and select 188 candidate monitoring variables. The primary criteria were as follows:

1) The monitoring variable will provide meaningful data on changes in Canadian ecosystems.
2) The monitoring variable can be applied across a range of ecosystem types.
3) The monitoring variable is cost effective to monitor and evaluate.

In the second step, a more detailed evaluation considered twenty criteria of data quality, applicability, data collection methods, data analysis and interpretation, existing data and programs and cost effectiveness. From the 188 candidate variables 96 were rejected and 92 monitoring variables were carried forward for further analysis. The recommended steps leading to the final selection of a suite of core variables to be recommended for monitoring are as follows:

1) Further definition and involvement of stakeholders in the selection process to provide further refinement of the ecosystem-based national monitoring framework that is presented here.
2) Monitoring variables that have been rejected in this study due to a lack information may be re-evaluated based on new available information.
3) The 35 components of the ecosystem framework not measured by the proposed monitoring variable groups (see bullets in Table 6) should be critically examined to determine if suitable monitoring variables not evaluated here do exist for them.

4) Further investigation should be undertaken to determine the linkages between proposed monitoring variable groups to better define a suite of core monitoring variables that are synergistic in terms of their ease of monitoring and in their provision of complimentary data.
5) Opportunities for selecting monitoring variables that are economically unfeasible on a site-by-site basis, but potentially economical when monitored across a network of sites (e.g., accumulation of persistent organic pollutants, endocrine disrupters, heavy metals, etc.) should be investigated.

Tiner, R. W. 2004. Remotely-sensed indicators for monitoring the general condition of "natural habitat" in watersheds: an application for Delaware's Nanticoke River watershed. ***Ecological Indicators*** 4:227-243.

<u>*Abstract taken directly from text*</u>
Over the past two decades there has been increasing interest in developing indicators to monitor environmental change. Remote sensing techniques have been primarily used to generate information on land use/land cover changes. The US Fish and Wildlife Service has used this technology to monitor wetland trends and recently developed a set of remotely-sensed indicators to characterize and assess trends in the integrity of natural habitat in watersheds. The indices largely focus on the extent of "natural" cover throughout a given watershed, with an emphasis on locations important to fish, wildlife, and water quality. Six indices address natural habitat extent and four deal with human-caused disturbance. A composite index of natural habitat integrity combining the habitat extent and habitat disturbance indices may be formulated to provide an overall numeric value for a watershed or sub-basin. These indices facilitate comparison between watersheds (and sub-basins) and assessment of trends useful for environmental monitoring. This paper describes the indices and presents an example of their application for characterizing and assessing conditions of sub-basins within Delaware's Nanticoke River watershed.

Troyer, M. E. 2002. A spatial approach for integrating and analyzing indicators of ecological and human condition. ***Ecological Indicators*** 2:211-220.

<u>*Abstract taken directly from text*</u>
"Sustainable development" is used in this study as an integrating theme and defined as a positive relationship between ecological integrity and human welfare over time within ecologically-relevant areas. Ecological rather than political areal units are used for aggregating data because human welfare ultimately relies on the natural resources and life support systems provided by healthy ecosystems. Although, no scientific consensus on defining and measuring "ecological integrity" and "human welfare" exists, partial metrics for each were taken from the literature. A geographic information system (GIS) was created to explore statistical relationships between selected measures of ecological and human condition aggregated up to the watershed scale. Rank correlation results at the watershed scale generally corresponded with other findings in the literature reporting negative interactions between society and nature at other spatial scales. The spatial analysis suggested that higher levels of well-being in Ohio, USA, (i.e. in terms of educational attainment, employment, income, and lack of poverty) were near metropolitan areas with connections to larger scale economies rather than isolated economies based on local natural resources (i.e. open rather than closed systems). The same locational arrangement was also found for several "sustainable watersheds" identified in the landscape (i.e. those with higher levels of both human and terrestrial and aquatic ecological conditions). In other words, sustaining high levels of ecological condition and human welfare in watersheds appeared dependent on linkages with external areas and their continued "sustainability" as well. Theoretically, relations between society and nature within one place and between different places may range from mutualistic to competitive interactions, but the former, along with cooperative and commensal relations, are preferred if sustainable development is desired.

Turnhout, E., M. Hisschemoller and H. Eijsackers. 2007. Ecological indicators: Between the two fires of science and policy. ***Ecological Indicators*** 7:215-228.

<u>*Abstract taken directly from text*</u>

This article approaches the concept of ecological indicators from a social science perspective. By applying theoretical concepts from policy analysis and social studies of science about knowledge utilization, problem structuring and the boundaries between science and policy to the issue of ecological indicators, we aim to contribute to our understanding not only of the development but more importantly of the actual use of ecological indicators in policy processes and the importance of political context. Our interest is in those ecological indicators that attempt to measure the ecological quality of ecosystems and that can be or are specifically developed to be used as instruments to evaluate the effects of policies on nature. We claim that these indicators, although they are highly dependent on scientific knowledge, cannot be solely science-based, due to the complexity of ecosystems and the normative aspects involved in assessing ecosystem quality. As a result, we situate ecological indicators in a fuzzy area between science and policy and between the production and the use of scientific knowledge. We will argue that ecological indicators can be expected to be used or rejected strategically, dependent on policy context. Furthermore we will argue that ecological indicators cannot be evaluated with traditional scientific quality criteria alone. The article concludes with some lessons for future indicator development one of them being the inclusion of stakeholder perspectives.

Venturelli, R. C. and A. Galli. 2006. Integrated indicators in environmental planning: Methodological considerations and applications. ***Ecological Indicators*** 6:228-237.

<u>*Abstract taken directly from text*</u>

After a short introduction on approaches using either structural or functional indicators, we develop a methodological framework for the analysis and management of landscapes, using landscape ecological principles related to a holistic approach. In a next step, we disaggregate some of the internal processes in landscapes in order to delineate groups of indicators in its spatiotemporal context. In a case study, conducted in an area in Central Italy, the use of some landscape ecological indicators is presented. It is an example of how a set of indicators can be applied to a part of the landscape, which is considered as a whole or integrated unit, according to the principles of landscape ecology. On the basis of four landscape metrics out of eight, calculated in a Geographical Information System (GIS), we present potential areas for greenways in our study area of 16,000 ha in a scale of 1:25,000. The results are directed to landscape planning and management and are, therefore, of particular interest not only from a scientific point of view, but also regarding land use planning by local administrators. Due to limitations in achieving more indicators, especially for the interrelation between ecology and socio-economy, the study group expresses the clear need for further refinement of this excellent analytical and management instrument with a special focus on integrated indicators.

Wiggering, H., C. Dalchow, M. Glemnitz, K. Helming, K. Muller, A. Schultz, U. Stachow and P. Zander. 2006. Indicators for multifunctional land use─ Linking socio-economic requirements with landscape potentials. ***Ecological Indicators*** 6:238-249.

<u>*Abstract taken directly from text*</u>

Indicators to assess sustainable land development often focus on either economic or ecologic aspects of landscape use. The concept of multifunctional land use helps merging those two focuses by emphasising on the rule that economic action is per se accompanied by ecological utility: commodity outputs (CO, e.g., yields) are paid for on the market, but non-commodity outputs NCO, e.g., landscape aesthetics) so far are public goods with no markets. Agricultural production schemes often provided both outputs by joint production, but with technical progress under prevailing economic pressure, joint production increasingly vanishes by decoupling of commodity from non-commodity production. Simultaneously, by public and political awareness of these shortcomings, there appears a societal need or even demand for some non-commodity outputs of land use, which induces a market potential, and thus, shift towards the status of a commodity outputs. An approach is presented to merge both types of output by defining an indicator of social utility (SUMLU): production schemes are considered with respect to social utility of both commodity and non-commodity outputs. Social utility in this sense includes environmental and economic services as long as society expresses a demand for them. For each combination of parameters at specific frame conditions (e.g., soil and climate properties of a landscape) a production possibility curve can reflect trade-offs between commodity and non-commodity outputs. On each production possibility curve a welfare optimum can be identified expressing the highest achievable value of social utility as a trade-off between CO and NCO production. When applying more parameters, a cluster of welfare optimums is generated. Those clusters can be used for assessing production schemes with respect to sustainable land development. Examples of production possibility functions are given on easy applicable parameters (nitrogen leaching versus gross margin) and on more complex ones (biotic integrity). Social utility, thus allows to evaluate sustainability of land development in a cross-sectoral approach with respect to multi-functionality.

Wilcox, B. A. 2001. Ecosystem Health in Practice: Emerging Areas of Application in Environment and Human Health. ***Ecosystem Health*** 7:317-325.

Abstract not available [excerpts directly from text]
The main purpose of the discipline of ecosystem health is to provide environment and health management and policy professionals with a theoretical framework and method, or practical tools, to improve society's ability to sustain earth's life-support systems. Indicator approaches that incorporate ecological goals, societal goals, and the notion of ecological stress, based largely on Karr and colleague's "Index of Biotic Integrity", are best developed for water resources. As geographic units distinguishable by hydrographically delineated topographic features, catchments frequently correspond to the human settlement patterns and political boundaries to which both scientists and lay people can easily relate. Ecosystem health is related in a number of ways to human health. The convergence of separate concerns about the state of human health and natural resources or landscape management have compelled the adoption of a systems perspective. The conditions of many, if not most of the ecosystems on earth, regardless of the scale chosen, are changing dramatically by most measures.

Wilson, J., P. Tyedmers and R. Pelot. 2007. Contrasting and comparing sustainable development indicator metrics. ***Ecological Indicators*** 7:299-314.

Abstract taken directly from text
Despite the fact that it has been well over a decade since Agenda 21 first called for sustainable development indicators, there is no consensus regarding the best approach to the design and use of SDI models. It is important, therefore, to question the effectiveness of SDIs in an effort to continue advancing sustainability. This paper addresses one aspect of this question by exploring whether our global SDI metrics are sending a clear message to guide us towards sustainable development. Six global SDI metrics are compared by relative ranking in colour coded tabular format and spatially in map format. The combined presentation of results clearly illustrates that the different metrics arrive at varying interpretations about the sustainability of nations. The degree of variability between the metrics is analyzed using correlation analysis. The variability in findings draws attention to the lack of a clear direction at the global level in how best to approach sustainable development. Canada is presented as a case study to highlight and explain the discrepancies between SDI measures.

Yoccoz, N. G., J. D. Nichols and T. Boulinier. 2001. Monitoring of biological diversity in space and time. ***Trends in Ecology and Evolution*** 16:446-453.

Abstract taken directly from text
Monitoring programmes are being used increasingly to assess spatial and temporal trends of biological diversity, with an emphasis on evaluating the efficiency of management policies. Recent reviews of the existing programmes, with a focus on their design in particular, have highlighted the main weaknesses: the lack of well-articulated objectives and the neglect of different sources of error in the estimation of biological diversity. We review recent developments in methods and designs that aim to integrate sources of error to provide unbiased estimates of change in biological diversity and to suggest the potential causes.

Zurlini, G., N. Zaccarelli and I. Petrosillo. 2006. Indicating retrospective resilience of multi-scale patterns of real habitats in a landscape. ***Ecological Indicators*** 6:184-204.

Abstract taken directly from text
Vegetation or habitat types are ecological phases, which can assume multiple states, and transformations from one type of phase to another are ecological phase transitions. If an ecological phase maintains its condition of normality in the linked processes and functions that constitute ecosystems then is believed healthy. An adaptive cycle, such as in Holling's model, has been proposed as a fundamental unit for understanding complex systems and their dynamics. Such model alternates between long periods of aggregation and transformation of resources and shorter periods that create opportunities for innovation. The likelihood of shifts among different phases largely depends on resilience; thereby, a clear and measurable definition of resilience has become paramount. Different resilience levels are expected to be intertwined with different scale ranges of real habitats, in relation to the kind and intensity of natural and human disturbances. We argue that the type, magnitude, length and timing of external pressure, its predictability, the exposure of habitats, and the habitat's inherent resistance have important interactive relationships which determine resilience at multiple scales. In this paper, we provide an operational framework to derive operational indices of short-term retrospective resilience of real grasslands in a northern Italy watershed, from multi-scale analysis of landscape patterns, to find scale domains for habitat edges where change is most likely, i.e. resilience is lowest and fragility highest. That is achieved through cross-scale algorithms like fractal analysis coupled with change detection of ecological response indices. The framework implements the integration of habitat edge fractal geometry, the fitting of empirical power functions by piecewise regressions, and change detection as a procedure to find scale domains for grassland habitat where retrospective resilience is lowest. The effects of external pressure are significantly related to habitat scale domains, resulting from the interactions among ecological, physical, and social controls shaping the systems. Grassland scale domains provide evidence and support for identifying and explaining scale invariant ecological processes at various scales, from which much insight can be gained for characterizing grassland adaptive cycles and capabilities to resist disturbances.

SECTION 5.0 - ECOLOGICAL LAND CLASSIFICATION

Abella, S. R., V. B. Shelburne and N. W. MacDonald. 2003. Multifactor classification of forest landscape ecosystems of Jocassee Gorges, southern Appalachian Mountains, South Carolina. ***Canadian Journal of Forest Research*** 33:1933-1946.

Abstract taken directly from text
Ecosystem classification identifies interrelationships within and among the geomorphology, soils, and vegetation that converge to form ecosystems across forest landscapes. We developed a multifactor ecosystem classification system for a 13 000 ha southern Appalachian landscape acquired in 1998 by the South Carolina Department of Natural Resources. Using a combination of multivariate analyses, we distinguished five ecosystem types ranging from xeric oak (*Quercus* spp.) to mesic eastern hemlock (*Tsuga canadensis* (L.) Carrière) ecosystems. Ecosystems segregated along geomorphic gradients influencing potential moisture availability, with soil properties such as solum thickness distinguishing among ecosystems occupying similar topographic positions. Our results suggest that different combinations of geomorphic and soil factors interact to form similar ecosystems across the landscape, and a given environmental factor can impact ecosystem development at some constituent sites of an ecosystem type but not at other sites. A regional comparison of ecosystem classifications indicates that environmental variables important for distinguishing ecosystems in the southern Appalachians vary, with Jocassee Gorges characterized by unique suites of environmental complexes. Our study supports the contention that the strengths of ecosystem classification are providing (i) comprehensive information on the interrelationships among ecosystem components, (ii) a foundation from which to develop ecologically based forest management plans, and (iii) an ecological framework in which to conduct future research on specific ecosystem components or processes.

Ahern, F. 2007. ***Ecosystem Status and Trends: Indicators Using Earth Observation by Satellite***. Report, TerreVista Earth Imaging, Cormac, ON. 64 pp.

This report is a response to a request by Environment Canada to examine, in considerable detail, how satellite observations could be used to assess the status of Canadian ecosystems, and how these ecosystems have been changing during the previous three or four decades, a time of tremendous growth in the Canadian economy and population. Concurrently with the development of terrestrial applications, the use of earth observations for oceanographic studies has undergone tremendous development during the last three decades. Because of improvements in spatial resolution, it is now feasible to use satellite data for large inland water bodies. The NASA MODIS sensor, and the ESA MERIS sensor can each provide data that can be used to monitor chlorophyll and sediment concentrations with a spatial resolution of 250 m (MODIS) and 300 m (MERIS). Net primary productivity is a better indicator of ecosystem productivity than leaf area index. It can be produced on an annual basis. The inputs are nationwide 10-day LAI maps, combined with meteorological observations and maps of land cover and soils. The largest source of uncertainty is rainfall, which can vary greatly over small distances. CCRS currently produces NPP maps as input for its carbon budget calculations, but the uncertainties involved in producing them suggest that more direct observations of land cover and land cover change at medium resolution will provide information that is both more reliable and more readily grasped by many scientists and the public alike. If climate change causes alterations in NPP that are so pronounced that they become apparent on 1 km satellite imagery, the ecosystem involved will already have sustained very serious damage.

Arnold, D. H., G. W. Smalley and E. R. Buckner. 1996. Landtype-Forest Community Relationships: A Case Study on the Mid-Cumberland Plateau. ***Environmental Monitoring and Assessment*** 39:339-352.

<u>*Abstract taken directly from text*</u>
Relationships between forest communities and landtypes (the most detailed level of a hierarchical land classification system) were determined for the Prentice Cooper State Forest (PCSF), located on the southern tip of Walden Ridge, west of Chattanooga, Tennessee. Four extensive landtypes within the Mullins Cove area of PCSF were sampled: 1) broad sandstone ridges - south aspect (LT-3), 2) north sandstone slopes (LT-5), 3) south sandstone slopes (LT-6), and 4) plateau escarpment and upper sandstone slopes and benches - south aspect (LT-17). Rectangular, 0.04-hectare plots specified sub-plots for sampling overstory, mid-story, sapling/shrub, seedling/herb forest strata, and physical site characteristics. Plots (139) were allocated by landtype using a random start with subsequent systematic location. Multivariate statistical techniques were used to 1) examine the distinctness of forest communities occurring among landtypes (discriminant analysis), 2) describe the forest communities occurring within landtypes (cluster analysis), and 3) determine factors controlling the spatial distribution of forest communities on the landscape (factor analysis). Different relative importance values of species among communities along with different community combinations among landtypes resulted in distinct forest vegetation among landtypes. Chestnut oak (Quercus prinus L.), white oak (Quercus alba L.), and shortleaf pine (Pinus echinata Miller) communities occurred on all four landtypes. Scarlet oak (Quercus coccinia Muenchh.) communities occurred on LT-5, LT-6, and LT-17. Black oak (Quercus velutina Lam.) communities occurred on LT-3 and LT-5. Yellow-poplar (Liriodendron tulipifera L.), northern red oak (Quercus rubra L.), and eastern hemlock (Tsuga canadensis (L.) Carr.), communities occurred only on LT-17. Landscape scale factors that varied along an elevation gradient were dominant in controlling spatial distribution of forest communities. Microsite factors were secondary controllers. Specific ecological factors could not be determined by factor analysis. Relatively distinct vegetation occurs among sampled landtypes on the PCSF. This study provides additional evidence that the land classification system divides the Mid-Cumberland Plateau landscape into distinct ecological units.

Bailey, R. G. 1999. Multi-Scale Ecosystem Analysis. ***Environmental Monitoring and Assessment*** 39:21-24.

<u>*Abstract taken directly from text*</u>
As a precursor to management, ecosystems of different sizes need to be mapped at different scales. The key to developing criteria for subdividing land into ecosystems is understanding the factors that control ecosystem size at various scales in a hierarchy. The relationships between an ecosystem at one scale and ecosystems at smaller or larger scales must be examined, in order to predict the effects of management. Multi-scale mapping is helpful in analyzing relationships of this type.

Baily, R. G. 2005. Identifying Ecoregion Boundaries. ***Environmental Management*** 34:S14-S26.

<u>*Abstract taken directly from text*</u>
This article summarizes the rationale I used in identifying ecoregion boundaries on maps of the United States, North America, and the world's continents, published from 1976 to 1998. The geographic reasoning used in drawing boundaries involves 20 principles, which are presented to stimulate discussion and further understanding. Brief background and references are provided for the principles.

Bajzak, D. and B. A. Roberts. 1996. Development of Ecological Land Classification and Mapping in Support of Forest Management in Northern Newfoundland, Canada. ***Environmental Monitoring and Assessment*** 39:199-213.

<u>*Abstract taken directly from text*</u>
For the sustainable development of forest land, as recently prescribed by the Canadian Forest Strategy, a land classification project in northern Newfoundland was initiated to support the local forest management activities. The method adopted here is a modification of the Canadian Committee for Ecological Land Classification's (CCELC) system, and it applies various levels of mapping to uniform areas based on geomorphology, soils, vegetation, climate, water, and fauna. In this study, all CCELC levels were mapped; resulting maps were digitized and imported into a Geographic Information System (GIS). The GIS data base contained the following maps: 1) digital terrain model, 2) bedrock geology, 3) surficial geology, 4) forest inventory, and 5) various levels of the ecological land classification, including Vegetation Types at the lowest level. In addition to the mapping, mensurational data were analyzed to provide stand and stock tables for each of the forest types, including growth curves that could be entered into specific forest growth modelling systems to predict wood supply scenarios based upon different management interventions.

Banner, A., D. V. Meidinger, E. C. Lea, R. E. Maxwell and B. C. Von Sacken. 1996. Ecosystem Mapping Methods for British Columbia. ***Environmental Monitoring and Assessment*** 39:97-117.

<u>*Abstract taken directly from text*</u>
Most resource professionals in British Columbia recognize the value of ecosystem classification
in providing a conceptual framework and common language for organizing ecological information and management experience about ecosystems. Ecosystem mapping utilizes principles of ecosystem classification in order to provide a permanent record of the location and distribution of ecosystems. This spatial framework is often required for developing, applying, and monitoring landscape level and site-specific management prescriptions for many potential resource values. Over the past 20 years, several approaches to ecosystem mapping have been applied throughout the province. Standard procedures for provincial resource inventories and standards for medium and large scale ecosystem mapping (1:10 000 to 1:100 000 scales) have recently been proposed for the province. The proposed mapping approach combines dements of two classification systems currently in use in the province: ecoregion classification and biogeoclimatic ecosystem classification (BEC). Ecoregion and biogeoclimatic units stratify the landscape into broad physiographically and climatically uniform units. Within this broad framework, permanent landscape units are then delineated based on terrain features. Ecosystem units represent the lowest-level mapping individuals and are derived from the site series classification within BEC. Ecosystem units thus reflect moisture and nutrient regime and the climax vegetation potential of the site. Additional site modifiers are included to recognize variation in topography and soils within the site series. Structural stage and seral association modifiers are included to describe existing vegetation

characteristics. The mapping methods present a core list of attributes required for basic resource interpretations, as well as additional attributes required for more specific interpretations.

Beauchesne, P., J.-P. Ducruc and V. Gerardin. 1996. Ecological Mapping: A Framework for Delimiting Forest Management Units. ***Environmental Monitoring and Assessment*** 39:173-186.

Abstract taken directly from text
Ecological mapping attempts to objectively and spatially delimit and represent the natural organization and structure of the landscape. It offers nested levels of resolution, based upon a regionalization process, and provides an ecological basis for planning activities that may impact upon the environment. The essential principles of ecological mapping, as applied by the Quebec Ministry of Environment and Wildlife, are summarized. A methodological mapping approach is proposed for the determination of significant land portions for forest management using an ecological map at a scale of 1:50 000. At this scale, two nested levels of perception are expressed: 1) the topographic complex, and 2) the topographic entity. The topographic entity can be further subdivided into working units based upon operational criteria oriented to forest management. Within each nested level from topographic complex to working unit, there is a corresponding increase in the amount of detailed information available. Ecological mapping undertaken at 1:50 000 scale can provide a reliable and robust tool for planning forest management activities. In most cases, major ecological variations can be expressed and mapped at this scale; however, a greater degree of generalization must be accepted in the planning process when working at this scale rather than at larger scales.

Britton, G. M., D. V. Meidinger and A. Banner. 1996. The Development of an Ecological Classification Data Management and Analysis System for British Columbia. ***Environmental Monitoring and*** Assessment 39:365-372.

Abstract taken directly from text
Since 1975, the British Columbia Ministry of Forests has been systematically developing an ecosystem classification of the province, an area covering 94 million hectares. This Biogeoclimatic Ecosystem Classification (BEC) system provides a framework for resource conservation and management. To date, approximately 250 person-years have been invested in the collection, analysis and synthesis of over 8000 ecological (vegetation and environmental data) plots, and in the production of ecological field guides. The development of a database and analysis system on the micro-computer platform to support a classification system of this magnitude was a complex procedure that required judicious planning and coordination. We have developed data-processing software that permits a user to select raw data from broad provincial or regional coverage to plot- and species-level summaries, and to export the data to a variety of output formats. This paper addresses key issues for handling ecological field data on the desktop computer with emphasis on standards, operator ease-of-use, and data access.

Bryan, B. A. 2006. Synergistic Techniques for Better Understanding and Classifying the Environmental Structure of Landscapes. ***Environmental Management*** 37:126-140.

Abstract taken directly from text
The desire to capture natural regions in the landscape has been a goal of geographic and environmental classification and ecological land classification (ELC) for decades. Since the increased adoption of data-centric, multivariate, computational methods, the search for natural regions has become the search for the best classification that optimally trades off classification complexity for class homogeneity. In this study, three techniques are investigated for their ability to find the best classification of the physical environments of the Mt. Lofty Ranges in South Australia: AutoClass-C (a Bayesian classifier), a Kohonen Self-Organising Map neural network, and a k-means classifier with homogeneity analysis. AutoClass-C is specifically designed to find the classification that optimally trades off classification complexity for class homogeneity. However, AutoClass analysis was not found to be assumption-free because it was very sensitive to the user-specified level of relative error of input data. The AutoClass results suggest that there may be no way of finding the best classification without making critical assumptions as to the level

of class heterogeneity acceptable in the classification when using continuous environmental data. Therefore, rather than relying on adjusting abstract parameters to arrive at a classification of suitable complexity, it is better to quantify and visualize the data structure and the relationship between classification complexity and class homogeneity. Individually and when integrated, the Self-Organizing Map and k-means classification with homogeneity analysis techniques also used in this study facilitate this and provide information upon which the decision of the scale of classification can be made. It is argued that instead of searching for the elusive classification of natural regions in the landscape, it is much better to understand and visualize the environmental structure of the landscape and to use this knowledge to select the best ELC at the required scale of analysis.

Bunce, R. G. H., C. J. Barr, M. K. Gillespie and D. C. Howard. 1996. The Ite Land Classification: Providing Environmental Stratification of Great Britain. ***Environmental Monitoring and Assessment*** 39:39-46.

<u>*Abstract taken directly from text*</u>
The surface of Great Britain (GB) varies continuously in land cover from one area to another. The objective of any environmentally based land classification is to produce classes that match the patterns that are present by helping to define clear boundaries. The more appropriate the analysis and data used, the better the classes will fit the natural patterns. The observation of inter-correlations between ecological factors is the basis for interpreting ecological patterns in the field, and the Institute of Terrestrial Ecology (ITE) Land Classification formalises such subjective ideas. The data inevitably comprise a large number of factors in order to describe the environment adequately. Single factors, such as altitude, would only be useful on a national basis if they were the only dominant causative agent of ecological variation. The ITE Land Classification has defined 32 environmental categories called 'land classes', initially based on a sample of 1-km squares in Great Britain but subsequently extended to all 240 000 1-km squares. The original classification was produced using multivariate analysis of 75 environmental variables. The extension to all squares in GB was performed using a combination of logistic discrimination and discriminant functions. The classes have provided a stratification for successive ecological surveys, the results of which have characterised the classes in terms of botanical, zoological and landscape features. The classification has also been applied to integrate diverse datasets including satellite imagery, soils and socio-economic information. A variety of models have used the structure of the classification, for example to show potential land use change under different economic conditions. The principal data sets relevant for planning purposes have been incorporated into a user-friendly computer package, called the 'Countryside Information System'.

Carolinian Canada. Undated. ***Guidelines for Assessing Ecological Boundaries of Vegetation Patches***. London, ON. 26 pp.

<u>*Abstract not available [excerpts directly from text]*</u>
The purpose of this guideline is to:
1) document and describe a repeatable process leading to a credible map which can be used for planning and monitoring;
2) outline a consistent basis by which ecological boundaries for natural features can be determined;
3) provide the basis for resolving variations between different scales and types of mapping; and
4) develop a common understanding and approach between planners, consultants and the public regarding the ecological aspects boundary delineation for natural features and hazards.
A vegetation patch is defined as an area that contains natural vegetation and associated features and functions, that is generally free of permanent disturbance and that can be distinguished from the surrounding land use. A patch is an integrated ecological unit.

Carter, R. E., M. D. MacKenzie and D. H. Gjerstad. 1999. Ecological land classification in the Southern Loam Hills of south Alabama. ***Forest Ecology and Management*** 114:395-404.

<u>*Abstract taken directly from text*</u>
A landscape scale classification of ecosystems was undertaken on the Conecuh National Forest and Solon Dixon Forestry Education Center in south Alabama. Nine landtypes (LTs) were identified in the study area. Each LT had a unique assemblage of plant species and environmental variables. In the Pine Hills, three LTs were identified with diagnostic species including Quercus incana, Ipomoea sp., Q. stellata, Rhus copallina, Vaccinium myrsinites, and Pityopsis graminifolia. The diagnostic environmental variables were landform index, slope, B horizon depth, percent B horizon nitrogen (N), percent A horizon fine sand, and percent A horizon silt. In the Dougherty Plain, two LTs were identified with diagnostic species including Diospyros virginiana, Elephantopus tomentosus, Vaccinium corymbosum, Lechea minor, Aristida stricta, and Q. virginiana. The diagnostic environmental variables were slope and percent B horizon fine sand. In the Wet Pine Flatwoods, four LTs were identified. The diagnostic species included Diospyros virginiana, Smilax glauca, Vaccinium stamineum, Hibiscus aculeatus, Pinus elliottii, Drosera brevifolia, Clethra alnifolia, and Aristida stricta. The diagnostic environmental variables were slope, landform index, depth to mottling, percent B horizon clay, and drainage class. The vegetation of the LTs is similar to longleaf pine ecosystems throughout the southeastern Coastal Plain.

Cartier, P., B. D. Harvey and Y. Bergeron. 1996. A Forest Ecosystem Guide for the Amos Lowlands Ecological Region, Northwestern Quebec: A Forest Management Approach. ***Environmental Monitoring and Assessment*** 39:249-263.

<u>*Abstract taken directly from text*</u>
In Quebec, forest stations are defined as forest units that are reasonably homogeneous in terms of forest composition and site characteristics - as expressed by surficial deposit and moisture regime - and within which similar operational constraints for silvicultural potential and productivity levels may be expected. In the course of developing a field guide to the forest stations of the Amos Lowlands Ecological Region in northwestern Quebec, classifications of 12 site types and 72 forest stations (38 forest cover types or 16 general cover types) were developed. The classifications were based on a hybrid approach involving cluster analysis of forest ecological units inventoried in sub-regional studies, classical classification and ordination analyses performed on a regional biophysical inventory database, and empirically associating forest cover types to site types. The guide, while similar to other published forest ecosystem classification guides, emphasizes forest dynamics by presenting forest stations common to a given site type according to their successional stage. Field keys and general interpretations of forest potential and operational constraints are included in the guide. A summary description of the guide and accompanying documents is provided. A first draft has been distributed recently for feedback from industrial and government foresters and researchers in the region. Analysis of inventory data is continuing and modifications will be incorporated into a second draft before publication in 1995.

Clatterbuck, W. K. 1996. A Community Classification System for Forest Evaluation: Development, Validation, and Extrapolation. ***Environmental Monitoring and Assessment*** 39:299-321.

<u>*Abstract taken directly from text*</u>
A community classification system integrating vegetation and landforms was developed for the 8,054-ha Cheatham Wildlife Management Area (CWMA), located on the Western Highland Rim of Tennessee, USA, to obtain information on which to base multi-resource land management decisions. A subjective procedure (synthesis tables) and several objective techniques (factor analysis, cluster analysis, and canonical discrimination) were used to evaluate importance values of overstory and midstory species, coverage values of understory species, and topographic parameters. These procedures were used collectively to guide and to provide evidence for interpretation of vegetational patterns on the landscape. The eight discrete communities identified on a 482-ha compartment within the CWMA were: northern red oak (*Quercus rubra* L.), chestnut oak (*Q. prinus* L.), scarlet oak (*Q. coccinea* Muenchh.), yellow-poplar (*Liriodendron tulipifera* L.), sycamore-sweetgum (*Platanus occidentalis* L. -*Liquidambar styraciflua* L.), black oak-hickory (*Q. velutina* Lam.- *Carya* spp.), post oak (*Q. stellata* Wangenh.), and American beech (*Fagus grandifolia* Ehrh.) communities. The classification system was validated with an independent data

set. The eight communities were successfully extrapolated to an unsampled portion of the CWMA. Clearly, community analysis can become an important facet in forest management and may play a major role where a holistic understanding of vegetative relationships is essential.

Cleland, D. T., P. E. Avers, W. H. McNab, M. E. Jensen, R.G. Bailey, T. King, and W. E. Russell. 1997. National Hierarchical Framework of Ecological Units. In: ***Ecosystem Management Applications for Sustainable Forest and Wildlife Resources***, ed by M.S. Boyce and A. Haney. Yale University Press, New Haven, CT. pp. 181-200.

Abstract taken directly from text

To implement ecosystem management, we need basic information about the nature and distribution of ecosystems. To develop this information, we need working definitions of ecosystems and supporting inventories of the components that comprise ecosystems. We also need to understand ecological patterns and processes and the interrelationships of social, physical, and biological systems. To meet these needs, we must obtain better information about the distribution and interaction of organisms and the environments in which they occur, including the demographics of species, the development and succession of communities, and the effects of humans activities and land use on species and ecosystems (Urban et al. 1987). Research has a critical role in obtaining this information. This chapter presents a brief background of regional land classifications, describes the hierarchical framework for ecological unit design, examines underlying principles, and shows how the framework can be used in resource planning and management. The basic objective of the hierarchical framework is to provide a systematic method for classifying and mapping areas of the earth based on associations of ecological factors at different geographic scales. The framework is needed to improve our efforts in national, regional, and forest level planning; to achieve consistency in ecosystem management across National Forests and regions; to advance our understanding of the nature and distribution of ecosystems; and to facilitate interagency data sharing and planning.

Daniels, F. J. A. 1994. Vegetation Classification in Greenland. ***Journal of Vegetation Science*** 5:781-790.

Abstract taken directly from text

An account of the description and classification of the vegetation of Greenland is presented. Four periods are recognized: the Physiognomic period, the Extension period, the Floristics-Dominance period, and the Syntaxonomic period. The approaches used in vegetation classification pertaining to Greenland are discussed. A first survey is presented of the higher syntaxa known from suboceanic-oceanic, subarctic-low arctic Greenland. 14 classes are dealt with. The syntaxa are floristically defined and their concept is discussed. The *Juncetalia trifidi, Caricetea curvulae* are described for the first time.

Didiuk, A. B. and R. S. Ferguson. 2005. Land cover mapping of Queen Maud Gulf Migratory Bird Sanctuary, Nunavut. ***Occasional Paper No 111,*** Canadian Wildlife Service, Ottawa, Ontario.

Abstract taken directly from text

The Queen Maud Gulf Migratory Bird Sanctuary in Nunavut, in the central Canadian Arctic, is an important breeding area for a variety of species of waterfowl and other wildlife. An assessment of the types and spatial extent of land cover, with a particular emphasis upon wildlife habitat capability, has not been available for this sanctuary, preventing adequate environmental assessment of proposed changes to the sanctuary's boundaries and limiting attempts to evaluate population trends and the distribution of wildlife species within the sanctuary. LANDSAT Thematic Mapper satellite imagery and digital image processing technology were used to prepare a land cover map for this large and remote area. Data from an examination of a variety of possible image enhancements, three field seasons of ground and aerial inspections of land cover types, and image classification were used to generate a thematic map of land cover types. An accuracy assessment of the classification provided an estimate of the reliability of the land cover map. Thirteen land cover types were identified and mapped, including three turbidity classes of water bodies and 10 terrestrial land cover types. An image enhancement, using power stretches of

Bands 4 and 5 and a linear stretch of Band 2, proved to be an excellent means of visually interpreting land cover types and was used to generate colour map plots for field inspections. During the three field seasons, 75 detailed ground visits and 2606 low-level aerial inspections of land cover sites were undertaken. Overall accuracy of the classification of water turbidity was 84%, with no confusion between turbid and clear lakes. Overall classification accuracy for terrestrial land cover types was 89%, with most of the individual cover types having an estimated accuracy of >80%. The land cover map will provide an effective means of assessing proposed boundary changes when used in conjunction with wildlife data and professional judgment. It will also provide a basis for effective design and evaluation of current and future surveys to monitor wildlife populations within the sanctuary. Similar land cover mapping of other migratory bird sanctuaries using satellite image analysis may be an effective means of evaluating the wildlife habitat of these other important areas.

Dolan, B. J. and G. R. Parker. 2005. Ecosystem classification in a flat, highly fragmented region of Indiana, USA. ***Forest Ecology and Management*** 219:109-131.

Abstract taken directly from text
A multifactor ecosystem classification of the Bluffton Till Plain Subsection of Indiana was created to characterize and organize ecosystem units within the Framework for Hierarchical Ecosystem Classification, which is used in forests throughout the eastern United States. The Bluffton Till Plain is a relatively flat landscape, typified by an undulating plain comprised of glacial till. The region is largely agrarian with forests scattered as distinct woodlots. Through examination of relationships among vegetation, soil, and landform characteristics, the Bluffton Till Plain has been organized into 3 ecological land-types (ELT) and 12 ecological land-type phases (ELTP). Nine herbaceous plant communities were described in the region, and they have been used to indicate site characteristics distinctive of each ELTP. Plant communities were found to be strongly related to landform topography, soil horizon depths, and soil texture through a process that identified communities with cluster analysis and related them to site characteristics with Classification and Regression Tree analysis. The most important factors in determining differences between plant community composition were the landform and landform component, which are related to the swell-and-swale topography of the till plain.

Duclos, I., E. Levesque, D. Gratton and P. A. Bordeleau. 2006. ***Vegetation Mapping of Bylot Island and Sirmilik National Park***. Final Report, Universite du Quebec a Trois Rivieres, prepared for Parks Canada, Nunavut Unit. 101 pp.

Abstract taken directly from text
This project was initiated in 2002 in Sirmilik National Park, Nunavut, with the objective of identifying dominant vegetation types and plant communities; and generating a vegetation map, using satellite imagery and the vegetation information collected. In order to map the vegetation of the whole park, we used images from the satellite Landsat 5 with the Thematic Mapper (TM) taken in July 1998, a Digital Elevation Model (DEM) produced from the 1:250 000 scale topographic maps and a digitized, orthorectified mosaic of 1:60 000 and 1:30 000 scale photographs (National Air Photo Library, mostly from 1982 but also from 1958, 1960, and 1961). Field data were collected in the course of two field seasons with 175 plots sampled in 2002 and 274 plots in 2003. Vegetation and environmental parameters were analysed using standard multivariate techniques (classification and ordination) to identify and describe a total of 10 vegetation types ranging from wet meadows to shrub-heath tundra and barrens. Many parts of Sirmilik National Park proved to be polar oases with lush vegetation not restricted only to valley bottoms but found on rolling hills and even some terraces and mountain Sirmilik National Park slopes. The plant communities described within the park compare well to others from northern oases. As in other arctic studies, the plant distribution is explained best by topography, moisture availability and soil characteristics. As some areas of Bylot Island and Baffin Island have not been sampled yet or have been under-sampled (e.g. wetlands, elevated plateaux with low vegetation cover, seashore, moraines), new species or plant communities can most likely be discovered. We strongly recommend that some areas be sampled to complete the work (for example, wetlands on Borden Peninsula and eastern valleys on Bylot Island).

EBA Engineering Consultants Ltd. 2002. ***Tibbitt to Contwoyto Winter Road Ecological Land Classification***. Prepared for Tibbitt to Contwoyto Winter Road Joint Venture, Yellowknife, NWT.

Abstract taken directly from text
Ecological Land Classification (ELC) investigations were conducted as an integral part of a comprehensive investigation to assemble environmental and engineering baseline information for the Tibbitt to Contwoyto Winter Road. The ELC component involved the development of a detailed ELC classification for terrestrial ecosystems associated with the Winter Road's portages. Activity focused upon Biophysical Study Area (BSA), defined as a 1 km wide strip of landbase centred on the road route, and the Winter Road Corridor, which is the terrestrial area in immediate proximity to the road route. A total of 64 portages were examined and mapped. On the basis of field plot data, 34 Ecosystem Types units were defined within a hierarchical framework, and then described, within fact sheets, in terms of key ecological features. Aggregations of Ecosystem Types (named Broad Ecosystem Units or BEUs) were also delineated and described. Ecosystem Types and BEUs were further aggregated within the three major ecological /geographic regions that the Winter Road passes through: Boreal, Transition and Tundra. Mapping of ELC units was conducted using a Geographic Information System (GIS). The base mapping consisted of high resolution and precision ortho-positioned aerial imagery, and elevational (contour) coverages that were specifically obtained for the baseline investigation. Given the quality of the base imagery, ELC mapping was prepared – using standardized photo-interpretation procedures – at a presentation scale of 1:6,000 for the BSA and 1:3,500 for the Winter Road Corridor. In total, 4,542 ELC polygons were delineated within 8,882 ha of portage, as part of the BSA mapping. In addition to Ecosystem Types, landscape features and various "modifiers" associated with terrain and vegetation (e.g., atypical ecosystem conditions, structural stage, stand composition and disturbance classes) were also mapped. As part of the summarization of the ELC mapping, the distribution of Ecosystem Types and BEUs throughout the BSA and along the corridor was characterized, along with the extent of the winter road's footprint. The ELC component was undertaken in coordination with other aspects of the integrated environmental and engineering baseline project. The ELC component provided an important set of outputs that were used by related aspects of the baseline investigation (e.g., wildlife studies, archaeological investigations and aquatic surveys). Results are prepared in both hard copy and digital (GIS-based) forms. The results of the ELC component provide a strong underpinning for the design and conduct of an environmental monitoring system, and engineering studies to upgrade Winter Road portages.

Ecological Stratification Working Group. 1995. ***A National Ecological Framework for Canada***. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull, ON.

Abstract not available [excerpts directly from text]
A collaborative project was undertaken by federal government agencies in 1991 with a wide range of stakeholders to revise the terrestrial component of a national ecological framework. This national framework has been revised to enhance the capability of both government and nongovernment organizations to assess, and report on, environmental quality and the sustainability of ecosystems in Canada. This classification system has evolved from previous national efforts and is part of an ongoing development of small-scale ecological mapping in Canada. This report: i) integrates the most recent ecological information (maps and reports); ii) contains narrative descriptions of each ecozone and ecoregion, iii) includes a relational database in a structure that facilitates further linking to federal and external databases, and iv) the framework provides a direct link to the Soil Landscapes of Canada digital map series. The national and regional map coverages have been created on a widely used commercial geographic information system with the ability to export to other software. This spatial framework was built on consultation, collaboration and compromise. As such, not all boundaries of the framework will be to the full satisfaction of all Canadian ecologists. It is presented for use to a wide range of users. National classifications evolve as knowledge is gained and ecological perspectives change. Following use and

feedback, it is intended that in the future this framework will again be revised to better reflect our understanding of the Canadian landscape and the sustainability of natural resources. This report describes the methods used to construct the spatial ecological framework, the concepts of the hierarchical levels of generalization (ecozones, ecoregions and ecodistricts), their linkages to various resource data sources, and some examples of applications of the framework. A copy of the corresponding 1:7 500 000 scale national map and narrative descriptions of each ecozone and ecoregion are also included.

Gallant, A. L., T. L. Sohl and D. E. Napton. 2004. Using an Ecoregion Framework to Analyze Land-Cover and Land-Use Dynamics. ***Environmental Management*** 34:S89-S110.

Abstract taken directly from text
The United States has a highly varied landscape because of wide-ranging differences in combinations of climatic, geologic, edaphic, hydrologic, vegetative, and human management (land use) factors. Land uses are dynamic, with the types and rates of change dependent on a host of variables, including land accessibility, economic considerations, and the internal increase and movement of the human population. There is a convergence of evidence that ecoregions are very useful for organizing, interpreting, and reporting information about land-use dynamics. Ecoregion boundaries correspond well with patterns of land cover, urban settlement, agricultural variables, and resource-based industries. We implemented an ecoregion framework to document trends in contemporary land-cover and land-use dynamics over the conterminous United States from 1973 to 2000. Examples of results from six eastern ecoregions show that the relative abundance, grain of pattern, and human alteration of landcover types organize well by ecoregion and that these characteristics of change, themselves, change through time.

Gillespie, M. K., D. C. Howard and M. J. Ness. 1996. Linking Satellite and Field Survey Data, Through the Use of GIS, as Implemented in Great Britain in the Countryside Survey 1990 Project. ***Environmental Monitoring and Assessment*** 39:385-398.

Abstract taken directly from text
The Institute of Terrestrial Ecology (ITE) has been studying land use and the effects of land use on ecology for two decades. A series of national field surveys have been undertaken by the Land Use Section of ITE since 1978, the most recent being Countryside Survey 1990 (CS1990). The three-year project brought together field survey and remote sensing data which were analyzed using Geographical Information Systems (GIS). National and regional land-cover patterns were described and changes estimated. The data collected by the field survey part of CS1990 recorded stratified samples based on a land classification. Thematic maps for surveyed 1-km squares covered physiography, agriculture and semi-natural vegetation, forestry, structures and boundaries. The same sites were surveyed in 1984 and 1990 with 14 000 digital maps produced describing both years. GIS was used to generate stock figures for each year, and overlay allowed change between survey dates to be estimated. GIS was used to compare data collected from both field survey and satellite imagery so that both sets of information could be qualified when expressed as national figures. This paper describes the historical development of the ITE Land Classification, examines the way in which data were collected for surveys, with particular reference to Countryside Survey 1990, and shows how satellite and field survey data can be linked through GIS.

Gillison, A. 2002. A Generic, Computer-assisted Method for Rapid Vegetation Classification and Survey: Tropical and Temperate Case Studies. ***Conservation Ecology*** 6: 3.

Abstract taken directly from text
Standard methods of vegetation classification and survey tend to be either too broad for management purposes or too reliant on local species to support inter-regional comparisons. A new approach to this problem uses species-independent plant functional types with a wide spectrum of environmental sensitivity. By means of a rule set, plant functional types can be constructed according to specific combinations from within a generic set of 35 adaptive, morphological plant functional attributes. Each

combination assumes that a vascular plant individual can be described as a "coherent" functional unit. When used together with vegetation structure, plant functional types facilitate rapid vegetation assessment that complements species-based data and makes possible uniform comparisons of vegetation response to environmental change within and between countries. Recently developed user-friendly software (VegClass) facilitates data entry and the analysis of biophysical field records from a standardized, rapid, survey pro forma. Case studies are presented at a variety of spatial scales and for vegetation types ranging from species-poor arctic tundra to intensive, multitaxa, baseline biodiversity assessments in complex, humid tropical forests. These demonstrate how such data can be rapidly acquired, analyzed, and communicated to conservation managers. Sample databases are linked to downloadable software and a training manual.

Groen, K. L. G., R. van der Meijden and H. Runhaar. 1994. The use of floristic data to establish the occurrence and quality of ecosystems. ***Ecosystem Classification for Environmental Management***. Kluwer Academic Publishers, Netherlands. Pp. 275-290.

Abstract taken directly from text

For environmental management, reliable information is needed on the occurrence and quality of ecosystems. A complete mapping of ecosystems in combination with an exhaustive survey is often expensive, especially on the nationwide scale. Therefore, it is worthwhile investigating whether floristic surveys can be a useful alternative. In this chapter the applicability of a nationwide floristic database for the Netherlands on 1-km^2 grid cells called FLORBASE is discussed. It is compared with a database on land-cover upgraded with information from vegetation releves, which is set up in the context of the Landscape Ecological Mapping of the Netherlands: LKN. It appears that floristic information can be used as a rough estimate of the occurrence of ecosystems in terms of presence in grid cells, and that this information is especially relevant for establishing the quality of these ecosystems. Floristic databases have obvious advantages, the most important of which is the fact that they can be filled and updated relatively easily with information gathered by both amateur and professional naturalists.

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 2000. ***International Classification of Ecological Communities: Terrestrial Vegetation of the United States***, ***Vol. 1, The National Vegetation Classification System: Development, Status, and Applications***. The Nature Conservancy, Arlington, Virginia. 139 pp.

Abstract not available [excerpts directly from text]

This report documents the development of the U.S. National Vegetation Classification (USNVC) System, emphasizing the key issues and requirements of such a system in relation to previous approaches to classification. The report reviews the current structure of the classification system and the standards that were used to develop, name, and describe the vegetation types. It summarizes the status of classifications, descriptions, conservation ranks, and overall distribution patterns for the vegetation types and provides a discussion of data gaps. The report also describes the data management systems and standards that have been implemented to ensure currency and consistency of information across the Conservancy and the Natural Heritage Programs. In addition, it includes some discussion of USNVC applications for conservation assessment and planning; vegetation mapping, inventory, and monitoring; resource management; regional planning; ecosystem management; and research associated with understanding vegetation patterns. Finally, the future directions envisioned for the USNVC system are discussed, including the need for continuing and expanding partnerships with the FGDC and individual federal agencies, the network of state Natural Heritage Programs, and the Ecological Society of America.

Hansen, D. J. and W. K. Ostler. 2002. ***Vegetation Change Analysis User's Manual***. Bechtel Nevada Ecological Services, Las Vegas, Nevada, prepared for U.S. Department of Energy, Las Vegas, Nevada. 84 pp.

Abstract taken directly from text

Approximately 70 percent of all U.S. military training lands are located in arid and semi-arid areas. Training activities in such areas frequently adversely affect vegetation, damaging plants and reducing the resilience of vegetation to recover once disturbed. Fugitive dust resulting from a loss of vegetation creates additional problems for human health, increasing accidents due to decreased visibility, and increasing maintenance costs for roads, vehicles, and equipment. Diagnostic techniques are needed to identify thresholds of sustainable military use. A cooperative effort among U.S. Department of Energy, U.S. Department of Defense, and selected university scientists was undertaken to focus on developing new techniques for monitoring and mitigating military impacts in arid lands. This manual focuses on the development of new monitoring techniques that have been implemented at Fort Irwin, California. New mitigation techniques are described in a separate companion manual. This User's Manual is designed to address diagnostic capabilities needed to distinguish between various degrees of sustainable and non-sustainable impacts due to military training and testing and habitat-disturbing activities in desert ecosystems. Techniques described here focus on the use of high-resolution imagery and the application of image-processing techniques developed primarily for medical research. A discussion is provided about the measurement of plant biomass and shrub canopy cover in arid lands using conventional methods. Both semi-quantitative methods and quantitative methods are discussed and reference to current literature is provided.

Hanson, D. S. and B. Hargrave. 1996. Development of a Multilevel Ecological Classification System for the State of Minnesota. ***Environmental Monitoring and Assessment*** 39:75-84.

Abstract taken directly from text

The Minnesota Department of Natural Resources (MNDNR) began development of an Ecological Classification System (ECS) in 1991. The ECS is hierarchically organized into six levels following the United States Forest Service structure. The upper four levels are being developed State-wide by an interdisciplinary group from several agencies. Geographic Information Systems approaches are being used to overlay and integrate existing data. The first two levels (Province and Section) have been completed. The third level (Subsection) is nearly completed, and work on the fourth level (Land Type Association (LTA)) started in January 1995. Classification and inventory for the lowest two levels (Ecological Land Type and Ecological Land Type Phase) was cooperatively undertaken on two Land Type Associations within the Chippewa National Forest. A sample set of management interpretations is being developed and tested for the two lower levels. Workshops demonstrating how ECS can be used for natural resource management began in mid-1995 and will continue for several years, as will development of the lower two levels on LTAs beyond the Chippewa National Forest.

Hargrove, W. W. and F. M. Hoffman. 2005. Potential of Multivariate Quantitative Methods for Delineation and Visualization of Ecoregions. ***Environmental Management*** 34:S39-S60.

Abstract taken directly from text

Multivariate clustering based on fine spatial resolution maps of elevation, temperature, precipitation, soil characteristics, and solar inputs has been used at several specified levels of division to produce a spectrum of quantitative ecoregion maps for the conterminous United States. The coarse ecoregion divisions accurately capture intuitively-understood regional environmental differences, whereas the finer divisions highlight local condition gradients, ecotones, and clines. Such statistically generated ecoregions can be produced based on user-selected continuous variables, allowing customized regions to be delineated for any specific problem. By creating an objective ecoregion classification, the ecoregion concept is removed from the limitations of human subjectivity, making possible a new array of ecologically useful derivative products. A red–green–blue visualization based on principal components analysis of ecoregion centroids indicates with color the relative combination of environmental conditions found within each ecoregion. Multiple geographic areas can be classified into a single common set of quantitative ecoregions to provide a basis for comparison, or maps of a single area through time can be classified to portray climatic or environmental changes geographically in terms of current conditions. Quantified representativeness can characterize borders between ecoregions as gradual, sharp, or of changing character along their length. Similarity of any ecoregion to all other ecoregions can be quantified and displayed as a ‘‘representativeness’’ map. The representativeness of an existing spatial array of sample locations or study sites can be mapped relative to a set of quantitative ecoregions, suggesting locations for additional samples or sites. In addition, the shape of Hutchinsonian niches in environment space can be defined if a multivariate range map of species occurrence is available.

Harvey, B. D., P. Cartier, Y. Bergeron and P. Nolet. 1996. Development of a Practical Forest Ecosystem Classification from Existing Biophysical Studies: an Approach Used in Northwestern Quebec. ***Environmental Monitoring and Assessment*** 39:231-247.

Abstract taken directly from text

While forest ecosystem classification work in Quebec has traditionally concentrated on inventory and mapping, more effort is now being placed on developing field guides similar to those produced in other Canadian provinces. As part of a project to produce a practical forest ecosystem field guide for the Amos Lowlands Ecological Region in northwestern Quebec, existing sub-regional ecological studies were exploited in order to develop a regional classification of forest ecosystems, or forest stations. Review of four fundamental studies provided a list of 107 ecological phases, each representing a particular combination of forest composition, surface deposit type and moisture regime. A series of silvicultural and environmental interpretations were developed and values for each were attributed to the ecological phases. Cluster analysis was then performed to classify phases into 29 broader units. A large, regional biophysical database which became available later in the project provided a means of validating and effectively modifying the classification. The justifications for using the original approach are discussed.

Host, G. E., C. W. Ramm, E. A. Padley, K. S. Pregitzer, J. B. Hart and D. T. Cleland. 1993. ***Field Sampling and Data Analysis Methods for Development of Ecological Land Classifications: An Application on the Manistee National Forest***. Report, USDA Forest Service, St. Paul, Minnesota. 49 pp.

Abstract taken directly from text

The Ecological Classification and Inventory of the Manistee National Forest was developed by stratifying the landscape to identify climatic and regional physiographic units, and then by intensively sampling the salient ecological components: overstory, ground flora, and surficial and deep soils. Univariate and multivariate analyses were used to examine the underlying variance structure of the individual data sets as well as correlations within and among these data sets. Classification and ordination procedures were used to group stands of similar floristic composition and soil properties. Ecological species groups were identified. These groups of stands became preliminary ecological types, which were further refined through continued analysis and field test mapping. Input from research scientists, field foresters, and forest management personnel was critical in developing classification units. Each ecological unit was described and interpreted; and a comprehensive field guide was developed. Ecological units were validated by conducting jackknife procedures on existing data, classifying new samples, and field testing mapping accuracy. The sampling and analysis protocol can be generally applied across forests of Eastern North America; specifics of the sampling design and variables measured will likely change across macroclimatic and physiographic boundaries. In all cases, however, highly accurate field sampling, care in data management and analysis, the combined experience of a multidisciplinary development team, and ongoing validation and refinement process are needed to ensure a robust and effective ecological classification.

Host, G. E., P. L. Polzer, D. J. Mladenoff, M. A. White and T. R. Crow. 1996. A Quantitative Approach to Developing Regional Ecosystem Classifications. ***Ecological Applications*** 6:608-618.

Abstract taken directly from text

Ecological land classification systems have recently been developed at continental, regional, state, and landscape scales. In most cases, the map units of these systems result from subjectively drawn boundaries, often derived by consensus and with unclear choice and weighting of input data. Such

classifications are of variable accuracy and are not reliably repeatable. We combined geographic information systems (GIS) with multivariate statistical analyses to integrate climatic, physiographic, and edaphic databases and produce a classification of regional landscape ecosystems on a 29 340-km^2 quadrangle of northwestern Wisconsin. Climatic regions were identified from a high-resolution climatic database consisting of 30-yr mean monthly temperature and precipitation values interpolated over a 1-km^2 grid across the study area. Principal component analysis (PCA) coupled with an isodata clustering algorithm was used to identify regions of similar seasonal climatic trends. Maps of Pleistocene geology and major soil morpho-sequences were used to identify the major physiographic and soil regions within the landscape. Climatic and physiographic coverages were integrated to identify regional landscape ecosystems, which are potentially different in characteristic forest composition, successional dynamics, potential productivity, and other ecosystem-level processes. Validation analysis indicated strong correspondence between forest cover classes from an independently derived Landsat Thematic Mapper Classification and ecological region. The development of more standardized data sets and analytical methods for ecoregional classification provides a basis for sound interpretations of forest management at multiple spatial scales.

Howard, D. C. and R. G. H. Bunce. 1996. The Countryside Information System: A Strategic-Level Decision Support System. ***Environmental Monitoring and Assessment*** 39:373-384.

Abstract taken directly from text
The Institute of Terrestrial Ecology (ITE) has monitored ecological change in Great Britain (GB) since 1978. The task has been undertaken using a stratified sampling scheme working with a 1 km square as the sample unit. In more recent years, scientific researchers at ITE have been working closely with the policy-makers of the United Kingdom Department of the Environment. The presentation of information to policy advisors and planners was a component within a large project investigating the ecological consequences of land-use change. A simple PC-based decision support system was developed during the project and subsequently has been expanded to produce a marketable product. The system, called the Countryside Information System (CIS), presents and links information at national, regional and thematic levels along with qualifying data describing accuracy and appropriateness of use (i.e., metadata). An integral part of the CIS is the ITE Land Classification, which divides GB into 32 environmental land classes; all 250 000 squares have been classified. The classification allows sampled data to be presented and, as the co-ordinate system is widely used in GB, it allows census datasets to be linked and compared. CIS has been described as a Geographical Information System, but the classification, data held within the system, and the use of metadata to assist in interpretation of results make the system much more decision-support oriented. Indeed, government departments have been involved in directing the development and are now starting to use the system to answer parliamentary questions and formulate, assess and monitor environmental policy. The CIS is an open system, running on a standard PC in Microsoft Windows. Tools for loading and editing new datasets (both sample and census) are incorporated in the suite of programs. The Windows environment and users comments during development have produced a system with an intuitive feel, removing some of the overhead of acquiring specialised technical skills before being able to operate a system. This paper describes the CIS and presents examples of its applications.

Howes, D. E. and E. Kenk (eds.). 1997. ***Terrain Classification System for British Columbia (Version 2)***. MOE Manual 10, Fisheries Branch and Surveys and Resource Mapping Branch, Ministry of Environment and Ministry of Crown Lands, Province of British Columbia, Victoria, B.C. 100 pp.

Abstract taken directly from text
The Terrain Classification System is a scheme designed for the classification of surficial materials, landforms and geomorphological processes. It has been specifically developed to provide an inventory of the terrain features in the landscape and to show their distribution, extent and location. The system is scale independent and provides base data applicable for a wide range of natural resource applications including planning, management, impact assessment and research. The data is conveyed in map form

by the use of terrain symbols and is conducive to computer digital storage, management and processing. This document (1997) includes updated terms and symbols which are found listed in Appendix III, and indicated throughout the manual. This update defines VERSION 2.

Hutto, C. J., V. B. Shelburne and S. M. Jones. 1999. Preliminary ecological land classification of the Chauga Ridges Region of South Carolina. ***Forest Ecology and Management*** 114:385-393.

Abstract taken directly from text
An ecological method of integrated multifactor land classification was applied in the Chauga Ridges, a subregion of the Blue Ridge Mountain Province, in northwest South Carolina. Phase I sampling involved measuring 61 reference plots in undisturbed late-successional upland hardwood stands. Four distinct site units (xeric, intermediate, submesic, and mesic) were identified using ordination, cluster analysis, discriminant function analysis, and canonical correspondence analysis. Using cross-validation of a discriminant function, a combination of five environmental features (landform index, terrain shape index, root mat thickness, slope gradient, and slope position) identified site units with an accuracy rate of 82%. A predictive GIS model which used spatial variables only (landform index, terrain shape index, topographic-related moisture index, distance-to-bottom, and slope gradient) was also developed and identified site units with the same success rate of 82%.

Jones, M. B., M. P. Schildhauer, O. J. Reichman and S. Bowers. 2006. Integrating Ecological data from the Gene to the Biosphere. ***Annual Review of Ecology, Evolution, and Systematics*** 37:519-544.

Abstract taken directly from text
Bioinformatics, the application of computational tools to the management and analysis of biological data, has stimulated rapid research advances in genomics through the development of data archives such as GenBank, and similar progress is just beginning within ecology. One reason for the belated adoption of informatics approaches in ecology is the breadth of ecologically pertinent data (from genes to the biosphere) and its highly heterogeneous nature. The variety of formats, logical structures, and sampling methods in ecology create significant challenges. Cultural barriers further impede progress, especially for the creation and adoption of data standards. Here we describe informatics frameworks for ecology, from subject-specific data warehouses, to generic data collections that use detailed metadata descriptions and formal ontologies to catalog and cross-reference information. Combining these approaches with automated data integration techniques and scientific workflow systems will maximize the value of data and open new frontiers for research in ecology.

Klijn, F. 1994. Spatially nested ecosystems: guidelines for classification from a hierarchical perspective. In: ***Ecosystem Classification for Environmental Management***, ed. by F. Klijn, Kluwer Academic Publishers, The Netherlands. pp. 85-116.

Abstract taken directly from text
Ecosystems are complex systems that can be described and classified by a large number of characteristics. Also, they can be distinguished at many spatial scale levels, all related to each other. This can be understood by regarded them as being spatially nested, thus forming a mosaic at the earth's surface. Both the complexity and the dependence on spatial scale pose problems for classification. To solve these, we argue for a deductive top-down approach based on hierarchy principles. It is based on a comprehensive hierarchical model of an ecosystem, related to spatial and mapping at different spatial scales: a set of guiding principles. Finally, we discuss and exemplify the applicability for environmental policy analyses.

Kojima, S. 1996. Ecosystem Types of Boreal Forest in the North Klondike River Valley, Yukon Territory, Canada, and their Productivity Potentials. ***Environmental Monitoring and Assessment*** 39:265-281.

Abstract taken directly from text

Vegetation, environmental characteristics, and forest productivity were studied in the boreal forest in the North Klondike River Valley, Yukon Territory, Canada. The concept and approach of biogeoclimatic ecosystem classification were followed. For the treed vegetation, five ecosystem types were distinguished based on vegetation structure and physical and chemical properties of soils. They were: 1) spruce-lichen type, 2) spruce-moss type, 3) spruce-Equisetum type, 4) spruce-willow type, and 5) bog forest type. These types were differentiated mainly by moisture regime and base status of soils. The sequence of the ecosystem types reflected their topographical position from slope summit to valley bottom. The spruce-lichen type developed in the driest and nutritionally impoverished habitats, the spruce-Equisetum type occurred in moist and nutritionally enriched sites, and the spruce-moss type was found in between them. The bog forest type occurred where peat had accumulated sufficiently to generate ombrotrophic conditions in habitats of high water table underlain with permafrost. The spruce-willow type developed along small creeks where substrates were very coarse. Tree growth characteristics were measured, except for the bog forest type that did not have trees over 5 m tall. Total volume of standing trees ranged from 29 to 582 m^3/ha, with an overall mean of 216.9 m^3/ha. The spruce-Equisetum type exhibited the highest figure, 413.5 m^3/ha, while the spruce - lichen type the lowest one, 87.7 m^3/ha Mean annual increment ranged from 0.15 to 2.66 m^3/ha, with an overall mean of 1.10 m^3/ha. A similar tendency was noted for all other forestry characteristics, i.e., the spruce-Equisetum type showed the highest productivity while the spruce-lichen type the lowest. This tendency was considered to be attributed to the availability of moisture and basic cations in soils.

Kupfer, J. A. and S. B. Franklin. 2000. Evaluation of an ecological land type classification system, Natchez Trace State Forest, western Tennessee, USA. ***Landscape and Urban Planning*** 49:179-190.

Abstract taken directly from text

In an effort to aid future research and forest management decisions, we incorporated data on forest type, soils and topography into a geographic information systems (GIS)-based ecological land classification system for Natchez Trace State Forest (NTSF) in western Tennessee. The area is still recovering from the effects of cultivation, logging, forest clearing and grazing during the 1800s and early 1900s, but the data indicated that most stands now contain saw timber-sized trees after more than 50 years of secondary succession. Our analyses showed that forest types were not randomly associated with soil characteristics or topography. For example, the most heavily gullied lands were strongly associated with pine forests while hardwoods were more associated with upland soils and certain types of side slopes. Mature hardwood stands, which were deemed to be of the greatest conservation value, were classified into eight ecological land types based on soil type, aspect, orientation and topographic setting for further study. When these land types were evaluated with respect to data on forest composition and environmental conditions collected in the field, we found that the variables used to derive the eight classes were important in influencing floristic patterns. It was, however, clear that the classes themselves imperfectly captured patterns of overstory community composition for a number of reasons. Thus, while land types provide a potentially valuable management tool, their utility and successful implementation are dependent upon a recognition of their inherent limitations.

Loveland, T. R. and J. M. Merchant. 2004. Ecoregions and Ecoregionalization: Geographical and Ecological Perspectives. ***Environmental Management*** 34:S1-S13.

Abstract taken directly from text

Ecoregions, i.e., areas exhibiting relative homogeneity of ecosystems, are units of analysis that are increasingly important in environmental assessment and management. Ecoregions provide a holistic framework for flexible, comparative analysis of complex environmental problems. Ecoregions mapping has intellectual foundations in both geography and ecology. However, a hallmark of ecoregions mapping is that it is a truly interdisciplinary endeavor that demands the integration of knowledge from a multitude of sciences. Geographers emphasize the role of place, scale, and both natural and social elements when delineating and characterizing regions. Ecologists tend to focus on environmental processes with special attention given to energy flows and nutrient cycling. Integration of disparate knowledge from the many key sciences has been one of the great challenges of ecoregions mapping, and may lie at the heart of the lack of consensus on the "optimal" approach and methods to use in such work. Through a review of the principal existing US ecoregion maps, issues that should be addressed in order to advance the state of the art are identified. Research related to needs, methods, data sources, data delivery, and validation is needed. It is also important that the academic system foster education so that there is an infusion of new expertise in ecoregion mapping and use.

Mah, S. and S. Thomson. 1996. An Ecological Framework for Resource Management in British Columbia. ***Environmental Monitoring and Assessment*** 39:119-125.

<u>*Abstract taken directly from text*</u>
British Columbia's landmass encompasses a complex diversity of ecosystems as a result of its diverse physiography, geology and climate. Resource planners and managers, depending upon their management objectives, use ecological information at different scales, from the very broad regional level to the local or site-specific level. The Ecoregion Classification and the Biogeoclimatic Ecosystem Classification systems provide the means for resource managers and others in British Columbia concerned with the environment to understand, manage, and communicate about the diverse ecosystems of the province. This paper outlines this multi-level regional ecological classification and describes how it is being applied by resource managers from various resource agencies and organizations responsible for forest, wildlife and habitat management in British Columbia.

Marshall, I. B., C. A. S. Smith and C. J. Selby. 1996. A National Framework for Monitoring and Reporting on Environmental Sustainability in Canada. ***Environmental Monitoring and Assessment*** 39:25-38.

<u>*Abstract taken directly from text*</u>
In 1991, a collaborative project to revise the terrestrial component of a national ecological framework was undertaken with a wide range of stakeholders. This spatial framework consists of multiple, nested levels of ecological generalization with linkages to existing federal and provincial scientific databases. The broadest level of generalization is the ecozone. Macroclimate, major vegetation types and sub-continental scale physiographic formations constitute the definitive components of these major ecosystems. Ecozones are subdivided into approximately 200 ecoregions which are based on properties like regional physiography, surficial geology, climate, vegetation, soil, water and fauna. The ecozone and ecoregion levels of the framework have been depicted on a national map coverage at 1:7 500 000 scale. Ecoregions have been subdivided into ecodistricts based primarily on landform, parent material, topography, soils, waterbodies and vegetation at a scale (1:2 000 000) useful for environmental resource management, rnonitoring and modelling activities. Nested within the ecodistricts are the polygons that make up the Soil Landscapes of Canada series of 1:1 000 000 scale soil maps. The framework is supported by an ARC-INFO GIS at Agriculture Canada. The data model allows linkage to associated databases on climate, land use and socio-economic attributes.

Matson, B. E. and R. G. Power. 1996. Developing an Ecological Land Classification for the Fundy Model Forest, Southeastern New Brunswick, Canada. ***Environmental Monitoring and Assessment*** 39:149-172.

<u>*Abstract taken directly from text*</u>
The methodology for developing and mapping a hierarchical Ecological Land Classification (ELC) is presented. The classification provided a systematic methodology that explained the distribution and composition of southern New Brunswick's forested landscape. The nested structure of the ELC identified and provided a hierarchical linkage between ecosystems from the size of forest stands to climate regions. This framework made the collection and analysis of data efficient and gave confidence that tree species distributions, which were central to understanding the influence of abiotic factors on the forest systems, were controlled by the factors examined at each level of the hierarchy. This ELC methodology, developed for the Fundy Model Forest, was successful in describing and mapping the Climate, Geomorphologic, and

Regolith controlled forest ecosystems. Preliminary classification indicates that spatial referencing of the Site Level is achievable.

McMahon, G., E. B. Wiken and D. A. Gauthier. 2004. Toward a Scientifically Rigorous Basis for Developing Mapped Ecological Regions. ***Environmental Management*** 34:S111-S124.

Abstract taken directly from text
Despite the wide use of ecological regions in conservation and resource-management evaluations and assessments, a commonly accepted theoretical basis for ecological regionalization does not exist. This fact, along with the paucity of focus on ecological regionalization by professional associations, journals, and faculties, has inhibited the advancement of a broadly acceptable scientific basis for the development, use, and verification of ecological regions. The central contention of this article is that ecological regions should improve our understanding of geographic and ecological phenomena associated with biotic and abiotic processes occurring in individual regions and also of processes characteristic of interactions and dependencies among multiple regions. Research associated with any ecoregional framework should facilitate development of hypotheses about ecological phenomena and dominant landscape elements associated with these phenomena, how these phenomena are structured in space, and how they function in a hierarchy. Success in addressing the research recommendations outlined in this article cannot occur within an ad hoc, largely uncoordinated research environment. Successful implementation of this plan will require activities - coordination, funding, and education - that are both scientific and administrative in nature. Perhaps the most important element of an infrastructure to support the scientific work of ecoregionalization would be a national or international authority similar to the Water and Science Technology Board of the National Academy of Sciences.

McNab, W. H. 1996. Classification of Local- And Landscape-Scale Ecological Types in the Southern Appalachian Mountains. ***Environmental Monitoring and Assessment*** 39:215-229.

Abstract taken directly from text
Five local ecological types based on vegetative communities and two landscape types based on groups of communities, were identified by integrating landform, soil, and vegetation components using multivariate techniques. Elevation and several topographic and soil variables were highly correlated with types of both scales. Landscape ecological types based only on landform and soil variables without vegetation did not correspond with types developed using vegetation. Models developed from these relationships could allow classification and mapping of extensive areas using geographic information systems.

McRae, D. J. 1996. Use of Forest Ecosystem Classification Systems in Fire Management. ***Environmental Monitoring and Assessment*** 39:559-570.

Abstract taken directly from text
Forest Ecosystem Classification (FEC) systems have been used in the past mainly for forest management decision-making. FEC systems can also serve an important role for decision-making in other disciplines, such as fire management for both wildfire suppression and prescribed burning operations. FEC systems can provide an important means of identifying potential fuels that may be present on a forest site. This fuel information, in combination with current fire weather conditions, as determined by the Canadian Forest Fire Weather Index (FWI) system, can assist fire managers in determining potential fire behaviour if ignition should occur. FEC systems provide a means of identifying the possible presence of a live understory vegetation component, a fuel layer that has been largely ignored in the past due to a lack of information. Dense understory vegetation can produce a very moist microclimate that can effectively hinder fire spread. The use of FEC systems can help in setting priorities on which wildfires need to be attacked aggressively. For prescribed burning, FEC systems can assist in achieving burn objectives better and more safely.

Moores, L. J., B. Pittman and G. Kitchen. 1996. Forest Ecological Classification and Mapping: Their Application for Ecosystem Management in Newfoundland. ***Environmental Monitoring and Assessment*** 39:571-577.

Abstract taken directly from text
A prerequisite to sustaining ecosystems is the inventory and classification of landscape structure and composition. Ecological classification and mapping involves the delineation of landscapes into easily recognizable units. Topography, soils, vegetation, physical landscape form, and successional pathways are delineation criteria commonly used. Damman (1967) developed a forest type classification system for Newfoundland using vegetation, soil and landforms as the defining criteria. Damman's forest types were used in combination with mensurational data to assign forest types to timber volume productivity classes. Since each of the Damman forest types is associated with characteristic soils, parent materials, moisture regime and topographic position, the mapping units are similar to Canada Land Inventory (CLI) mapping units. Field work to confirm the correlation between Damman forest types and CLI capability classes was initiated in 1993. CLI maps were receded in 1994 and Damman forest types were determined; resulting ecosystem- based maps provide a common framework to assess forestry/wildlife interactions in an ecosystem planning process.

Nadeau, L. B. and I. G. W. Corns. 2002. Post-fire vegetation of the Montane natural subregion of Jasper National Park. ***Forest Ecology and Management*** 163:165-183.

Abstract taken directly from text
Ecological Land Classification information gathered in the mid to late 1970s was used to predict post-fire vegetation for the Montane natural subregion of Jasper National Park. Percentage similarity indices (SI) between vegetation types based on understory species composition and cover, calculated distances (D) generated from altitude, nutrient and moisture, broad patterns of vegetation canopy based on moisture regimes, canonical correspondence analysis (CCA), and cluster analysis were used. Of the 33 Montane plant communities, grassland, low shrub and shrub communities were considered to regenerate after fire. Nineteen percent of the area was predicted as Potentilla fruticosa/Arctostaphylos uva-ursi/Galium boreale (L1), and 33% of the area as Pinus contorta var. latifolia/Shepherdia canadensis/Aster conspicuus (C6) or Pinus contorta var. latifolia/ Shepherdia canadensis/Linnaea borealis (C19) after fire. Dominant post-fire understory species were Juniperus communis, Sherpherdia canadensis, Rosa acicularis, Elymus innovatus and Linnaea borealis. Some closed canopy forests were assumed to open after fire, while other communities reverted to closed canopy pine forests.

Neily, P. D., E. Quigley, L. Benjamin, B. Stewart and T. Duke. 2003. ***Ecological Land Classification for Nova Scotia, Volume 1, Mapping Nova Scotia's Terrestrial Ecosystems***. Report DNR 2003 - 2, Nova Scotia Department of Natural Resources, Renewable Resources Branch. 83 pp.

Abstract taken directly from text
When land is classified from an ecological perspective areas of similar ecology are identified and mapped in an ecological land classification (ELC). Within the classification the ecological information is presented in a hierarchy of ecosystems where broad to specific levels of detail are presented on a series of maps. In this framework the ELC provides a description of the physical and biological environment affecting the ecological structures and process and the biodiversity of ecosystems. As one of the major tools required for planning and managing sustainable forests an ELC provides a common language for discussions concerning biodiversity, forest ecosystems and resource management. Within an ELC an appropriate level of ecosystem information and representation can be selected to use in t he planning and managing for the various elements of biodiversity such as individual species, habitats, ecosystem structures, age class, species associations or genetics. As a signatory to the National Forest Strategy (1998) and the Canadian Biodivesity Strategy (1995) Nova Scotia has recognized the importance of an ELC for forest ecosystem management. The ecological information in an ELC concerning the structures and functions and distribution of forest ecosystems will assist forest planners and managers of all land tenures in Nova Scotia. The following text will provide the methodology for mapping Nova Scotia's ecological land

classification. A description of the various units is also provided. Volume 2 (in progress) will provide an interpretation for the natural disturbance regimes within an ELC and Volume 3 (in progress) will examine the potential climax forests for each of the levels of the ELC.

Noble, I. R. and H. Gitay. 1996. A Functional Classification for Predicting the Dynamics of Landscapes. ***Journal of Vegetation Science*** 7:329-336.

<u>*Abstract taken directly from text*</u>
Functional classifications have been derived for various purposes using subjective, objective and deductive approaches. Most of the classifications were derived to describe a static state of a region or landscape rather than to predict the dynamics of the system. Here, we suggest a simple, but comprehensive functional classification based on life history parameters that can predict the dynamics of plant communities subject to recurrent disturbances. The predicted dynamics are described in terms of survival and local extinction of the functional groups. The groups derived from the classification are probably largely Independent of functional groupings that may be derived for other aspects of community composition (e.g. structure, phenology) and community interactions (roughness, albedo etc.). We emphasize that functional classification is context-dependent and we should not expect to find a useful, universal classification into functional groups. Software has been developed to help classify the species into functional groups, to derive successional sequences and to predict community composition under different disturbance regimes both in point and landscape models.

Omernik, J. M. 2004. Perspectives on the Nature and Definition of Ecological Regions. ***Environmental Management*** 34:S27-S38.

<u>*Abstract taken directly from text*</u>
Among environmental managers, recognition of the importance of integrating management activities across agencies and programs that have different responsibilities for the same geographic areas has created an awareness of the need for a common hierarchical framework of ecological regions (ecoregions) to implement the strategy. Responding to this need in the United States, nine federal agencies have signed a memorandum of understanding on the subject of developing a common framework of ecoregions. However, considerable disagreement over how to define ecoregions and confusion over the strengths and limitations of existing frameworks stand in the way of achieving this goal. This paper presents some perspectives on the nature and definition of ecoregions related to this confusion and provides a brief overview of the weight of evidence approach to mapping ecoregions, using an example initiated by the US Environmental Protection Agency. To effectively implement ecosystem assessment, management, and research at local, regional, and national levels, research is needed to increase our understanding of ecoregions. We must find ways to illustrate the nature of ecoregion boundaries and the variability of characteristics within ecoregions as they relate to management issues. Research must also be conducted on comparing existing frameworks and developing indices of ecological integrity to effectively evaluate their usefulness.

Papadimitriou, F. and P. Mairota. 1996. Spatial Scale-Dependent Policy Planning for Land Management in Southern Europe. ***Environmental Monitoring and Assessment*** 39:47-57.

<u>*Abstract taken directly from text*</u>
This study outlines an original tool for rural policy planning in southern Europe. This new tool is a process-based, scale-dependent, rural policy-making approach, which is designed to address increasing land degradation problems in southern Europe. Seven important processes are identified (land abandonment, de-vegetation, intensification in agriculture, global climate change, accelerated soil erosion, increasing water demands, urbanisation) and plotted on a space-time diagram, which clearly shows the spatial and temporal scales for which these processes are significant for landscape change in southern Europe. Conclusions are derived concerning, in particular, sustainable (optimal) rural policy-making for southern Europe's problematic land management. An optimal spatial-temporal scale for land management in southern Europe may range spatially from the "farm" (0.5 km 2) to "sub-provincial"

level (450 km 2) and temporally from 7 to 30 years. The study delineates methods and results derivable from such a new policy-planning approach and suggests the usefulness of combining this approach with ecological land classification at the landscape level.

Parker, W. H., A. Van Niejenhuis and J. Ward. 1996. Genecological Variation Corresponding to Forest Ecosystem Classification Vegetation and Soil Types for Jack Pine and Black Spruce from Northwestern Ontario. ***Environmental Monitoring and Assessment*** 39:589-599.

Abstract taken directly from text
A preliminary study was undertaken to reveal ecotypic differentiation in jack pine and black spruce corresponding to ecological land classification groups. Seed sources of jack pine (64) and black spruce (68) from northwestern Ontario were classified according to Vegetation Types (VTypes) and Soil Types (S-Types) defined by the Forest Ecosystem Classification (FEC) developed by the Ontario Ministry of Natural Resources and Forestry Canada for northwestern Ontario. Two short-term common garden field trials and a greenhouse trial were established for each species. Significant differences were present among ecological groupings of seed sources for both species. These differences were expressed according to V-Types and S-Types based on first, second, and third year heights as well as needle flushing dates for jack pine and second year growth increments for black spruce. Rank differences among the groups based on FEC V-Types and S-Types were generally consistent for each of the two species although certain groups showed rank reversals at the two field trials. Apparently, selection pressures corresponding to different FEC V-Types and S-Types have resulted in a detectable pattern of adaptive variation for both jack pine and black spruce in northwestern Ontario. However, the management implications for these two species are uncertain since additional tests are required to verify these results.

Perera, A. H., J. A. Baker, L. E. Band and D. J. B. Baldwin. 1996. A Strategic Framework to Eco-Regionalize Ontario. ***Environmental Monitoring and Assessment*** 39:85-96.

Abstract taken directly from text
Ontario is a spatially heterogeneous province. Natural resource policies and management plans must therefore address and account for this heterogeneity. An eco-regionalization scheme must possess certain minimum criteria to be effective. These criteria are: 1) an explicit explanation of spatial and temporal scales and variation; 2) a hierarchical construct of eco-regional domains; 3) an explicit quantitative description of the eco-regional domains; and, most importantly, 4) an ability to test a given eco-regional scheme as a hypothesis. This paper describes a hierarchical eco-regional framework (HEF) currently being constructed for Ontario. HEF is based on the scale-specific expression of ecological domain structure (geo-climatological parameters) and function (primary productivity). The approach relies on current advances in ecological hierarchy theory, remote sensing techniques, GIS methodologies, and statistical techniques. When completed, HEF will serve as a hypothesis which may be tested and validated at several different spatial scales.

Ontario Ministry of Natural Resources. 2007. ***Ecological Land Classification Primer: Central and Southern Ontario***. Ministry of Natural Resources, Queen's Park, Toronto, ON. 8 pp.

Abstract not available [excerpts directly from text]
In Ontario, the Ministry of Natural Resources (MNR) defines ecological units on the basic of bedrock, climate (temperature, precipitation), physiography (soils, slope, aspect) and corresponding vegetation, creating an Ecological Land Classification (ELC) system. Ontario's ELC system is founded on Angus Hills' Site Regions and Districts, first adopted in the 1950s. Since them, MNR has continued to develop and refine the province's ecological divisions, enhancing their compatibility with national and continental systems. The ELC hierarchy and associated products are multi-scale and extend from broad provincial level down to very fine-scale vegetation and substrate levels. Ontario's ELC system presently is composed of three upper level nested ecological units: ecozones, ecoregions and ecodistricts and two non-nesting finer scale units, ecosites and ecoelements.

Roberts, B. A., E. F. Woodrow, D. Bajzak and S. M. Osmond. 1996. A Cooperative, Integrated Project to Classify Forest Sites in Newfoundland. ***Environmental Monitoring and Assessment*** 39:353-364.

Abstract taken directly from text
Most existing systems of forest site classification attempt to combine vegetation, soil, terrain, geology, climatic and hydrologic factors. The current paper describes an ongoing project to assess the relationship of these factors to forest site capability in Newfoundland. Through the description and classification of forest inventory plots, this project is providing productivity data for species, descriptions of vegetational succession, growth and yield projections, as well as an indication of soil type variation within Forest Management Districts. The cooperative, multi-agency approach employed in this project has benefited all parties concerned, and has resulted in a mix of expertise and focus of resources that would not be possible within one agency. A large and valuable bank of vegetation, soil and site data is being acquired. Elements of the project include: 1) establishment of permanent forest inventory sample plots, in Management Districts throughout the province; 2) training of forest inventory crews so that they recognize forest vegetation, accurately prepare soil descriptions and undertake soil sampling; 3) laboratory analyses of soil samples for chemical and physical parameters, and integration of these results into the forest site classification; and, 4) formal reporting of the forest site classification, including improved descriptions of Damman Forest Site Types (FSTs) and soils.

Robitaille, A. and J.-P. Saucier. 1996. Land District, Ecophysiographic Units and Areas: the Landscape Mapping of the Ministere Des Ressources Naturelles du Quebec. ***Environmental Monitoring and Assessment*** 39:127-148.

Abstract taken directly from text
In 1985, the Ministere Des Ressources Naturelles established a Forest Ecological Survey Program for Southern Quebec. One component of the program was the mapping of land districts, which provide a physiographically-based territorial reference system. The land districts have an average surface area of between 100 and 300 sq km. Since its inception, the department has further refined the methodologies and standardized the results. The current methodologies are based on inventory and analysis of the geographical distribution of permanent environmental components (e.g., relief, surficial deposits, geology, hydrography). The products include 1:50 000 maps of surficial deposits, 1:250 000 maps of the land districts and physiographic systems, and a computerized data bank. To date, 500 000 km square have been covered, and the estimated completion date for the work is 1999. To facilitate use of the products and to encourage the development of new applications, a guide for forest managers and other users has been recently published. The guide assists with forest management planning strategies based upon the physical environment, in particular the production and use of interpretation grids and maps. The products of the mapping process are, for many regions of Southern Qu6bec, the only source of information on permanent environmental components. Currently, the Ministere des Ressources naturelles is planning to develop landscape maps of Southern Qu6bec which identify ecophysiographic units (1:1 250 000) and ecophysiographic areas (1:2 500 000). These maps are based upon the integration of critical physiographic features and the synthesis of land regions.

Rowe, J. S. 1996. Land Classification and Ecosystem Classification. ***Environmental Monitoring and Assessment*** 39:11-20.

Abstract taken directly from text
Earth, the ecosphere, is a unified functional ecosystem. Ecological land classification (ELC) and regionalization divides and categorizes this unity into similar and dissimilar pieces – sectoral ecosystems - at various scales, in the interests of admiration and understanding. The recognition of land/water ecosystems in a hierarchy of sizes provides a rational base for the many-scaled problems of protection and careful exploitation in the fields of agriculture, forestry, wildlife and recreation. In forested terrain the protection of biodiversity, old growth forests, watersheds and wildlife habitat depends on spatial-temporal planning of forestry operations to maintain a preferred mosaic structure of local ecosystems within each ecological region. Without ecological understanding and a good ELC, this is impossible. Conceiving the

world as comprising nested land/water ecosystems that are the source of life, elevates the role of Earth-as-context, an antidote to destructive anthropocentrism.

Runhaar, H. and H. A. U. de Haes. 1994. The use of site factors as classification characteristics for ecotopes. In: ***Ecosystem Classification for Environmental Management***, ed. by F. Klijn, Kluwer Academic Publishers, The Netherlands. pp. 139-172.

Abstract taken directly from text
This chapter describes a classification of small-scale ecosystems or ecotopes using abiotic and biotic site factors as classification characteristics. The plant species composition of the types distinguished can be used for mapping purposes. To this end, ecological species groups have been defined that are characteristic for ecosystem types. The classification is meant for use in environmental impact assessment. So far, efforts have focused on the classification of terrestrial ecosystems and their description in terms of floristic composition. However, our goal is to classify all ecosystems occurring in the Netherlands and, also, to include fauna in the description. The use of the classification in environmental impact assessment is discussed, and a comparison is made with vegetation classifications. Our conclusion is that the use of site factors for the classification of ecosystems is of more than merely practical importance, because it facilitates the integration of knowledge about the abiotic and biotic components of ecosystems.

Sims, R. A., I. G. W. Corns and K. Klinka. 1996. Introduction – Global to Local: Ecological Land Classification. ***Environmental Monitoring and Assessment*** 39:1-10.

Abstract taken directly from text
Ecological Land Classification (ELC) is a scientific endeavour which attempts to organize, stratify and evaluate ecosystems (and complexes of ecosystems) for the purposes of land resource management. Since ecosystems themselves are not easily defined in practical terms, ELC is likewise not a trivial concept. Nonetheless, ELC is a prerequisite for ecosystem management and the conservation of biological diversity simply because ecosystems must be described, characterized and spatially-located before they can be managed. Regarding the current status and future direction of ELC, mainly in relation to forest management: 1) approaches to ELC construction and utilization have shifted considerably over the past 2 decades; 2) there appears to be a current consensus regarding basic approaches to ELC; 3) spatial scale is a critical variable that must be addressed by ELCs; 4) ELCs must strive to more directly address management objectives; 5) natural ecosystem functions need to be better integrated within ELC frameworks; and, 6) the need for quality, georeferenced ELC-related data will continue to grow.

Smalley, G. W., L. B. Sharber and J. C. Gregory. 1996. Ecological Land Classification as a Basic Theme for the Management of Wildlands in Tennessee: A Start. ***Environmental Monitoring and Assessment*** 39:579-588.

Abstract taken directly from text
The Tennessee Wildlife Resources Agency (TWRA) owns and/or cooperatively manages nearly 247 000 ha scattered across the state. To aid the management of this diversity of soils, landforms, and plant communities, TWRA has selected a flexible, ecological land classification system developed for the Interior Uplands in southeastern United States. Landtypes are the most detailed unit of the 5-level hierarchy. To date, four wildlife management areas and one state wetland have been mapped and entered into the agency s Geographic Information System (GIS). These five tracts are in the Upper Coastal Plain of west Tennessee, in the Western and Eastern Highland Rim regions of middle Tennessee, and in the Cumberland Mountains of east Tennessee. The history, physiography, geology, soils, topography, and vegetation of each area are discussed. After forest cover type and age information is merged with the landtypes, wildlife habitat modelling will commence.

Smith, M. L. and C. Carpenter. 1996. Application of the USDA Forest Service National Hierarchical Framework of Ecological Units at the Sub-Regional Level: The New England-New York Example. ***Environmental Monitoring and Assessment*** 39:187-198.

<u>*Abstract taken directly from text*</u>

Ecological regionalization according to the USDA Forest Service National Hierarchical Framework of Ecological Units was undertaken for the New England-New York region. A top down, map-overlay approach was used to map sections and subsections. Where available, landscape level units (LTAs) were aggregated and evaluated to supplement the subsection mapping. A regional collaborative effort was undertaken to counterbalance the shortfalls of a purely mechanistic approach. As a result of this process, 17 section and 58 draft subsection units were delineated for the New England-New York region. The sub-regional units developed reflect the strong correspondence among climate, topography and geography at this scale. Geologic factors, due to their influence on landform and mineral availability, are also reflected in the ecological unit boundaries. Efforts to apply the multifactor model at the sub-regional level have been hampered by the lack of scale appropriate information on a number of factors particularly meso-scale climate and potential natural community composition and distribution. Further research and investigation are required before these criterion are adequately met.

Thompson, D. C. 1980. A Classification of the Vegetation of Boothia Peninsula and the Northern District of Keewatin, N.W.T. ***Arctic*** 33:73-99.

<u>*Abstract taken directly from text*</u>

The vegetation of Boothia Peninsula and the northern District of Keewatin (212,500 km^2) was surveyed, and a vegetation classification suitable for synoptic level surveys of wildlife habitat was produced. A total of 45 plant communities was recognized on Boothia Peninsula. Principal components and discriminant function analysis were used to identify seven significant groupings of these communities. These seven groups, designated as the vegetation groups for Boothia Peninsula, were: Sedge Meadows, Willow Hummocks, Lichen-Dryas Plateaus, Seepage Slopes, Moss Tundra, Purple-Saxifrage Plains, and Rock Barrens. Forty-two plant communities were recognized in the northern District of Keewatin. The six significant groupings which resulted, and which were designated as the vegetation groups for the northern District of Keewatin, were: Sedge Meadows, Willow-Sedge Meadows, Orthophyll Shrub, Lichen-Heath Plateaus, Lichen Uplands, and Barrens. The species composition and relationship to the physical environment for each of these vegetation groups is described.

Thompson, R. S., S. L. Shafer, K. H. Anderson, L. E. Strickland, R. T. Pelltier, P. J. Partlein and M. W. Kerwin. 2005. Topographic, Bioclimatic, and Vegetation Characteristics of Three Ecoregion Classification Systems in North America: Comparisons Along Continent-wide Transects. ***Environmental Management*** 34:S125-S148.

<u>*Abstract taken directly from text*</u>

Ecoregion classification systems are increasingly used for policy and management decisions, particularly among conservation and natural resource managers. A number of ecoregion classification systems are currently available, with each system defining ecoregions using different classification methods and different types of data. As a result, each classification system describes a unique set of ecoregions. To help potential users choose the most appropriate ecoregion system for their particular application, we used three latitudinal transects across North America to compare the boundaries and environmental characteristics of three ecoregion classification systems [Kuchler, World Wildlife Fund (WWF), and Bailey]. A variety of variables were used to evaluate the three systems, including woody plant species richness, normalized difference in vegetation index (NDVI), and bioclimatic variables (e.g., mean temperature of the coldest month) along each transect. Our results are dominated by geographic patterns in temperature, which are generally aligned north–south, and in moisture, which are generally aligned east–west. In the west, the dramatic changes in physiography, climate, and vegetation impose stronger controls on ecoregion boundaries than in the east. The Kuchler system has the greatest number of ecoregions on all three transects, but does not necessarily have the highest degree of internal

consistency within its ecoregions with regard to the bioclimatic and species richness data. In general, the WWF system appears to track climatic and floristic variables the best of the three systems, but not in all regions on all transects.

Turner, M. G. 2005. Landscape Ecology: What is the State of the Science? ***Annual Review of Ecology, Evolution, and Systematics*** 36:319-344.

Abstract taken directly from text
Landscape ecology focuses on the reciprocal interactions between spatial pattern and ecological processes, and it is well integrated with ecology. The field has grown rapidly over the past 15 years. The persistent influence of land-use history and natural disturbance on contemporary ecosystems has become apparent. Development of pattern metrics has largely stabilized, and they are widely used to relate landscape pattern to ecological responses. Analyses conducted at multiple scales have demonstrated the importance of landscape pattern for many taxa, and spatially mediated interspecific interactions are receiving increased attention. Disturbance remains prominent in landscape studies, and current research is addressing disturbance interactions. Integration of ecosystem and landscape ecology remains challenging but should enhance understanding of landscape function. Landscape ecology should continue to refine knowledge of when spatial heterogeneity is fundamentally important, rigorously test the generality of its concepts, and develop a more mechanistic understanding of the relationships between pattern and process.

Uhlig, P. W. C. and J. K. Jordan. 1996. A Spatial Hierarchical Framework for the Co-Management of Ecosystems in Canada and the United States for the Upper Great Lakes Region. ***Environmental Monitoring and Assessment*** 39:59-73.

Abstract taken directly from text
Over the past three decades, considerable effort has been invested in the development of complex and comprehensive ecosystem classifications and inventories in many parts of North America. Paralleling this has been an evolution in those hierarchical frameworks guiding the development and application of classifications. However, resource management agencies continue to grapple with the dilemma of applying multiple classification and inventory templates over large jurisdictions, especially as they attempt to address ecosystem management objectives. Given that Canada and the United States share ecosystems and that commitments have been made by all levels of government to make progress towards ecosystem-based approaches to management, there is a need to provide the proper tools. Comprehensive goals will not be achieved without collaboration and cooperation. This paper outlines the range of ecosystem classification approaches that exist in the Upper Great Lakes region. Canadian and American national hierarchical frameworks are briefly examined. Specific information needs and tasks are outlined which must be followed, independent of national boundaries, for the successful integration of planning and monitoring programs for large regional ecosystems. A general model is proposed for the development and application of an integrated, multi-scale and bi-national ecosystem classification, inventory and information system. This approach would facilitate data sharing and communication across jurisdictional boundaries.

Virtanen, T., K. Mikkola and A. Nikula. 2004. Satellite image based vegetation classification of a large area using limited ground reference data: a case study in the Usa Basin, north-east European Russia. ***Polar Research*** 23:51-66.

Abstract taken directly from text
Predicted global changes can be studied effectively by combining spatially explicit data sets on vegetation and other landscape properties with process models. However, detailed knowledge of the vegetation distribution of remote Arctic areas is relatively scarce. This paper shows how a meso-scale vegetation and land cover classification of a large, remote Arctic area can be conducted at a fine spatial resolution (30 m cell size) using a limited ground reference data set. The study area is the catchment of the River Usa (93 500 km^2) in north-eastern European Russia. Vegetation zones in the Usa Basin range from taiga

in the south to forest-tundra and tundra in the north, and to alpine in the Ural mountains in the east. Classification was done using a mosaic of spectrally adjusted Landsat TM5 images from five different dates and a semi-supervised method. Ground reference data were collected during the summers of 1998, 1999 and 2000. Accuracy of the 21-class vegetation type/land cover classification produced was tested against test points interpreted from oblique aerial photographs taken from a helicopter (logistic limitations prohibited the collection of representative ground reference data). The main vegetation types (forests, willow dominated stands and meadows, peatlands, tundra heaths, mainly unvegetated areas, and water bodies) were distinguished with relatively high accuracy: 84% of the test points were classified correctly. Spatially detailed land cover data sets like the one described here allow detailed landscape-level analysis and process modelling on many different subjects.

Walker, D. A. 2000. Hierarchical subdivision of Arctic tundra based on vegetation response to climate, parent material and topography. ***Global Change Biology*** 6:19-34.

Abstract taken directly from text
Current land-cover classifications used for global modelling portray Arctic tundra as one or two classes. This is insufficient for analysis of climate-vegetation interactions. This paper presents a simple three-level vegetation-map legend system useful for modelling at global, regional, and landscape scales. At the highest level (global scale: 107-108km^2) the Tundra Zone is divided into four subzones based on vegetation response to temperature along the latitudinal temperature gradient from north to south: (1) Cushion-forb, (2) Prostrate Dwarf-shrub, (3) Erect Dwarf-shrub, and (4) Low Shrub subzones. The boundaries follow a modification of Yurtsev's phytogeographic subzones. Parent material and topography are also major considerations at global, regional, and landscape scales. Soil pH is a key variable for many ecosystem responses, and a division into acidic (pH 5.5 or less) and non-acidic soils is used. A conceptual meso-topographic gradient is used to characterize the influence of soil-moisture and snow regimes. The example legend framework focuses on the Northern Alaska floristic sub-province, and could be expanded to other floristic provinces using local expert knowledge and available literature. Dominant plant functional types within each habitat type within the four subzones are also presented. Modellers could include or ignore different levels of resolution depending on the purpose of the mode. The approach resolves conflicts in terminology that have previously been encountered between the Russian, North American, and Fennoscandian approaches to Arctic zonation.

Yoke, K. A. and J. C. Rennie. 1996. Landscape Ecosystem Classification in the Cherokee National Forest, East Tennessee, U.S.A. ***Environmental Monitoring and Assessment*** 39:323-338.

Abstract taken directly from text
A landscape ecosystem classification is described for the 43 800 ha Foothills section (elevation 305 to 610 m) of the southern unit of the Cherokee National Forest. Vegetative cover, landform, and soils data were obtained from sixty 0.04 ha plots located in stands representing late successional stages. Vegetation data were grouped by dominant cover type utilizing agglomerative, hierarchical clustering and detrended correspondence analysis. Detrended canonical correspondence analysis (DCCA) and stepwise discriminant analysis (SDA) were used to identify patterns in species composition explained by environmental variables. Four community types were identified: (1) *Tsuga canadensis -Acer saccharum - Fagus grandifolia - Fraxinus americana*, (2) *Tsuga canadensis - Rhododendron maximum*, (3) *Quercus prinus*, and (4) *Quercus prinus - Quercus coccinea -Acer rubrum*. A recently developed "Landform Index" that quantifies slope type and degree of protection by adjacent land masses was identified through DCCA and SDA as the most important predictor of community types. The strength of the correlations between elevation and several soil thickness variables with DCCA axis 1 indicated that vegetation varies along an interpreted moisture gradient. No ecological meaning was attributed to the second axis.

Yurtsev, B. A. 1994. Floristic Division of the Arctic. ***Journal of Vegetation Science*** 5:675-776.

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CONSULTING

Abstract taken directly from text
The progress in the floristic study of the circumpolar Arctic since the 1940s is summarized and a new floristic division of this region is presented. The treeless areas of the North Atlantic and North Pacific with an oceanic climate, absence of permafrost and a very high proportion of boreal taxa are excluded from the Arctic proper. It is argued that the Arctic deserves the status of a floristic region. The tundra zone and some oceanic areas are divided into subzones according to their flora and vegetation. Two groups of subzones are recognized: the Arctic group (including the Arctic tundras proper and the High Arctic) and the Hypoarctic group. The Arctic phytochorion is floristically divided into sectors: 6 provinces and 20 sub-provinces reflecting the regional features of each sector in connection with flora history, physiography and continentality-oceanity of the climate. Each sector is described and differentiated by a set of differential and co-differential species. The peculiarities of the Arctic flora are manifest in different ways in the various sectors, and endemism is not the universal criterion for subdivision.

Zimmerman, C. L. 1998. ***Using Ecological Land Units in a Gap Analysis for Conservation Planning in a Southwestern Ohio Watershed***. Master's Thesis, Department of Biological Sciences, Wright State University, Dayton, OH. 107 pp.

Abstract taken directly from text
Gap analysis is a method to identify insufficiency in biodiversity protection. In degraded agricultural landscapes, it requires information on the past, present, and the potential natural distribution of forest vegetation to construct a comprehensive nature reserve network. Using Geographic Information Systems (GIS), I conducted a biodiversity gap analysis to assess the representation of ecological land units (ELUs) supporting forest vegetation both within and external to the current reserve network in the Lower Twin Creek Watershed (LTCW), southwestern Ohio. I used this analysis to make conservation planning recommendations to the local park district. ELUs are based on relatively stable associations of soils, physiography, and potential natural vegetation. In heavily deforested landscapes, such as the LTCW, ELUs model a more intact functioning landscape by predicting the distribution of potential natural forest vegetation. ELUs were classified using multivariate and cluster analyses on forest canopy tree species and seven physiographic and soil variables derived from digital elevation models and a soil series map in GIS. A cluster analysis of the five most significant variables (landform, drainage, hill-shade, curvature, and percent slope) influencing vegetation distribution resulted in nine discrete ELUs. They included uplands dominated by *Fagus grandifolia – Acer saccharum*, dry slopes dominated by *Quercus spp*. - *Carya ovata*, mesic slopes dominated by a mixed mesophytic community, and wet floodplains dominated by *Platanus occidentalis – Populus deltoides*. A reference ecosystem map was constructed using ArcView GIS Spatial Analyst with the five environmental variables identified in the multivariate analysis. To determine the area of forest cover in each ELU within the reserve network and the watershed as a whole, the reference ecosystem map was overlaid with a 1990 land cover type map and the reserve boundaries. The area of forest in each ELU in the reserve network was then compared to the area of forest in each ELU in the watershed as a whole and the potential natural distribution of forest cover as predicted by the reference ecosystem map to determine the percent of forest protected in each condition. The gap analysis, using the current forest distribution, indicated that the well and poorly drained upland ecosystems were underrepresented in the reserve network. A similar pattern emerged using the reference ecosystem map; however, reflecting the degree to which these upland ecosystems are deforested, to meet a 25% representation target would require three to four times more forest than existed in these ELUs in 1990. The results of the gap analysis based on the current vegetation distribution were influenced by the pattern of deforestation in the LTCW. The reference ecosystems map provided a model of an intact functioning landscape from which to establish conservation planning targets. Although the upland matrix forest ecosystems may have lower species richness per land unit area and are relatively common, restoring portions of the matrix forest may be the key to the long-term maintenance of biological diversity in the LTCW.

Zonneveld, I. S. 1994. Basic principles of classification. In: ***Ecosystem Classification for Environmental Management***, ed. by F. Klijn, Kluwer Academic Publishers, The Netherlands. pp. 23-47 pp.

Abstract taken directly from text
Classification is a systematic ordering of the object of research, in this case, ecosystems at the earth's surface or, in other words: landscape units as 'holons'. As for general principles of classification, we can learn a lot from the best-known classification, the taxonomical classification of species. This has functioned as an example for similar classifications of land attributes, such as soil or vegetation. For a classification of ecosystems, we must select diagnostic characteristics from the large number of ecosystem properties, for which selection guiding principles are an aid. Examples are given of the most important guiding principles and possible diagnostic characteristics are discussed. Also, it is argued that typifications of land attributes are the best diagnostic characteristics for ecosystem classification. Two different approaches to classification are compared, viz. by agglomeration, which leads to the most pure typification, and by sub-division, which is always connected with mapping. These two approaches are related to two different hierarchies. A hierarchy of agglomeration is related to classification by agglomeration with abstract boundaries in a typification, whereas a hierarchy in space is related to classification by sub-division with concrete boundaries in the field. A map's legend, for example, is essentially a classification by subdivision. However, units can be described by means of the units of a typification. Finally, it is questioned whether a world embracing typification is worthwhile to strive for. It is concluded that for most applied surveys an ad-hoc classification by sub-division is the most appropriate, but using land attribute typifications for defining the legend units.

SECTION 6.0 - ENVIRONMENTAL IMPACT ASSESSMENT

6.1 GENERAL

Allan, J. D. 2004. Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems. ***Annual Review of Ecology, Evolution and Systematics*** 35:257-284.

Abstract taken directly from text
Local habitat and biological diversity of streams and rivers are strongly influenced by landform and land use within the surrounding valley at multiple scales. However, empirical associations between land use and stream response only varyingly succeed in implicating pathways of influence. This is the case for a number of reasons, including (a) covariation of anthropogenic and natural gradients in the landscape; (b) the existence of multiple, scale-dependent mechanisms; (c) nonlinear responses; and (d) the difficulties of separating present-day from historical influences. Further research is needed that examines responses to land use under different management strategies and that employs response variables that have greater diagnostic value than many of the aggregated measures in current use. "In every respect, the valley rules the stream", H.B.N. Hynes (1975)

Allard, M., R. Fortier, D. Sarrazin, F. Calmels, C. Marchildon, G. Delisle and E. L'Herault. 2006. ***The impact of recent warming on permafrost in Nunavik (2.4 permafrost)***. Presentation, Centre d'études nordiques, Université Laval, Québec, and Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Germany. 31 pp.

Abstract
This presentation discusses the observed warming in the atmosphere and in the permafrost, the impact of permafrost thawing in the discontinuous, palsa, zone of permafrost, and permafrost mapping in communities. It says that warming, increased snow depth and thermokarst favours expansion of shrubs, which might be the principal biogeographical impact of warming in the low Arctic tundra.

Antoniades, D., S. F. Lamoureux, R. Pienitz, D. R. Mueller, P. Van Hove, J. D. Tomkins and W. F. Vincent. 2005. ***Extreme northern aquatic ecosystems as sentinels of global environmental change***. Poster, Universite Laval, Quebec and Queen's University, Ontario.

Abstract not available [excerpts directly from text]
Due to sensitivity of arctic environments to global change, aquatic ecosystems at extreme latitudes are particularly well suited as sentinels of past and future environmental change. This study looks at fiords and meromictic lakes located along the northern coast of Ellesmere Island to understand their responses to recent climate change, and to reconstruct long-term environmental change in the High Arctic. Several rare ecosystem types characterize the northern coast of Ellesmere Island, including ice shelves, epishelf lakes, and meromictic lakes. Their region is also highly susceptible to ongoing changes in the global environment, which threaten the existence of many of these ecosystems and their biota. Fiords and meromictic lakes have the potential to provide proxy records of long-term climate change in the region that are crucial to understanding both regional climate change and the future viability of these rare ecosystems. Due to sensitivity of these extreme northern ecosystems and the amplification of climate change in polar regions, these systems may be viewed as sentinels of global environmental change.

Beanlands, G. E. and P. N. Duinker. 1983. ***An Ecological Framework for Environmental Impact Assessment in Canada***. Report, Institute for Resource and Environmental Studies, Dalhousie University, Nova Scotia and Federal Environmental Assessment Review Office, Hull, Quebec. 132 pp.

Abstract not available [excerpts directly from text]
This report presents the results of a two-year project designed to address this concern in the Canadian context. The objective of the project was to determine the extent to which the science of ecology could contribute to the design and conduct of assessment studies to recommend ways in which this could realistically be achieved. By design, the project involved the active participation of environmental scientists who conduct impact assessment studies and those who are responsible for the administration of assessment procedures in Canada. Participants in 10 regional workshops, held across the country, included personnel from the federal and provincial governments, representatives of industrial proponents, consultants and members of the university community- some 150 people in total. The project also included a comprehensive review of literature pertinent to scientific and ecological inputs to environmental impact assessment. This report primarily reflects the opinions and suggestions emanating from the workshops coupled with the state-of-the-art in assessment studies as presented in scientific writings. For some time, members of the scientific community have been stressing the need to clarify the scientific basis for assessment studies. The main scientific and technical requirements are: boundaries (the establishment of time and space boundaries), quantification, modelling, prediction, and study design (to show a clear direction through a framework or strategy).

Beaulac, I., G. Dore, M. Allard and A. Bourque. 2004. ***Permafrost Thawing Impacts on Roads and Airfields: Problem Assessment and Review of Possible Solutions***. Presentation, Laval University. 23 pp.

Abstract
This presentation describes problems related to permafrost degradation. It also describes possible adaptation techniques, airfield condition assessments, and proposed adaptation strategy in Nunavik.

Berteaux, D. 2004. ***Climate Change and the Distribution of Mammals in the Eastern Canadian Arctic***. Presentation, University of Quebec at Rimouski.

Abstract
This presentation asks the question: what are going to be the impacts of warming on the Canadian arctic wildlife? It stresses the need for monitoring (precise, short-term planning), and predictive science (less precise, long-term planning). It also discusses the benefits and limitations of the latitudinal shift framework.

Bridge, G. 2004. Contested Terrain: Mining and the Environment. ***Annual Review of Environment and Resources*** 29:205-259.

Abstract taken directly from text
This review critically surveys an extensive literature on mining, development, and environment. It identifies a significant broadening over time in the scope of the environment question as it relates to mining, from concerns about landscape aesthetics and pollution to ecosystem health, sustainable development, and indigenous rights. A typology compares and contrasts four distinctive approaches to this question: (a) technology and management-centered accounts, defining the issue in terms of environmental performance; (b) public policy studies on the design of effective institutions for capturing benefits and allocating costs of resource development; (c) structural political economy, highlighting themes of external control, resource rights, and environmental justice; and (d) cultural studies, which illustrate how mining exemplifies many of society's anxieties about the social and environmental effects of industrialization and globalization. Each approach is examined in detail.

Cargill, S. M. and F. S. Chapin III. 1987. Application of Successional Theory to Tundra Restoration: A Review. ***Arctic and Alpine Research*** 19:366-372.

Abstract taken directly from text
Life-history traits of individual species, competitive interactions, and facilitation all contribute to the pattern and rate of succession in tundra ecosystems. An understanding of these natural successional processes will permit the development of effective strategies for restoration of disturbed areas in tundra. In mesic disturbed sites, the soil organic mat remains, providing a source of buried seed and vegetative propagules as well as a store of nutrients. Except where surface erosion is severe, natural succession can proceed quite rapidly, and sowing of exotic grasses is likely to inhibit rather than promote the establishment of native plants. By contrast, re-vegetation of xeric disturbed sites is often restricted by inadequate supplies of seed, nitrogen, and/or water. Sowing or planting may facilitate the invasion of native plants by increasing nutrient availability, especially if species with symbiotic nitrogen fixation are used. Where erosion hazards are severe, planting may be necessary for engineering reasons, regardless of its effect on the establishment of native plants.

Churchill, J., M. Tenuta, R. Bello and T. Papakriakou. 2005. ***Are Greenhouse Gas Emissions Determined By Plant Community Composition or Edaphic Conditions at Churchill, Manitoba?*** Poster, University of Manitoba and York University.

Abstract not available [excerpts directly from text]
Regional estimates of greenhouse gas emissions of the Hudson Bay Lowlands are important as the area is a main store of organic carbon as peat, and has the potential for methane emissions. The objective of this study was to determine which plant community or soil type is a better predictor of greenhouse gas emissions from a subarctic environment. Based on the results, edaphic conditions surprisingly did not exert great influence upon greenhouse gas emissions at least for emissions within a similar lichen community. However, there were small differences in methane and carbon dioxide emissions for the transect sections that are likely related to some soil characteristics, but these were not nearly as great as expected based on different peat accumulation, water table height and active layer in the four soil pits. The ridge had lower carbon dioxide emissions whereas the lower section had the largest emission. Further work needs to be done to separate lichen respiration and heterotrophic soil respiration as influenced by edaphic conditions at this site.

Churchill, J., M. Tenuta, R. Bello and T. Papakriakou. 2005. ***Greenhouse Gas Emissions in Relation to Moisture Content, Temperature and Landscape Position in a Subarctic Environment at Churchill, Manitoba***. Poster, University of Manitoba and York University.

Abstract not available [excerpts directly from text]
The objective of this study was to determine the relation between major environmental conditions (temperature, moisture), landscape position and plant communities to greenhouse gas emissions. The Hudson Bay Lowland is the second largest contiguous peat accumulation in the world, the third largest

wetland in the world and an important repository of organic carbon in the world. Global warming is expected to alter hydrologic regimes, permafrost extent and vegetation dynamics in the area. This study concluded that temperature, moisture, landscape position and plant community all combined to alter greenhouse gas emissions in both the sites. N_2O showed no significant consumption or production regardless of landscape position. Increased moisture content for the Sedge-Moat related to dramatically greater CH_4 production and lower moisture at Polygon Top related to CH_4 consumption. Later in the season CH_4 related to increased temperature. Increased moisture and temperature coincided with increased CO_2 production.

Constant, P., L. Poissant, D. Lean, M. Pilote and R. Villemur. 2005. ***Mercury and Methyl Mercury within the Tundra Snowpacks at Kuujjuarapik, Quebec (Canada)***. Poster, McGill University, University of Quebec in Montreal, and University of Ottawa.

Abstract not available [excerpts directly from text]
Early after the polar sunrise, BrO radicals are formed in the northern atmosphere when the photolysis of bromide or dibromomethane occurs in presence of ozone (O_3). These BrO react with atmospheric Hg0, generating Hg^{+1} and Hg^{2+} species which are rapidly deposited onto snow surface. Atmospheric Hg0 and O_3 concentrations are then reduced below 1 ng m^{-3} and 10 ppbv respectively. These so known mercury depletion events (MDEs) should represent a potential contamination for northern ecosystems. The aim of this study is to improve knowledge about the Hg biogeochemical cycle in sub-arctic ecosystems (Tundra of the Hudson Bay) and determine the possible impacts of MDEs for local communities. These works combine (1) a chemical approach, to measure ozone (O_3) and total gaseous mercury (TGM) air concentrations in addition to total mercury (THg) and methyl mercury (MeHg) snow concentrations and (2) a microbiological approach to study snow microbial populations. Two field campaign were conducted at Whapmagoostui-Kuujjuarapik. The first investigation was done in March 2004, to investigate the impact of cold weathers and MDEs for THg and MeHg snow concentrations. The second field works were done in April 2005 in order to follow THg and MeHg snow concentrations during snowmelt.

Cote, G. 2005. ***Present and Past Impacts of Animal Populations on the Nutrient and Contamination Status of Freshwater Lakes on Bylot Island, Nunavut***. Poster, Laval University.

Abstract not available [excerpts directly from text]
The Bylot Island Migratory Bird Sanctuary was established in 1965 by Parks Canada to protect the nesting grounds of large concentrations of bird populations (Thickbilled Murres, Black-legged Kittiwakes and Greater Snow Geese) (figure 1). Due to protection measures and changes in the overwintering habitat, the population of breeding Snow Geese on Bylot Island has increased dramatically over recent years. As a result, the nutrient load originating from faecal goose droppings has increased, which may profoundly change the relative concentrations of C, N and P in the usually dilute and unproductive (oligotrophic) arctic lakes. Both nutrient loading (due to increased numbers of birds) and temperature elevation (due to rapid warming of high latitude regions) may cause large shifts in the composition and functioning of these tundra lakes. Sampling was conducted from the 15th until the 19th of July 2005 at 10 sites that seemed heavily impacts by goose dropping enrichment. Surface sediments were looked at, as well as chemical, physical, and sediment contamination data. Three short cores were also sampled to obtain information on the evolution of past trophic status in 3 lakes. With the sediment cores extracted from lakes near breeding bird colonies, paleolimnological techniques will be used to track short- and long-term changes in lake nutrient (trophic) status, primary production rate and contamination.

Cumming, G. S., D. H. M. Cumming and C. L. Redman. 2006. Scale Mismatches in Social-Ecological Systems: Causes, Consequences, and Solutions. ***Ecology and Society*** 11:14.

Abstract taken directly from text
Scale is a concept that transcends disciplinary boundaries. In ecology and geography, scale is usually defined in terms of spatial and temporal dimensions. Sociological scale also incorporates space and time, but adds ideas about representation and organization. Although spatial and temporal location determine

the context for social and ecological dynamics, social-ecological interactions can create dynamic feedback loops in which humans both influence and are influenced by ecosystem processes. We hypothesize that many of the problems encountered by societies in managing natural resources arise because of a mismatch between the scale of management and the scale(s) of the ecological processes being managed. We use examples from southern Africa and the southern United States to address four main questions: (1) What is a "scale mismatch?" (2) How are scale mismatches generated? (3) What are the consequences of scale mismatches? (4) How can scale mismatches be resolved? Scale mismatches occur when the scale of environmental variation and the scale of social organization in which the responsibility for management resides are aligned in such a way that one or more functions of the social-ecological system are disrupted, inefficiencies occur, and/or important components of the system are lost. They are generated by a wide range of social, ecological, and linked social-ecological processes. Mismatches between the scales of ecological processes and the institutions that are responsible for managing them can contribute to a decrease in social-ecological resilience, including the mismanagement of natural resources and a decrease in human well-being. Solutions to scale mismatches usually require institutional changes at more than one hierarchical level. Long-term solutions to scale mismatch problems will depend on social learning and the development of flexible institutions that can adjust and reorganize in response to changes in ecosystems. Further research is needed to improve our ability to diagnose, understand, and resolve scale mismatches in linked social-ecological systems.

Daniel, S. E., G. T. Tsoulfas, C. P. Pappis and N. P. Rachaniotis. 2004. Aggregating and evaluating the results of different Environmental Impact Assessment methods. ***Ecological Indicators*** 4:125-138.

Abstract taken directly from text
The role of life cycle analysis (LCA) in identifying and measuring the environmental impact of extended supply chains, i.e., chains involving both forward and reverse activities, is very important. Particularly, in the case of alternative supply chain management policies or scenarios, life cycle analysis may significantly help to quantify the environmental result of these alternatives for the purpose of comparison and decision making. It is debatable, however, whether such comparison is always possible. Indeed, life cycle analysis has often raised discussion and disagreements, especially regarding the stage of Impact Assessment (valuation), and, until now, there is no generally accepted framework of analysis. In this paper, different models are used in order to extend the usability of the Environmental Design of Industrial Products method of Impact Assessment. Furthermore, research results that are produced by applying different methods of Impact Assessment are examined in the cases of the recovery and disposal chains of lead–acid batteries.

Fritz, K. M., B. R. Johnson and D. M. Walters. 2006. ***Field Operations Manual for Assessing the Hydrologic Permanence and Ecological Condition of Headwater Streams***. U.S. Environmental Protection Agency, Office of Research and Development, Washington DC.

Abstract not available [excerpts directly from text]
The purposes of this manual are to: 1) document procedures that were developed and used by the United States Environmental Protection Agency's (USEPA) Ecosystem Exposure Research Division (EERD) for the assessment of the physical and biological characteristics of headwater streams; and 2) provide a catalog of procedures to other groups with an interest in headwater stream assessment. This document provides methods specifically designed for assessing the hydrologic permanence and ecological condition of headwater streams.

Forbes, B. C. 1997. Anthropogenic Tundra Disturbance in Canada and Russia. In: ***Disturbance and Recovery in Arctic Lands***, ed. by R. M. M. Crawford, Kluwer Academic Publishers, The Netherlands. pp. 365-379.

Abstract not available [excerpts directly from text]
Long-term data on both natural and assisted recovery from anthropogenic disturbance regimes have traditionally been lacking, particularly in the High Arctic. Recent investigations of surface disturbance in high arctic Canada and low arctic Russia are discussed in the context of the following comparisons: high arctic vs. low arctic; minerotrophic vs. acidic substrates; assisted vs. unassisted recovery; short- vs. Long-term responses; natural vs. anthropogenic disturbance; and scale of impact vs. scale of response. There is also the question: when do the increasing numbers of anthropogenic patches begin to affect the landscape-level patterns and processes? Among the key differences between the Canadian Arctic Archipelago and northwest Siberia are the much larger scope of industrial development and the presence of ice-rich permafrost and domestic reindeer herds in the latter. Although the most common impacts in the Canadian High Arctic are relatively small-scale by comparisons with northwest Siberia, the effects are persistent. In the case of vehicle tracks, drained and desiccated meadows constitute a serious cumulative impact and indicate that even patchy, seemingly innocuous disturbances such as the single passage of a vehicle can inadvertently alter large portions of tundra landscapes.

Forbes, B. C., J. J. Ebersole and B. Strandberg. 2001. Anthropogenic Disturbance and Patch Dynamics in Circumpolar Arctic Ecosystems. ***Conservation Biology*** 15:954-969.

Abstract taken directly from text
It has been 30 years since environmental concern was first expressed over the prospect of large-scale resource development in the Arctic. Human effects are more extensive within the tundra biome now than at any time in the past. With or without predicted climactic changes, interaction among different natural and contemporary anthropogenic disturbance regimes are bound to have a significant effect on local and regional vegetation patterns and plant migration. We summarize the results of recent studies of patchy anthropogenic disturbance. We pay particular attention to the natural regeneration of plant communities, emphasize patch dynamics over the medium term (20-75 years), and discuss the data in the context of popular models of vegetation change following disturbance. Disturbance is important because it produces patches of partially or totally denuded ground that permit propagule establishment but may also open affected areas to erosion. Even relatively low-intensity, small scale disturbances have immediate and persistent effects on arctic vegetation and soils. On all but the wettest sites, the patches support new, relatively stable vegetation states. Where slope is minimal, such disturbances are capable of expanding over large areas in as short a time as 4 years. The effects result in an artificial mosaic of patches of highly variable quality and quantity that compromise feeding and nesting habits for terrestrial herbivores.

Garneau, M.-E. and C. Barnard (presentation coordinators). 2006. ***Food, water and land resources in the shifting N-S gradients of the terrestrial eastern Canadian Arctic***. Presentation, ArcticNet.

Abstract
This presentation outlines climate change impacts. Topics include wildlife and food diversity, water and climate indicators, emerging diseases, permafrost and landscape stability, culture and traditional resources, tundra and health, Arctic char, and trails and access.

Henry, G. 2004. ***Tundra Ecosystem Responses to Climate Variability and Change: Observational and Experimental Results***. Presentation, University of British Columbia.

Abstract
This presentation discusses changes in nutrient stock, vegetation cover, soil organic matter, and periglacial processes in the Arctic that are expected to occur with climate change.

Hill, G. and G. Henry. 2005. ***Long-term Response of Sedge Meadows to High Arctic Climate Change***. Poster, University of British Columbia.

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Abstract
Aerial photos of the Western Arctic show increased shrubbiness. Experimental control plots show species response to ambient climate change in the Western Arctic. The objective of this study was to establish the longest-term study on Arctic ecosystem response to actual climate change in the Canadian High Arctic by replicating above and below ground peak standing crop measurements made in 1980-1983 in wet sedge meadows. Conclusions from this study were that sedge meadow species have responded to air and soil warming by increasing their above and below ground biomass.

Johnson, C. J., M. S. Boyce, R. L. Case, H. D. Cluff, R. J. Gau, A. Gunn and R. Mulders. 2005. Cumulative Effects of Human Developments on Arctic Wildlife. ***Wildlife Monographs*** 160:1-36.

Abstract taken directly from text
Recent discoveries of diamondiferous kimberlite deposits in the Canadian central Arctic led to unprecedented levels of mineral exploration and development. The cumulative effects of such activities are an issue of concern for government regulatory agencies, regional and international conservation organizations, wildlife managers, and indigenous peoples. We investigated the impacts of human activities and associated infrastructure on the distribution of Arctic wildlife in 190,000 km^2 of the Taiga Shield and Southern Arctic ecozones 400 km northeast of Yellowknife, Northwest Territories, Canada. We used covariates for vegetation, interspecific interactions, and human disturbance features to develop seasonal resource-selection models for barren-ground caribou (Rangifer tarandus groenlandicus), gray wolves (Canis lupus), grizzly bears (Ursus arctos), and wolverines (Gulo gulo). We used an information-theoretic approach to select 11 seasonal models for the 4 species. Nine models were good predictors of species occurrence and vegetation covariates were important components of all models. Mines and other major developments had the largest negative effect on species occurrence, followed by exploration activities, and outfitter camps. We did not, however, record strong avoidance responses by all species during all seasons to each disturbance type (i.e., major developments, mineral exploration sites, outfitter camps) and for some models carnivores selected for disturbance features (i.e., occurred closer to sites than comparison random locations). We used a geographic information system (GIS) to extrapolate each seasonal resource-selection model to the study area and quantified the reduction in habitat effectiveness as a function of modeled and hypothetical disturbance coefficients. Across all models, grizzly bears and wolves demonstrated the strongest negative response to disturbance and corresponding reduction in habitat effectiveness, followed by caribou and wolverines. The largest seasonal effect was recorded for caribou during the post-calving period, where model coefficients suggested a 37% reduction in the area of the highest quality habitats and an 84% increase in the area of the lowest quality habitats. This is the first study to demonstrate the cumulative effects of multiple sources of human disturbance for caribou, wolves, bears, and wolverines found across the Canadian central Arctic. Resource selection models and corresponding maps of important habitats can be used to guide and evaluate future development proposals and can serve as a component of a regional environmental assessment. However, inferences from large-scale modeling efforts should be carefully evaluated when making detailed prescriptive recommendations. Study design, sample size, reliability of GIS data, and accuracy of model predictions are important considerations when evaluating the strength and scale of inference of correlative resource selection studies such as this. We recommend that regional cumulative effects analyses serve as the coarsest framework for understanding the impacts of human developments on wide-ranging animals. Monitoring and research should be conducted at various behavioral scales leading to a body of knowledge that fully describes the range and strength of impacts resulting from cumulative effects.

Johnson, L. A. 1987. Management of Northern Gravel Sites for Successful Reclamation: A Review. ***Arctic and Alpine Research*** 19:530-536.

Abstract taken directly from text
In the Arctic and Subarctic, roads and other construction projects require large amounts of gravel to provide well-insulated, stable surfaces. Gravel pits create large disturbed, terrestrial areas and produce significant on-site and off-site impacts, at least some of which are long lasting or even permanent. Gravel

substrates are difficult to re-vegetate since they typically have low moisture- and nutrient-holding capacities. There are several possible approaches to maximize the likelihood of successfully reclaiming northern gravel sites: (1) Minimize their areal extent and visual impact; (2) improve the substrate characteristics for plant growth by such measures as erosion control and reuse of topsoil; (3) select adapted biological materials; and (4) proper siting of gravel pits to enhance reinvasion of native plant species. The extreme conditions of most arctic and subarctic sites require site specific approaches. These conditions also increase the need to use native plant species and to utilize their successional strategies to develop appropriate reclamation plans for gravel sites.

Kevan, P. G., B. C. Forbes, S. M. Kevan and V. Behan-Pelletier. 1995. Vehicle Tracks on High Arctic Tundra: Their Effects on the Soil, Vegetation, and Soil Arthropods. ***Journal of Applied Ecology*** 32:655-667.

Abstract taken directly from text
1) Examination of the effects of vehicle and pedestrian tracks of known age (13 or more years) and intensity of use (single to multiple passages) on vegetation, soil chemistry, soil arthropods, soil thaw characteristics, and small-scale hydrological changes showed clear and inter-related patterns.
2) In general, all tracks, regardless of age, showed small increases in the depth of thaw beneath them (c. 2.8 cm).
3) Tracks were generally depleted of carbon and to a lesser, but significant extent, of potassium and phosphorus. Slight increases in NO, NH, and calcium were noted. Magnesium and total nitrogen seemed unaffected.
4) On all tracks which had suffered multiple passages vegetation cover was significantly reduced. In a few sites where single passages were recorded, cover increased through proliferation of the sedge, *Kobresia myosuroides*.
5) Abundance of soil arthropods was significantly reduced on tracks, but the diversity was not.
6) In most sites, soil moisture and over-ground water flow did not seem affected. Only in sedge meadows where compression from a single passage resulted in channelling of water, and where multiple passages removed vegetation and initiated gulley erosion, were effects serious.

Lamoureux, S., J. Cockburn, K. Stewart, D. McDonald, P. Treitz, D. Atkinson, J. Wall, M. Lafreniere, B. McLeod, P. Francus, S. Cuven, M. Simpson, A. Otto and J. Austin. 2005. ***High Arctic integrated landscape and ecological processes, Cape Bounty, Melville Island, Nunavut***. Poster, Queen's University and University of Toronto.

Abstract not available [excerpts directly from text]
A key uncertainty in assessing the impact due to projected climate change in the Canadian High Arctic is the integrated response by the different elements of the earth system. The challenge to collect systematic datasets to explore the processes that are likely to be impacted by climate change has hitherto precluded an integrated approach to identifying and testing these key sensitivities. The Cape Bounty Integrated Landscape and Ecosystem Project was established in 2003 to build datasets in order to establish quantitative responses, develop monitoring strategies, and build linkages between elements of the arctic environmental system. This work provides the basis for additional exploration of the interactions between coastal land areas and the adjacent ocean to further integrate with oceanographic studies.

Male, S. K. and E. Nol. DATE. Impacts of roads associated with the Ekati Dimaond Mine, Northwest Territories, Canada, on reproductive success and breeding habitat of Lapland Longspurs. ***Canadian Journal of Zoology*** 83:1286-1296.

Abstract taken directly from text
We examined the effects of roads associated with the Ekati Diamond Mine™, Nortwest Territories, Canada, on reproductive success and breeding habitat of Lapland Longspurs (*Calcarius lapponicus* (L., 1758)) by comparing these attributes on study sites located directly beside and at least 5 km away from roads. No significant differences between roads and reference sites were detected for first-egg

dates, clutch size, mean nestling mass on the 7th day following hatch, or daily nest survival. We found no evidence that Lapland Longspurs were avoiding nest sites located near roads. Recorded frequencies of male song overlapped with the harmonics of heavy-truck noise. Snow-water equivalent and percent cover of mosses were significantly higher on reference sites, while soil moisture and dust deposition were higher on road sites. Dust suppressant applied midway through the breeding season significantly reduced dust deposition. Lapland Longspur nest sites had significantly higher percent cover of graminoids and of shrubs and forbs, and significantly lower percent cover of lichens than random sites, an effect that occurred both near and distant from roads. Currently, there appears to be no measurable effect of roads associated with the Ekati Diamond Mine™ on current territorial choice and reproductive performance of Lapland Longspurs. Observed differences in habitat characteristics between reference plots and road plots suggest that long-term changes in the vegetation community may occur that could affect nest-site selection of Lapland Longspurs.

Munns Jr., W. R. 2006. Assessing Risks to Wildlife Populations from Multiple Stressors: Overview of the Problem and Research Needs. ***Ecology and Society*** 11:23.

Abstract taken directly from text
Wildlife populations are experiencing increasing pressure from human-induced changes in the landscape. Stressors including agricultural and urban land use, introduced invasive and exotic species, nutrient enrichment, direct human disturbance, and toxic chemicals directly or indirectly influence the quality and quantity of habitat used by terrestrial and aquatic wildlife. Governmental agencies such as the U.S. Environmental Protection Agency are required to assess risks to wildlife populations, in its broadest definition, that result from exposure to these stressors, yet considerable uncertainty exists with respect to how such assessments should be conducted. This uncertainty is compounded by questions concerning the interactive effects of co-occurring stressors, appropriate spatial scales of analysis, extrapolation of response data among species and from organisms to populations, and imperfect knowledge and use of limited data sets. Further, different risk problems require varying degrees of sophistication, methodological refinement, and data quality. These issues suggest a number of research needs to improve methods for wildlife risk assessments, including continued development of population dynamics models to evaluate the effects of multiple stressors at varying spatial scales, methods for extrapolating across endpoints and species with reasonable confidence, stressor-response relations and methods for combining them in predictive and diagnostic assessments, and accessible data sets describing the ecology of terrestrial and aquatic species. Case study application of models and methods for assessing wildlife risk will help to demonstrate their strengths and limitations for solving particular risk problems.

Noble, B. F. and J. E. Bronson. 2005. Integrating human health into environmental assessment: case studies of Canada's northern mining resource sector. ***Arctic*** 58:395-405.

Abstract taken directly from text
This paper examines the integration of human health considerations into environmental impact assessment (EIA) in the Canadian North. Emphasis is placed on the northern mining sector, where more land has been staked in the past decade than in the previous 50 years combined. Using information from interviews with northern EIA and health practitioners and reviews of selected project documents, we examined three principal mining case studies, northern Saskatchewan uranium mining operations, the Ekati diamond project, and the Voisey's Bay mine/mill project, to determine whether and how health considerations in EIA have evolved and the current nature and scope of health integration. Results suggest that despite the recognized link between environment and health and the number of high-profile megaprojects in Canada's North, human health, particularly social health, has not been given adequate treatment in northern EIA. Health considerations in EIA have typically been limited to physical health impacts triggered directly by project-induced environmental change, while social and other health determinants have been either not considered at all, or limited to those aspects of health and well-being that the project proponent directly controlled, namely employment opportunities and worker health and safety. In recent years, we have been seeing improvements in the scope of health in EIA to reflect a broader range of health determinants, including traditional land use and culture. However, there is still a

need to adopt impact mitigation and enhancement measures that are sensitive to northern society, to monitor and follow up actual health impacts after project approval, and to ensure that mitigation and enhancement measures are effective.

Parmesan, C. 2006. Ecological and Evolutionary Responses to Recent Climate Change. ***Annual Review of Ecology, Evolution, and Systematics*** 37:637-669.

<u>*Abstract taken directly from text*</u>
Ecological changes in the phenology and distribution of plants and animals are occurring in all well-studied marine, freshwater, and terrestrial groups. These observed changes are heavily biased in the directions predicted from global warming and have been linked to local or regional climate change through correlations between climate and biological variation, field and laboratory experiments, and physiological research. Range-restricted species, particularly polar and mountaintop species, show severe range contractions and have been the first groups in which entire species have gone extinct due to recent climate change. Tropical coral reefs and amphibians have been most negatively affected. Predator-prey and plant-insect interactions have been disrupted when interacting species have responded differently to warming. Evolutionary adaptations to warmer conditions have occurred in the interiors of species' ranges, and resource use and dispersal have evolved rapidly at expanding range margins. Observed genetic shifts modulate local effects of climate change, but there is little evidence that they will mitigate negative effects at the species level.

Pretzlaw, T. and M. M. Humphries. 2005. ***Habitat or Climate: Correlates of mammal composition across the Canadian forest-tundra transition***. Poster, McGill University.

<u>*Abstract taken directly from text*</u>
Climate is warming globally and there is clear evidence that the warming is causing shifts in many species ranges. Predicting range shifts of wildlife species is thus integral in understanding climate change impacts. The first step in this process is to access the utility of climate in explaining the current distribution of species. Here we highlight the preliminary findings of our research in modeling patterns of mammal species occurrence over the forest tundra ecotone. Our analyses suggests as we move from large spatial grains to medium spatial grains there is an increasing importance of habitat and decreasing but still integral importance of climate as predictive variables. This has important consequences for predicting climate mediated range shifts.

Pretzlaw, T and M. M. Humphries. 2006. ***Wildlife at the Edge: Assemblage and Abundance across the Forest to Tundra Transition***. Poster, McGill University, Montreal, Quebec.

<u>*Abstract not available [excerpts directly from text]*</u>
The southern edge of the Arctic is defined the forest to tundra transition. The objective of this study was to determine the pattern of diversity, species assemblage, and resource selection of terrestrial vertebrates over the forest to tundra transition. The relative abundance of 22 species across 66 sites in the Yukon was determined. It was found that at this transition, vegetation was the most powerful predictor of the observed species in occurrence and abundance. This suggests that with an understanding of the effects of climate change on vegetation, predictions of the occurrence of most species could be made.

Rapport, D. J., H. A. Regier and T. C. Hutchinson. 1985. Ecosystem Behavior under Stress. ***The American Naturalist*** 125:617-640.

<u>*Abstract not available [excerpts directly from text]*</u>
In ecosystems as in organisms, what constitutes health is not (despite the popular view) based on objective scientific criteria, but rather involves judgment. The signs or symptoms of ecosystem distress are thus, to a greater or lesser degree, dependent on one's perspective. In classifying stresses we have been pragmatic, reflecting conventional approaches to environmental problems. Five groups of stresses appear sufficient to include most of the specific impacts of human activity on natural ecosystems, as well

as extreme natural events. (1) Harvesting of renewable resources directly affects the biotic capital of the ecosystem. (2) Pollutant discharges are purposely or accidentally made into air, water, or land, and include a variety of pollutants such as PCB's, SO_2, pesticides, heavy metals, oil spills, and radiation, in addition to sewage. Leakage into the environment often occurs from transportation, consumption, and storage of products, as well as their production. (3) Physical restructuring includes purposive land-use charges, such as from forests to farms, wetlands to dry lands, sloping shores to harbors, lowlands to cities, valleys to artificial lakes, ridges to pits. (4) Introductions of exotics, both plant and animal, may be made intentionally or carelessly. (5) Extreme natural events occur with sufficient irregularity, such that they are not readily accommodated by the recipient ecosystem. The ecosystem-level distress syndrome is manifest through changes in nutrient cycling, productivity, the size of dominant species, species diversity, and a shift in species dominance to opportunistic shorter-lived forms.

Rapport, D. J., M. Hilden and E. R. Roots. 1997. Transformation of Northern Ecosystems Under Stress. Arctic Ecological Changes from the Perspective of Ecosystem Health. In: ***Disturbance and Recovery of Arctic Lands***, ed. R. M. M. Crawford, Kluwer Academic Publishers, Netherlands. pp. 73-89.

Abstract not available [excerpts directly from text]
The Arctic and sub-Arctic regions are some of the least impacted landscapes of the biosphere, but are beginning to show some characteristic signs of degradation, as a consequence of economic development and resource exploitation. Our purpose is to provide an ecosystem health perspective for addressing questions of stress and disturbance in Northern Ecosystems. The central questions posed here are: 1) what characteristics have to be taken into account in defining health in an Arctic context? 2) what kind of transformations seen from an ecosystem health perspective do Arctic systems undergo when stressed? and 3) what are the future prospects for conservation and rehabilitation of Arctic systems? If current trends continue, then the health of these sensitive high-latitude ecosystems is surely to be continually compromised. Both specific activities - oil exploration and production, hydroelectric development, overharvesting of living resources, etc., and generalized stresses - transportation development, climate changes, far-travelled toxic substances are bound to result, separately and collectively, in significant damages to Northern Ecosystems. The root cause appears to be the trend towards commercial and managerial integration of northern peripheral areas into the policy and market activities of lower latitudes.

Silvert, W. 1997. Ecological impact classification with fuzzy sets. ***Ecological Modelling*** 96:1-10.

Abstract taken directly from text
It is difficult to quantify the ecological impacts of human activities. There are often many different indicators that can conflict with each other, frequently important observations are lacking, and potentially valuable information may be non-quantitative in nature. Fuzzy set theory offers a methodology for dealing with these problems and provides a useful approach to difficult classification problems. This paper describes how fuzzy logic can be applied to analysis of ecological impacts.

Strandberg, B. 1997. Vegetation Recovery Following Anthropogenic Disturbances in Greenland. In: ***Disturbance and Recovery of Arctic Lands***, ed. R. M. M. Crawford, Kluwer Academic Publishers, Netherlands. pp. 381-390.

Abstract not available [excerpts directly from text]
Many definitions of disturbance have been given in the literature and, as stated by Rykiel, the problem is to define terms that distinguish between cause and effect. The definition to be followed here is given by van Andel and van den Bergh and considers disturbance to be a change in conditions which interferes with the normal functioning of a biological system. Two important and distinct properties of ecosystems relative to disturbance are the ability to withstand displacement from a given state and the ability to return to the original state after displacement. Webber and Walker distinguished between four states of recovery and one state of no recovery. They found two pathways leading to complete recovery of the original

ecosystem, and also found two states of functional recovery (where the new ecosystem has recovered to a stable and functioning ecosystem). In Greenland, assisted recovery was tested.

Urbanska, K. M. 1997. Reproductive Behaviour of Arctic/Alpine Plants and Ecological Restoration. In: ***Disturbance and Recovery of Arctic Lands***, ed. R. M. M. Crawford, Kluwer Academic Publishers, Netherlands. pp. 481-501.

Abstract not available [excerpts directly from text]
A good understanding of reproductive behaviour in plants is indispensable to a correct assessment of population dynamics in the natural environment. The concept of ecological restoration is widely debated and various interpretations have been proposed. Ecological restoration aims at reinstating organisms and their interactions with each other and also with the abiotic site environment. Restoration of extreme ecosystems requires careful planning, implementation, and assessment. This chapter attempts to show the importance of reproductive plant behaviour to these steps, and to focus on mating, seed production, dispersal, and seed banks in relation to population growth and possible diversity increase in restored sites. A scientific international research network which would provide a scientific basis for the development of a programme for native plant material is needed for data-sharing and the co-ordination of research efforts.

Veillette, J., D. Antoniades, M.-E. Garneau, D. C. G. Muir and W. F. Vincent. 2006. ***Development of Environmental Change Indicators in the Canadian High Arctic***. Poster, Laval University, Quebec.

Abstract not available [excerpts directly from text]
This research was conducted on ice shelves, fjords, meromictic, and epishelf lakes. The purpose of this study was to identify the most appropriate indicators of climate change for long term monitoring in this region. This study retrieved sediment cores from fjords, looked at molecular diversity and the food webs of meromictic lakes, and looked at the genetic studies of the biodiversity of microbial mat communities on ice shelves.

Walker, D. A. 1997. Arctic Alaskan Vegetation Disturbance and Recovery. In: ***Disturbance and Recovery of Arctic Lands***, ed. R. M. M. Crawford, Kluwer Academic Publishers, Netherlands. pp. 457-479.

Abstract taken directly from text
This paper briefly summarises the vegetation disturbance and recovery research in northern Alaska. It uses an hierarchic approach to organize the discussion according to the scales of disturbance and emphasizes that the scales have changed dramatically in recent years. It emphasizes a need for more attention to the issues of cumulative impacts and sound long-term ecosystem management plans based on a hierarchic series of geo-referenced databases for Alaska and the Arctic as a whole.

Walker, D. A. and K. R. Everett. 1987. Road Dust and its Environmental Impact on Alaskan Taiga and Tundra. ***Arctic and Alpine Research*** 19:479-489.

Abstract taken directly from text
The physical and chemical characteristics and ecological consequences of road dust in arctic regions are reviewed with emphasis on recent information gathered along the Dalton Highway and the Prudhoe Bay Spine Road in northern Alaska. The primary observed ecological effects of dust are (1) early snowmelt in roadside areas due to lower albedos, resulting in a snow-free band of vegetation within 30 to 100 m of the road in early spring, which is used by waterfowl and numerous other species of wildlife; (2) a decrease in Sphagnum and other acidophilous mosses near the road; (3) an increase in many minerotrophic mosses; (4) a decrease in soil lichens, particularly species of Cladina, Peltigera, and Stereocaulon; (5) elimination of corticolous lichens near the road in areas of particularly high dust fall; (6) a general opening of the ground cover near the road and a consequent colonization of these barren surfaces by many taxa that are common on mineral-rich soils; (6) few effects on vascular plant abundance except in areas of very

high dust, where ericaceous taxa and conifers are affected; (7) increased depth of thaw within 10 m of the road, possibly due to decreased plant cover and earlier initiation of thaw; and (8) contribution to thermokarst in roadside areas. Enhanced dust control measures should be considered, particularly where the road passes through scenic lichen woodlands, acidophilous tundra, and in calm valleys where dust commonly is a traffic safety hazard.

Young, O. R., and F. S. Chapin III. 1995. Anthropogenic Impacts on Biodiversity in the Arctic. In: ***Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences***, ed. by F. S. Chapin and C. Korner, Ecological Studies Vol.113, Springer-Verlag, New York. pp. 183-196.

Abstract taken directly from text
The actions of humans are major determinants of the biological composition of the Earth's ecosystems at scales ranging from the genetic diversity of local populations to the level of landscapes. Although the anthropogenic impacts of modern industrial societies are obvious, early settlers using simple technologies also altered their environments dramatically through such practices as slash-and-burn clearing and the cultivation of crops in the rain forests of Central America; the diversion of river water for irrigation in the Near East; the intentional use of fire in the woodlands and prairies of North America's temperate zones, and alternations in the assemblages of harvested and unharvested species in the far north (Turner et al. 1990). At the same time, some societies have proven far more destructive than others of the natural systems they inhabitat; the impacts of individual societies on the environment have also varied greatly over time. The goals of this chapter are to (1) describe and account for this variance in the impacts of human action on the composition and diversity of ecosystems with particular reference to tundra systems located in the far north and (2) consider the responses of plant and animal communities to anthropogenic impacts under northern conditions. The chapter begins with the articulation of an analytic framework identifying the proximate causes of human action leading to changes in surrounding ecosystems as well as the social drives underlying these forms of human action. It then proceeds to locate the principal anthropogenic impacts on arctic systems in terms of this framework and to comment on ecosystem responses to these impacts.

6.2 MILLENIUM ECOSYSTEM ASSESSMENT

DeFries, R. and S. Pagiola. 2005. Analytical Approaches for Assessing Ecosystem Condition and Human Well-being. In: ***Ecosystems and Human Well-Being: Current State and Trends***, Island Press, Washington, DC. 71 pp.

Abstract taken directly from text
Many tools are available to assess ecosystem condition and support policy decisions that involve trade-offs among ecosystem services. Clearing forested land, for example, affects multiple ecosystem services (such as food production, biodiversity, carbon sequestration, and watershed protection), each of which affects human well-being (such as increased income from crops, reduced tourism value of biodiversity, and damage from downstream flooding). Assessing these trade-offs in the decision-making process requires scientifically based analysis to quantify the responses to different management alternatives. Scientific advances over the past few decades, particularly in computer modeling, remote sensing, and environmental economics, make it possible to assess these linkages. The availability and accuracy of data sources and methods for this assessment are unevenly distributed for different ecosystem services and geographic regions. Data on provisioning services, such as crop yield and timber production, are usually available. On the other hand, data on regulating, supporting, and cultural services such as nutrient cycling, climate regulation, or aesthetic value are seldom available, making it necessary to use indicators, model results, or extrapolations from case studies as proxies. Systematic data collection for carefully selected indicators reflecting trends in ecosystem condition and their services would provide an improved basis for future assessments. Methods for quantifying ecosystem responses are also uneven. Methods to estimate crop yield responses to fertilizer application, for example, are well developed. But methods to quantify relationships between ecosystem services and human well-being, such as the effects of deteriorating biodiversity on human disease, are at an earlier stage of development.

Ecosystems respond to management changes on a range of time and space scales, and careful definition of the scales included in analyses is critical. Soil nutrient depletion, for example, occurs over decades and would not be captured in an analysis based on a shorter time period. Some of the impact of deforestation is felt in reduced water quality far downstream; an analysis that only considers the forest area itself would miss this impact. Ideally, analysis at varying scales would be carried out to assess trade-offs properly. In particular, it is essential to consider nonlinear responses of ecosystems to perturbations in analysis of trade-offs, such as loss of resilience to climate variability below a threshold number of plant species. Ecosystem condition is only one of many factors that affect human wellbeing, making it challenging to assess linkages between them. Health outcomes, for example, are the combined result of ecosystem condition, access to health care, economic status, and myriad other factors. Interpretations of trends in indicators of well-being must appropriately account for the full range of factors involved. The impacts of ecosystem change on well-being are often subtle, which is not to say unimportant; impacts need not be drastic to be significant. A small increase in food prices resulting from lower yields will affect many people, even if none starve as a result. Tracing these impacts is often difficult, particularly in aggregate analyses where the signal of the effect of ecosystem change is often hidden by multiple confounding factors. Analyses linking well-being and ecosystem condition are most easily carried out at a local scale, where the linkages can be most clearly identified. Ultimately, decisions about trade-offs in ecosystem services require balancing societal objectives, including utilitarian and non-utilitarian objectives, short- and long-term objectives, and local- and global-scale objectives. The analytical approach for this report aims to quantify, to the degree possible, the most important trade-offs within different ecosystems and among ecosystem services as input to weigh societal objectives based on comprehensive analysis of the full suite of ecosystem services.

Millennium Ecosystem Assessment. 2005. ***Ecosystems and Human Well-Being: Biodiversity Synthesis***. Report, World Resources Institute, Washington, DC. 100 pp.

Abstract taken directly from text

Biodiversity benefits people through more than just its contribution to material welfare and livelihoods. Biodiversity contributes to security, resiliency, social relations, health, and freedom of choices and actions. Changes in biodiversity due to human activities were more rapid in the past 50 years than at any time in human history, and the drivers of change that cause biodiversity loss and lead to changes in ecosystem services are either steady, show no evidence of declining over time, or are increasing in intensity. Under the four plausible future scenarios developed by the MA, these rates of change in biodiversity are projected to continue, or to accelerate. Many people have benefited over the last century from the conversion of natural ecosystems to human-dominated ecosystems and from the exploitation of biodiversity. At the same time, however, these gains have been achieved at growing costs in the form of losses in biodiversity, degradation of many ecosystem services, and the exacerbation of poverty for other groups of people. The most important direct drivers of biodiversity loss and ecosystem service changes are habitat change (such as land use changes, physical modification of rivers or water withdrawal from rivers, loss of coral reefs, and damage to sea floors due to trawling), climate change, invasive alien species, overexploitation, and pollution. Improved valuation techniques and information on ecosystem services demonstrate that although many individuals benefit from biodiversity loss and ecosystem change, the costs borne by society of such changes are often higher. Even in instances where knowledge of benefits and costs is incomplete, the use of the precautionary approach may be warranted when the costs associated with ecosystem changes may be high or the changes irreversible. To achieve greater progress toward biodiversity conservation to improve human well-being and reduce poverty, it will be necessary to strengthen response options that are designed with the conservation and sustainable use of biodiversity and ecosystem services as the primary goal. These responses will not be sufficient, however, unless the indirect and direct drivers of change are addressed and the enabling conditions for implementation of the full suite of responses are established. Trade-offs between achieving the 2015 targets of the Millennium Development Goals and the 2010 target of reducing the rate of biodiversity loss are likely, although there are also many potential synergies between the various internationally agreed targets relating to biodiversity, environmental sustainability, and development. Coordinated implementation of these goals and targets would facilitate the consideration of trade-offs and synergies.

An unprecedented effort would be needed to achieve by 2010 a significant reduction in the rate of biodiversity loss at all levels. Short-term goals and targets are not sufficient for the conservation and sustainable use of biodiversity and ecosystems. Given the characteristic response times for political, socioeconomic, and ecological systems, longer-term goals and targets (such as for 2050) are needed to guide policy and actions. Improved capability to predict the consequences of changes in drivers for biodiversity, ecosystem functioning, and ecosystem services, together with improved measures of biodiversity, would aid decision-making at all levels. Science can help ensure that decisions are made with the best available information, but ultimately the future of biodiversity will be determined by society.

Millennium Ecosystem Assessment. 2005. ***Ecosystems and Human Well-Being: Opportunities and Challenges for Business and Industry***. Report, World Resources Institute, Washington, DC. 36 pp.

Abstract taken directly from text
The Millennium Ecosystem Assessment (MA) is a four-year international scientific assessment of the consequences of ecosystem change for human well-being. A multisectoral Board of Directors—consisting of senior representatives from government, business, NGOs, U.N. agencies, academia, and indigenous peoples—developed and managed the MA. The assessment was conducted by 1,360 natural and social scientists from 95 countries and was comprehensively peer-reviewed by an additional 600 experts. It provides a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources). The assessment also analyzed options to restore, conserve, or enhance the sustainable use of ecosystems and their contributions to human well-being. Financial support for the MA was provided by a variety of governments, institutions, and foundations around the world. This report synthesizes the take-home messages of the MA for the business community throughout the industrial and developing world. It begins by highlighting key MA findings with particular relevance for businesses large and small. The report then provides an interpretation of the significance of these findings for business and industry, including a checklist of questions designed to help tailor the general findings of the MA to a particular business. This report was prepared by a panel of assessment authors and representatives of businesses and partner organizations, academic experts, and members of the NGO community. It provides a portal for businesses into the Millennium Ecosystem Assessment.

Millennium Ecosystem Assessment. 2005. ***Business Industry Sector Perspectives on the Findings of the Millenium Ecosystem Assessment***. Report, World Resources Institute, Washington, DC. 21 pp.

Abstract taken directly from text
The word "Agriculture" covers a wide range of ecosystems management practices, including crop and livestock production and agro-forestry; sometimes it is extended to include food processing and marketing, forestry, fishing and aquaculture. Agricultural production is primarily on large numbers of individually managed units, whose impacts on ecosystems are often unplanned and unintended. Production practices are strongly influenced by external drivers such as climate change, land tenure, production subsidies, market and consumer preferences and access to technologies, inputs and credit. The agricultural sector is characteristically served by some large agriculture-based industries. These fall into four major groups: Those that supply production inputs – seed, fertilizer, machinery and power, pesticides, credit etc. Those that process the products – the principle being the food industries. Those that retail the products – supermarkets and food chains. Those that rely on the landscape services – such as tourism, leisure, water supplies. The industry is segmented and diverse, such that the supply and value chain is often fragmented and serving the requirements of different customers. Agriculture depends on a large number of ecosystems around the world both directly and indirectly and is the basis of the livelihoods of the majority of poor people. Food production has doubled over the last 40 years, but nearly 1 billion people remain under-nourished. The MA predicts that the demand for food and other goods and services produced by agriculture will double over the next generation. Combinations of population, economic and urbanisation growth will drive these demands. These demands will diversify and must be met with less water, no additional land and in competition with the expanding needs of conservation,

infrastructure and urbanisation. These changes are, and will be, driven by markets (consumers), public opinion and regulation. Production agriculture has had a major impact on the ecosystems of the world. Many ecosystems have been damaged, particularly though intensive systems of production and the over use of marginal and fragile ecosystems. However the demand for a full range of ecosystem services is projected to double over the coming years. The MA tells us that these demands must be met without further degradation and with the restoration of damaged ecosystems. This presents both opportunities and threats for agribusiness.

SECTION 7.0 - CONSERVATION

Anderson, M., P. Comer, D. Grossman, C. Groves, K. Poiani, M. Reid, R. Schneider, B. Vickery and A. Weakley. 1999. ***Guidelines for Representing Ecological Communities in Ecoregional Conservation Plans***. The Nature Conservancy, Arlington, Virginia. 74 pp.

Abstract taken directly from text
As strategies for biodiversity conservation continue to evolve, scientists and practitioners are placing increased emphasis on the conservation of native communities and ecosystems. The most recent iteration of The Nature Conservancy's conservation goal calls for representation of "all viable, native community types within portfolios of [conservation] sites within ecoregions." This paper provides a set of guidelines for representing ecological communities within conservation sites. Although tailored towards ecoregions, the guidelines should apply to any broad-scale conservation planning effort. First developed for an ecoregional planning effort in the northern Appalachians, a group of ecologists from The Nature Conservancy and Natural Heritage network broadened these guidelines into a framework that should be universally applicable. A national workshop held in Estes Park, Colorado, in summer 1998, attended by scientists from inside and outside of the Conservancy, provided substantial peer review and improvements to an early draft, the final form of which is contained in this report. Conservation planners must address five key questions when designing a network of conservation reserves: What are the community targets?; What are the sources of information and analyses that allow us to identify on-the-ground occurrences of these community targets?; How do we establish quantitative goals for replication of communities in portfolios of conservation sites?; What criteria do we use to select occurrences of community targets for inclusion in the portfolio?; How do we best configure a network of conservation sites or reserves so that it will have the greatest chance of achieving the conservation goals for communities? The first critical step in conservation planning is to identify conservation targets. In the case of ecological communities, these are usually derived from a community or ecosystem classification, or in some cases, multiple classification systems. There are four important factors to consider when selecting a classification system: What factors is the system based on?; Is the system arranged hierarchically for working at multiple scales?; Are the units of the classification easily mapped?; What geographic area does the classification include? For The Nature Conservancy's ecoregional planning efforts in the United States, we recommend the use of the National Vegetation Classification System (USNVC)—a taxonomic, hierarchical, and geographically comprehensive classification system developed by ecologists from The
Nature Conservancy and the Natural Heritage Network, and now adopted by the Federal Geographic Data Standards Committee.

Adams, J. and R. Mullen (eds.). 2000. ***Designing a Geography of Hope: A Practitioner's Handbook for Ecoregional Conservation Planning 1 & 2***. The Nature Conservancy, Arlington, Virginia.

Abstract taken directly from text
The second edition of Designing a Geography of Hope, The Nature Conservancy's handbook on ecoregional planning, builds upon the Conservancy's and other organizations' experiences in large-scale conservation planning over the last four years and improves upon the first edition in a number of significant ways. It details advances we have made in identifying conservation targets at multiple spatial scales and levels of biological organization, in setting goals for communities and ecological systems, in

conceptualizing functional sites and landscapes, in selecting conservation targets in freshwater and marine systems, and in the site selection or assembly process itself. The value of ecoregional plans is best understood when placed in the context of the Conservancy's overall conservation work. This work is best described through the four-part conservation process: 1) ecoregional planning—selecting and designing networks of conservation sites that will conserve the diversity of species, communities, and ecological systems in each ecoregion, 2) site planning—applying the Five-S Framework to priority conservation sites identified through ecoregional planning to develop strategies to abate threats to conservation targets, 3) taking conservation action—implementing any number of different strategies to abate threats and conserve targets at conservation sites, and 4) measuring success—using the Biodiversity Health and Threat Status Measures to assess the efficacy of conservation strategies and actions

Beazley, K. and N. Cardinal. 2004. A systematic approach for selecting focal species for conservation in the forests of Nova Scotia and Maine. ***Environmental Conservation*** 31:91-101.

Abstract taken directly from text

Focal species are a critical component of conservation planning, along with representation of ecosystems, special elements and ecologically sustainable management. They warrant conservation attention because they are functionally important, wide-ranging or space-demanding, habitat-quality indicators, 'flagship', and/or vulnerable or special populations. A delphi survey matrix-based approach, involving regional experts in the selection of potential focal species, was applied in Nova Scotia, Canada and Maine, USA. Matrices with native species on one axis and selection characteristics on the other axis were used to summarize expert knowledge and judgment. Characteristics were related to biological traits and habitat requirements that make some species more vulnerable than others in human-modified landscapes. In Nova Scotia and Maine, 19 and 11 experts, respectively, completed the matrices, which were subsequently numerically assessed. Species with the highest scores were identified as potential focal species, including wolf, cougar, lynx, river otter, eastern pipistrelle, wood turtle, four-toed salamander, golden eagle and Atlantic salmon. Concerns remain around the lack of representation of some classes of species, subjectivity in selecting and weighting characteristics, and the relative nature of assessing species against the characteristics. Accordingly, potential focal species should be subject to verification through more rigorous and quantitative analysis and monitoring. Nonetheless, if applied with care, the matrix-based approach can provide a relatively systematic and effective way of engaging regional experts in focal species selection.

Bishop, J. A. and W. L. Myers. 2005. Associations between avian functional guild response and regional landscape properties for conservation planning. ***Ecological Indicators*** 5:33-48.

Abstract taken directly from text

This project facilitates a regional approach to conservation planning in Pennsylvania based on avian breeding habitat selection. The objectives were to: (1) determine the sensitivity of spatial pattern in avian diversity to changing thresholds of intra-guild species richness and (2) relate change of spatial pattern in avian diversity with landscape characteristics of bird Atlas blocks. Two state-wide spatial data layers, based on Landsat satellite data were constructed for this study. These regional landscape data were compared to Breeding Bird Atlas data from 1983 to 1989 using a geographic information system. Breeding bird data were recorded from 4928 blocks that form a grid covering Pennsylvania. Correlation analysis reduced landscape variables to 12 originally derived from forest, urban, roads, streams, and topographic data. Avian functional response guilds were used to analyze associations between breeding bird data and landscape variables. Functional response guilds were created by grouping organisms based on shared habitat preferences or behavioral characteristics. Most of the 18 avian guilds identified for this study were based on shared structural resource characteristics of preferred breeding habitat. Preferred structural resources frequently included the amount and type of forest. For this study, guilds separate resource characteristics by: (1) primary habitat (i.e. forest interior, forest edge), (2) area sensitivity (i.e. forest and grassland), (3) migratory status (i.e. resident, temperate, and tropical), and (4) nest placement (i.e. canopy nester, forest ground nester).Wetland obligate species were treated as a separate guild. Breeding Bird Atlas blocks were tabulated with respect to the number of species present from each guild. For a given guild, the number of its species in a block is termed guild-specific species richness. Sample blocks having high species richness for a given guild often occur adjacent or in close proximity forming spatial clusters in the landscape. Spatial coherence (adjacency/proximity) among the blocks forming these islands is shared guild-specific richness. Spatial clustered blocks of each guild represent areas that presumably possess required resources for members of that guild. Blocks having high intra-guild richness were evaluated with a group of block-level continuous variables using multiple logistic regressions. Logistic regression results indicate that a convincing connection exists between landscape properties of Breeding Bird Atlas blocks and habitat selection characteristics of guild members. Percent of forest cover and mean elevation were the most important habitat characteristics influencing intra-guild richness for most of the guilds tested. Concordance values from logistic regression were used to determine the strength of each guild model. Concordance, the proportion that represents the percent of correct guild richness predictions versus incorrect predictions, suggests a relationship between guild-rich clusters and habitat resources required by each guild. The highest concordance was for the exotics guild at 76.3% and the next highest was 74.8% for the grassland area sensitive guild. This signifies a 75% certainty that landscape variables could predict occurrence of guild-rich block. Eight more guilds had concordance values greater than 65%. By using a guild approach, this study goes beyond total diversity to the more informative structural and functional diversity of guilds. Spatially clustered blocks of high species richness for a particular guild are more indicative of habitat availability and quality than would be the case for overall species richness. Clusters of blocks having high intra-guild species richness become candidate areas for conservation efforts.

Bogaert, J., A. Farina and R. Ceulemans. 2005. Entropy increase of fragmented habitats: A sign of human impact? ***Ecological Indicators*** 5:207-212.

Abstract taken directly from text

Analysis of a recently validated fragmentation index, named ‘coherence’, shows a direct relationship with the Simpson and Shannon indices. Since these diversity metrics are also denoted as ‘entropy metrics’, it can be accepted that patch size heterogeneity can adequately be described by an entropy metric. Since both indices are used to determine the entropy of a sample, the Brillouin index should be applied instead to correctly determine the entropy of a landscape pattern, this because this latter index is developed for fully censused data sets, such as landscapes when a complete coverage by cartographic data or imagery is available. Calculation of the Brillouin entropy index for three specific sites located in Cadiz Township (USA), the Poole Basin (Dorset, UK) and Sao Paulo State (Brazil), respectively, and using long-term data of patch size diversity, reveals increasing entropy levels associated with anthropogenic land cover dynamics (fragmentation). The observed entropy trends defy the laws of thermodynamics and signal the impact of human action on landscape integrity.

Carroll, C., R. F. Noss and P. C. Paquet. 2001. Carnivores as Focal Species for Conservation Planning in the Rocky Mountain Region. ***Ecological Applications*** 11:961-980.

Abstract taken directly from text

Viability analysis of well-selected focal species can complement ecosystem level conservation planning by revealing thresholds in habitat area and landscape connectivity. Mammalian carnivores are good candidates for focal species because their distributional patterns often strongly reflect regional-scale population processes. We incorporated focal species analysis of four carnivore species, fisher (*Martes pennanti*), lynx (*Lynx canadensis*), wolverine (*Gulo gulo*), and grizzly bear (*Ursus arctos*), into a regional conservation plan for the Rocky Mountains of the United States and Canada. We developed empirical habitat models for fisher, lynx, and wolverine based on a geographically extensive data set of trapping and sighting records. Predictor variables derived directly from satellite imagery were significantly correlated with carnivore distribution and allowed us to predict distribution in areas lacking detailed vegetation data. Although we lacked similar distributional data for grizzly bear, we predicted bear habitat by adapting and extrapolating previously published, regional-scale habitat models. Predicted habitat for grizzly bear has high overlap with that for wolverine, intermediate overlap with fisher, and low overlap with lynx. High-quality habitats for fisher and lynx, unlike those for wolverine and grizzly bear, are not strongly associated with low levels of human population and roads. Nevertheless, they are naturally fragmented by topography and vegetation gradients and are poorly represented in existing protected areas. Areas with high biological productivity and low human impact are valuable habitat for all four species but are limited in extent. Predicted habitat values for lynx and wolverine are significantly correlated with trapping data from an area outside the extent of the original data set. This supports the use of empirical distribution models as the initial stage in a regional-scale monitoring program. Our results suggest that a comprehensive conservation strategy for carnivores in the region must consider the needs of several species, rather than a single, presumed umbrella species. Coordinated planning across multiple ownerships is necessary to prevent further fragmentation of carnivore habitat, especially in the U.S.-Canada border region.

Chetkiewicz, C.-L. B., C. C. St. Clair and M. S. Boyce. 2006. Corridors for Conservation: Integrating Pattern and Process. ***Annual Review of Ecology, Evolution, and Systematics*** 37:317-342.

Abstract taken directly from text

Corridors are commonly used to connect fragments of wildlife habitat, yet the identification of conservation corridors typically neglects processes of habitat selection and movement for target organisms. Instead, corridor designs often are based on binary patterns of habitat suitability. New technologies and analytical tools make it possible to better integrate landscape patterns with behavioral processes. We show how resource selection functions can be used to describe habitat suitability with continuous and multivariable metrics and review methods by which animal movement can be quantified, analyzed, and modeled. We then show how the processes of habitat selection and movement can be integrated with landscape features using least-cost paths, graph theory, and step selection functions. These tools offer new ways to design, implement, and study corridors as landscape linkages more objectively and holistically.

D'Eon, R. G., S. M. Glenn, I. Parfitt and M.-J. Fortin. 2002. Landscape Connectivity as a Function of Scale and Organism Vagility in a Real Forested Landscape. ***Conservation Ecology*** 6:10. 14 pp.

Abstract taken directly from text

Landscape connectivity is considered a vital element of landscape structure because of its importance to population survival. The difficulty surrounding the notion of landscape connectivity is that it must be assessed at the scale of the interaction between an organism and the landscape. We present a unique method for measuring connectivity between patches as a function of organism vagility. We used this approach to assess connectivity between harvest, old-growth, and recent wildfire patches in a real forested landscape in southeast British Columbia. By varying a distance criterion, habitat patches were considered connected and formed habitat clusters if they fell within this critical distance. The amount of area and distance to edge within clusters at each critical distance formed the basis of connectivity between patches. We then assessed landscape connectivity relative to old-growth associates within our study area based on species' dispersal abilities. Connectivity was greatest between harvest patches, followed by old-growth, and then wildfire patches. In old-growth patches, we found significant trends between increased connectivity and increased total habitat amount, and between decreased connectivity and increased old-growth harvesting. Highly vagile old-growth associates, such as carnivorous birds, perceive this landscape as connected and are able to access all patches. Smaller, less vagile species, such as woodpeckers, chickadees, and nuthatches, may be affected by a lack of landscape connectivity at the scale of their interaction with old-growth patches. Of particular concern is the northern flying squirrel (Glaucomys sabrinus), which we predict is limited in this landscape due to relatively weak dispersal abilities.

DePhilip, M. 1999. ***Guide to Information for Assessing Quality of and Threats to Biodiversity of Freshwater Systems***. Freshwater Initiative, Strategy One, The Nature Conservancy, Chicago, Illinois.

Abstract not available [excerpts directly from text]
This guide presents information in three sections. Section II. General Resources contains brief summaries of two major sources of data and threats assessment tools: EPA's Index of Watershed Indicators (IWI) and EPA's Better Assessment Science Integrating Point and Non-point Sources (BASINS). Section III. Sources of Data That Address Particular Stresses organizes information by four leading stresses to aquatic systems: hydrologic alteration, sedimentation, water quality, and biological alteration. These categories are further divided into possible sources of stresses and data sources are listed under each one.

Diniz-Feilho, J. A. F., L. M. Bini and B. A. Hawkins. 2003. Spatial autocorrelation and red herrings in geographical ecology. ***Global Ecology & Biogeography*** 12:53-64.

Abstract taken directly from text
Aim: Spatial autocorrelation in ecological data can inflate Type I errors in statistical analyses. There has also been a recent claim that spatial autocorrelation generates 'red herrings', such that virtually all past analyses are flawed. We consider the origins of this phenomenon, the implications of spatial autocorrelation for macro-scale patterns of species diversity and set out a clarification of the statistical problems generated by its presence.
Location: To illustrate the issues involved, we analyse the species richness of the birds of western/central Europe, north Africa and the Middle East.
Methods: Spatial correlograms for richness and five environmental variables were generated using Moran's I coefficients. Multiple regression, using both ordinary least-squares (OLS) and generalized least squares (GLS) assuming a spatial structure in the residuals, were used to identify the strongest predictors of richness. Autocorrelation analyses of the residuals obtained after stepwise OLS regression were undertaken, and the ranks of variables in the full OLS and GLS models were compared.
Results: Bird richness is characterized by a quadratic north–south gradient. Spatial correlograms usually had positive autocorrelation up to c. 1600 km. Including the environmental variables successively in the OLS model reduced spatial autocorrelation in the residuals to non-detectable levels, indicating that the variables explained all spatial structure in the data. In principle, if residuals are not autocorrelated then OLS is a special case of GLS. However, our comparison between OLS and GLS models including all environmental variables revealed that GLS de-emphasized predictors with strong autocorrelation and long-distance clinal structures, giving more importance to variables acting at smaller geographical scales.
Conclusion: Although spatial autocorrelation should always be investigated, it does not necessarily generate bias. Rather, it can be a useful tool to investigate mechanisms operating on richness at different spatial scales. Claims that analyses that do not take into account spatial autocorrelation are flawed are without foundation.

Dirzo, R. and P. H. Raven. 2003. Global State of Biodiversity and Loss. ***Annual Review of Environment and Resources*** 28:137-167.

Abstract taken directly from text
Biodiversity, a central component of Earth's life support systems, is directly relevant to human societies. We examine the dimensions and nature of the Earth's terrestrial biodiversity and review the scientific facts concerning the rate of loss of biodiversity and the drivers of this loss. The estimate for the total number of species of eukaryotic organisms possible lies in the 5–15 million range, with a best guess of ~ 7 million. Species diversity is unevenly distributed; the highest concentrations are in tropical ecosystems. Endemisms are concentrated in a few hotspots, which are in turn seriously threatened by habitat destruction—the most prominent driver of biodiversity loss. For the past 300 years, recorded extinctions for a few groups of organisms reveal rates of extinction at least several hundred times the rate expected on the basis of the geological record. The loss of biodiversity is the only truly irreversible global environmental change the Earth faces today.

Fleishman, E., R. F. Noss and B. R. Noon. 2006. Utility and limitations of species richness metrics for conservation planning. ***Ecological Indicators*** 6:543-553.

<u>*Abstract taken directly from text*</u>

The appropriateness of species richness as an ecological indicator or decision variable for setting conservation and management priorities depends on many assumptions. Most critical is that current levels of species richness allow prediction of future contributions of various locations to biodiversity conservation and ecological function. Also important is the assumption that estimates of species richness can be compared among locations. Challenges arise because estimates of species richness are affected by area, scale and intensity of sampling, taxonomic grouping, estimation methods, and the dynamic nature of species richness. Nonetheless, species richness can contribute to prioritizing locations for biodiversity conservation provided it is not used in isolation—additional metrics, such as species composition, endemism, functional significance, and the severity of threats, are also required. The spatial domain of measurement also must be documented and justified. A multi-criteria decision process is more likely to realize comprehensive conservation goals than prioritization of locations based on species richness alone.

The Nature Conservancy. 1999. ***Freshwater Initiative: Evaluating Ecological Integrity at Freshwater Sites***. FWI Ecological Integrity Workshop, October 29, 1999, Temecula, California. 44 pp.

<u>*Abstract taken directly from text*</u>

This document presents the results of the Freshwater Initiative's workshop on 'Evaluating Ecological Integrity at Freshwater Sites' held July 7–9, 1999, near Temecula, California. Rather than providing a summary of the workshop, this document instead builds the results of the workshop into a primer on the adaptive management of overall freshwater biodiversity across watersheds and similarly large landscapes. While recognizing the importance of ecological integrity, this primer advocates the conservation of ecosystem "functionality" as a more pragmatic standard for the conservation of biodiversity. The approach to adaptive management recommended for conserving freshwater ecosystem functionality parallels the Conservancy's approach to site-based conservation, but diverges in three respects. First, we recommend focusing adaptive management efforts on representative conservation targets – species, communities and ecological systems – and emphasize the need to do so at multiple biogeographic scales. Second, we explicitly emphasize the need to conserve the natural range of variation in all ecological factors shaping the viability of each conservation target, and discuss ways to do this. Third, we strongly recommend and explain the use of indicators as vital tools in the monitoring program, and explain both the differences and similarities between representative targets and indicators. We discuss how these three crucial concepts can be used to design a monitoring program that will result in a robust program of overall adaptive management, discuss the helpful role of reference and control data in such a monitoring program, and summarize the key questions that must be addressed in designing a monitoring program. We regard this primer as a "first iteration" of an approach to the conservation of landscape-scale freshwater ecosystem functionality, and strongly encourage its adoption so that we can learn and improve it through experience.

Goodchild, M. F. 2003. Geographic Information Science and Systems for Environmental Management. ***Annual Review of Environment and Resources*** 28:493-519.

<u>*Abstract taken directly from text*</u>

The geographic context is essential both for environmental research and for policy-oriented environmental management. Geographic information systems are as a result increasingly important computing applications in this domain, and an understanding of the underlying principles of geographic information science is increasingly essential to sound scientific practice. The review begins by defining terms. Four major sections follow that discuss advances in GIS analysis and modeling, in the supply of geographic data for GIS, in software design, and in GIS representation. GIS-based modeling is constrained in part by architecture, but a number of recent products show promise, and GIS continues to support modeling through the coupling of software. The GIS data supply has benefited from a range of new satellite-based sensors and from developments in ground-based sensor networks. GIS software design is being revolutionized by two developments in the information technology mainstream: the trend to component-based software and object-oriented data modeling. Advances in GIS representation focus largely on time, the third spatial dimension, and uncertainty. References are provided to the more important and recent literature. The concluding section identifies three significant and current trends: toward increasing interoperability of data and services, increasing mobility of information technology, and increasing capabilities for dynamic simulation.

Hess, G. R. and T. J. King. 2002. Planning open spaces for wildlife I. Selecting focal species using a Delphi survey approach. ***Landscape and Urban Planning*** 58:25-40.

<u>*Abstract taken directly from text*</u>
In a world being transformed by human population growth, conservation biology has emerged as one discipline focused on preventing, mitigating, and reversing the loss of species, ecosystems, and landscapes. Because of the need to act quickly with incomplete information, conservation biologists have developed shortcuts that rely on identifying key species to be focused on during planning efforts. We describe a process that can be used to select those species, using a suburbanizing region in the United States as an example. The Triangle region of North Carolina, USA─ Raleigh-Durham-Chapel Hill and surroundings─ is undergoing rapid suburbanization, resulting in land-use changes that will alter wildlife communities and might result in the loss of some species. We are developing a wildlife conservation plan for the region based on a combination of landscape and focal species approaches. The objective of the research described in this paper was to identify focal species to be used for conservation planning in the region; our effort focused on amphibians, birds, mammals, and reptiles. In theory, habitat conserved by planning for a few carefully chosen focal species is expected to encompass habitat for many other species with similar requirements. To identify focal species, we used a three-part Delphi survey, administered to a panel of experts. The panel identified six landscape types and nine associated focal species: extensive undisturbed habitat (bobcat, eastern box turtle); riparian and bottomland forest (barred owl, beaver); upland forest (ovenbird, broad-winged hawk); mature forest (pileated woodpecker); pastures and grassy fields (loggerhead shrike); and open and early successional forest (northern bobwhite). The panelists generally agreed that a combined landscape─ focal species approach was reasonable, but noted a number of problems to be expected during the planning phase. The most critical of the problems are that the approach has not been well tested, required data are often unavailable, and implementation will be difficult in the face of extreme economic pressures to develop land. Administering the Delphi survey was more labor-intensive, and took longer, than we anticipated; it might have been more effective had it been completed more quickly. Nevertheless, we believe this process can be applied to a broad range of conservation problems, which are often characterized by a high degree of uncertainty and the need to act quickly.

Kerkhoff, L. van and L. Lebel. 2006. Linking Knowledge and Action for Sustainable Development. ***Annual Review of Environment and Resources*** 31:445-477.

<u>*Abstract taken directly from text*</u>
It is now commonplace to assert that actions toward sustainable development require a mix of scientific, economic, social and political knowledge, and judgments. The role of research-based knowledge in this complex setting is ambiguous and diverse, and it is undergoing rapid change both in theory and in practice. We review conventional views of the linkages between research-based knowledge and action, and the early response to concerns that these links could and should be improved, through efforts at translation and transfer. We then examine the range of critiques that challenge those conventional views by highlighting different aspects of the relationships between science and society, focusing on the implications for action toward sustainable development. We then review the theories and strategies that have emerged in the attempt to improve the linkages between research-based knowledge and action in the context of sustainability across four broad categories: participation, integration, learning, and negotiation. These form a hierarchy with respect to how deeply they engage with the various critiques. We propose that the relationships between research-based knowledge and action can be better understood as arenas of shared responsibility, embedded within larger systems of power and knowledge that evolve and change over time. The unique contribution of research-based knowledge needs to be

understood in relation to actual or potential contributions from other forms of knowledge. We conclude with questions that may offer useful orientation to assessing or designing research-action arenas for sustainable development.

Lambeck, R. J. 1997. Focal Species: A Multi-Species Umbrella for Nature Conservation. ***Conservation Biology*** 11:849-856.

Abstract taken directly from text

To prevent further loss of species from landscapes used for productive enterprises such as agriculture, forestry, and grazing, it is necessary to determine the composition, quantity, and configuration of landscape elements requirements to meet the needs of the species present. I present a multi-species approach for defining the attributes required to meet the needs of the biota in a landscape and the management regimes that should be applied. The approach builds on the concept of umbrella species, whose requirements are believed to encapsulate the needs of other species. It identifies a suite of "focal species," each of which is used for define different spatial and compositional attribute that must be present in a landscape and their appropriate management regimes. All species considered at risk are grouped according to the processes that threaten their persistence. These threats may include habitat loss, habitat fragmentation, weed invasion, and fire. Within each group, the species most sensitive to the threat is used to define the minimum acceptable level at which that threat can occur. For example, the area requirements of the species most limited by the availability of particular habitats will define the minimum suitable area of those habitat types; the requirements of the most dispersal-limited species will define the attribute of connecting vegetation; species reliant on critical resources will define essential compositional attribute; and species whose populations are limited by processes such as fire, predation, or weed invasion will define the levels at which these processes must be managed. For each relevant landscape parameter, the species with the most demanding requirements for that parameter is used to define its minimum acceptable value. Because the most demanding species are selected, a landscape designed and managed to meet their needs will encompass the requirements of all other species.

Lindenmayer, D. B., A. D. Manning, P. L. Smith, H. P. Possingham, J. Fischer, I. Oliver and M. A. McCarthy. 2002. The Focal-Species Approach and Landscape Restoration: a Critique. ***Conservation Biology*** 16:338-345.

Abstract taken directly from text

In many parts of the world there is an urgent need for landscape restoration to conserve biodiversity. Landscape restoration is not straightforward, however, because many issues and processes must be understood for effective action to take place. In an attempt to guide restoration efforts for biodiversity conservation, Lambeck (1997, 1999) developed a taxon-based surrogate scheme called the focal-species approach. The focal-species approach involves the identification of a suite of species targeted for the management of threatening processes and vegetation-restoration efforts. Together, their "requirements for persistence define the attributes that must be present if [the landscape] is to meet the needs of the remaining biota" (Lambeck 1999). Some of our concerns with the focal-species approach include the following. First, the underlying theoretical basis of the focal-species approach is problematic. As part of taxon-based surrogate scheme, a suite of focal species is presumed to act collectively as a surrogate for other elements of the biota. But taxon-based surrogate schemes have bad limited success everywhere they have been applied. Second, the focal-species approach may be unsuitable for practical implementation, primarily because of the lack of data to guide the selection of a set of focal species in the majority of landscapes. We argue that restoration strategies should be based on appropriate theory, realistic assessment of available information, and an achievable outcome of the land managers who own or control the majority of land in the most significantly affected landscapes. Given the potential limitations of the focal-species approach, a mix of different strategies should be adopted in any given landscape and between different landscapes to spread risk of failure of any one approach. We believe that it is important to raise awareness about the potential limitations of the focal-species approach and to ensure that land managers do not assume it will inevitably lead to the conservation of all biota in a landscape.

Maybury, K. P. (ed.). 1999. ***Seeing the Forest and the Trees: Ecological Classification for Conservation***. The Nature Conservancy, Arlington, Virginia.

Abstract not available [excerpts directly from text]
The Nature Conservancy, in partnership with the network of Natural Heritage programs, has developed a scientifically sound, consistent, and flexible classification system that can be applied to terrestrial ecological communities throughout the world. The system can be used to classify all types of vegetated communities, from verdant wetlands to arid deserts nearly lacking in plant life, and from the most pristine old-growth forests to cultivated annual crop fields. Using this system, a team of Conservancy and Heritage ecologists has now completed a first iteration of the natural vegetation types of the United States. This represents the first time the country's natural terrestrial communities have been classified using a single system on a scale fine enough to be useful for the conservation of specific sites. The ecological community concept has been recognized as an important conservation planning tool.

National Center for Environmental Assessment. 1999. ***Workshop Report on Characterizing Ecological Risk at the Watershed Scale***. Arlington, Virginia.

Abstract taken directly from text
As ecological risk assessment evolves, it is moving beyond a focus on single species toward addressing multiple species and their interactions, and from assessing effects of simple chemical toxicity to the cumulative impacts of multiple interacting chemical, physical, and biological stressors. While EPA and others have developed guidance and have considerable experience in applying the ecological risk assessment paradigm in source-based approaches (such as those focused on particular chemical contaminants), specific guidance for using it in "place-based" approaches (such as those conducted on a watershed-wide scale) is still limited. One of the principal challenges in applying ecological risk assessment to watershed management and decision making is the need for a framework for characterizing risks that involve numerous stressors, interconnected pathways, and multiple endpoints. To develop the needed guidance in this area a workshop was held that gathered 35 participants with extensive experience in relevant disciplines such as watershed ecological risk assessment, ecological risk assessment, watershed management, or regional-scale assessment. To focus workshop discussions, several charge questions addressing the issues of greatest concern for characterizing risk at the watershed scale were developed prior to the workshop. This report provides the proceedings from the workshop and includes an introduction, a synthesis of discussion and recommendations, and summaries of presentations and breakout sessions.

Naughton-Treves, L. and M. B. Holland. 2005. The Role of Protected Areas in Conserving Biodiversity and Sustaining Local Livelihoods. ***Annual Review of Environment and Resources*** 30:219-252.

Abstract taken directly from text
The world's system of protected areas has grown exponentially over the past 25 years, particularly in developing countries where biodiversity is greatest. Concurrently, the mission of protected areas has expanded from biodiversity conservation to improving human welfare. The result is a shift in favor of protected areas allowing local resource use. Given the multiple purposes of many protected areas, measuring effectiveness is difficult. Our review of 49 tropical protected areas shows that parks are generally effective at curtailing deforestation within their boundaries. But deforestation in surrounding areas is isolating protected areas. Many initiatives now aim to link protected areas to local socioeconomic development. Some of these initiatives have been successful, but in general expectations need to be tempered regarding the capacity of protected areas to alleviate poverty. Greater attention must also be paid to the broader policy context of biodiversity loss, poverty, and unsustainable land use in developing countries.

Parkes, M. and R. Penelli. 2001. Integrating Catchment Ecosystems and Community Health: The Value of Participatory Action Research. ***Ecosystem Health*** 7:85-106.

Abstract taken directly from text
Understanding links between catchment management and community health demands consideration of complex bio-physical, socio-economic, and public health relationships. These relationships cut across a spectrum of health, environment and development considerations and highlight the need for appropriate and integrative models of inquiry and decision making. What can Participatory Action Research (PAR) contribute towards achieving an integrated approach to catchment management and community health issues? In addition to a methodological overview of Participatory Action Research, this paper reviews other participatory, community, action, and ecosystems-based methods. Commonalities in principles and methods are highlighted across a number of fields of research and practice including rural and community development, public health and health promotion, natural resource management, environmental health, and integrated ecosystem-based approaches. Lessons learned from application to Participatory Action Research are described in relation to a catchment and community health project, based in the Taieri River catchment, New Zealand. The case study emphasizes the importance of both horizontal and vertical connections between diverse coalitions of catchment stakeholders and the contribution of PAR cycles of inquiry, reflection, and action, toward this type of integration. Both generic and location-specific examples highlight the value of participatory methods that respond to the challenge of how to integrate the complex social and bio-physical processes that characterize human and ecosystem health.

Parris, T. M. and R. W. Kates. 2003. Characterizing and Measuring Sustainable Development. ***Annual Review of Environment and Resources*** 28:559-586.

Abstract taken directly from text
Sustainable development has broad appeal and little specificity, but some combination of development and environment as well as equity is found in many attempts to describe it. However, proponents of sustainable development differ in their emphases on what is to be sustained, what is to be developed, how to link environment and development, and for how long a time. Despite the persistent definitional ambiguities associated with sustainable development, much work (over 500 efforts) has been devoted to developing quantitative indicators of sustainable development. The emphasis on sustainability indicators has multiple motivations that include decision making and management, advocacy, participation and consensus building, and research and analysis. We select a dozen prominent examples and use this review to highlight their similarities and differences in definition of sustainable development, motivation, process, and technical methods. We conclude that there are no indicator sets that are universally accepted, backed by compelling theory, rigorous data collection and analysis, and influential in policy. This is due to the ambiguity of sustainable development, the plurality of purpose in characterizing and measuring sustainable development, and the confusion of terminology, data, and methods of measurement. A major step in reducing such confusion would be the acceptance of distinctions in terminology, data, and methods. Toward this end, we propose an analytical framework that clearly distinguishes among goals, indicators, targets, trends, driving forces, and policy responses. We also highlight the need for continued research on scale, aggregation, critical limits, and thresholds.

Paul, J. F. 2003. Developing and applying an index of environmental integrity for the U.S. Mid-Atlantic region. ***Journal of Environmental Management*** 67:175-185.

Abstract taken directly from text
Environmental conditions in the Mid-Atlantic region of United States are presently being documented in a series of reports that use ‘environmental report cards’ to summarize the condition of individual natural resources (e.g. estuaries, streams, forests, and landscapes) over the entire region and within major subregions. An ‘index of environmental integrity’ (IEI) approach has been developed and is illustrated using the information content of these report cards to evaluate the overall condition throughout the region. The IEI approach is a four-step process: (1) select individual components for the index, (2) calculate sub-index values for each of the individual components, (3) aggregate the sub-index values into the overall index, and (4) interpretation of index values. The IEI approach was illustrated by applying to the Mid-Atlantic estuaries and wadable streams in the Mid-Atlantic Highlands. Because the IEI approach is

new, application should not be made without considering issues such as evaluation of the selection of the indicators, weighting scheme, uncertainties, and appropriate way to interpret the values.

Petrik, P. and H. Bruelheide. 2006. Species groups can be transferred across different scales. ***Journal of Biogeography*** 33:1628-1642.

<u>*Abstract taken directly from text*</u>
Aim: To test whether species groups (i.e. assemblages of species co-occurring in nature) that are statistically derived at one scale (broad, medium, or fine scale) can be transferred to another scale, and to identify the driving forces that determine species groups at the various scales.
Location: Northern Bohemia (Czech Republic, central Europe) in the Jestedsky hrbet mountain range and its neighbourhood.
Methods: Three data sets were sampled: a floristic data set at the broad scale, another floristic data set at the intermediate scale, and a vegetation data set at the habitat scale. First, in each data set, species groups were produced by the COCKTAIL algorithm, which ensures maximized joint occurrence in the data set using a fidelity coefficient. Corresponding species groups were produced in the individual data sets by employing the same species for starting the algorithm. Second, the species groups formed in one data set, i.e. at a particular scale, were applied crosswise to the other data sets, i.e. to the other scales. Correspondence of a species group formed at a particular scale with a species group at another scale was determined. Third, to highlight the driving factors for the distribution of the plant species groups at each scale, canonical correspondence analysis was carried out.
Results: Twelve species groups were used to analyse the transferability of the groups across the three scales, but only six of them were found to be common to all scales. Correspondence of species groups derived from the finest scale with those derived at the broadest scale was, on average, higher than in the opposite direction. Forest (tree layer) cover, altitude and bedrock type explained most of the variability in canonical correspondence analysis across all scales.
Main conclusions: Transferability of species groups distinguished at a fine scale to broader scales is better than it is in the opposite direction. Therefore, a possible application of the results is to use species groups to predict the potential occurrence of missing species in broad-scale floristic surveys from fine-scale vegetation-plot data.

Poiani, K. and B. Richter. Undated. ***Functional Landscapes and the Conservation of Biodiversity***. The Nature Conservancy, Arlington, Virginia.

<u>*Abstract not available [excerpts directly from text]*</u>
Scientists and conservation practitioners have long recognized that biodiversity exists at many levels of biological organization (i.e., genes, species, communities, ecosystems, and landscapes). The levels of biological organization on which the Conservancy now focuses its conservation efforts - species, ecological communities, and ecological systems - can be categorized based on their spatial scale and pattern.

Poiani, K. A., B. D. Richter, M. G. Anderson and H. E. Richter. 2000. Multiple Scales: Functional Sites, Landscapes, and Networks. ***BioScience*** 50:133-146.

<u>*Abstract not available [excerpts directly from text]*</u>
Approaches to conservation and natural resource management are maturing rapidly in response to changing perceptions of biodiversity and ecological systems. In past decades, biodiversity was viewed largely in terms of species richness, and the ecosystems supporting these species were seen as static and predictable. More recently, biodiversity is being viewed more expansively, to include genes, species, populations, communities, ecosystems, and landscapes, with each level of biological organization exhibiting characteristics and complex composition, structure, and function. As a result, current recommendations for biodiversity conservation focus on the need to conserve dynamic, multi-scale ecological patterns and processes that sustain the full complement of biota and their supporting natural systems. The Yampa River case study illustrates the importance and challenge of clearly defining the

focus and scale of biodiversity conservation at a given site. Evaluating the four functional attributes relative to the target riparian ecosystem also provided important insights into management and restoration strategies needed to conserve the site.

Richter, B. D., J. V. Baumgartner, J. Powell and D. P. Braun. Undated. ***A Method for Assessing Hydrologic Alteration within Ecosystems***. The Nature Conservancy, Boulder, Colorado & Arlington, Virginia.

<u>*Abstract taken directly from text*</u>
Hydrologic regimes play a major role in determining the biotic composition, structure, and function of aquatic, wetland, and riparian ecosystems. However, human land and water uses are substantially altering hydrologic regimes around the world. Improved quantitative evaluations of human-induced hydrologic changes are needed to advance research on the biotic implications of hydrologic alteration, and to support ecosystem management and restoration plans. To facilitate such improved hydrologic evaluations, we propose a method for assessing the degree of hydrologic alteration attributable to human impacts within an ecosystem. This method, referred to as the Indicators of Hydrologic Alteration (IHA), is based upon an analysis of hydrologic data available either from existing measurement points within an ecosystem (such as at stream gauges or wells) or model-generated data. We use 32 different parameters, organized into five groups, to statistically characterize hydrologic variation within each year. These 32 parameters provide information on some of the most ecologically significant features of surface and ground water regimes influencing aquatic, wetland, and riparian ecosystems. The hydrologic perturbations associated with activities such as dam operations, flow diversion, ground water pumping, or intensive land use conversion are then assessed by comparing measures of central tendency and dispersion for each parameter, between user-defined "pre-impact" and "post-impact" time frames, generating 64 different "Indicators of Hydrologic Alteration." The IHA method is intended to be used conjunctively with other ecosystem metrics in inventories of ecosystem integrity, in planning ecosystem management activities, and in setting and measuring progress towards conservation or restoration goals.

Sanderson, E. W., K. H. Redford, A. Vedder, P. B. Coppolillo and S. E. Ward. 2002. A conceptual model for conservation planning based on landscape species requirements. ***Landscape and Urban Planning*** 58:41-56.

<u>*Abstract taken directly from text*</u>
Effective conservation planning requires, considering all the complicated biological, social and economic factors which impinge on the ecological integrity of a site, and then focusing inevitably limited conservation resources on those times, places and activities that most impact ecological structure and function. The landscape species concept provides a useful lens for defining conservation landscapes and highlighting potential threats from human activity. The paper outlines a conceptual methodology for landscape conservation being tested by the Wildlife Conservation Society at three sites in Latin America and Africa. Based on the biological requirements of an ecologically functioning population of a landscape species, the “biological” landscape is defined. This landscape is compared to the landscape of human activities through the use of Geographic Information Systems (GIS). Focal landscapes sufficient to meet species requirements are defined and threats from humans activity evaluated with respect to biological requirements. A suite of landscape species may be selected depending on resources, leading to multiple, often overlapping, focal landscapes. A hypothetical example is presented.

Sarkar, S., R. L. Pressey, D. P. Faith, C. R. Margules, T. Fuller, D. M. Stoms, A. Moffett, K. A. Wilson, K. J. Williams, P. H. Williams and S. Andelman. 2006. Biodiversity Conservation Planning Tools: Present Status and Challenges for the Future. ***Annual Review of Environment and Resources*** 31:123-159.

<u>*Abstract taken directly from text*</u>
Species extinctions and the deterioration of other biodiversity features worldwide have led to the adoption of systematic conservation planning in many regions of the world. As a consequence, various software

tools for conservation planning have been developed over the past twenty years. These tools implement algorithms designed to identify conservation area networks for the representation and persistence of biodiversity features. Budgetary, ethical, and other socio-political constraints dictate that the prioritized sites represent biodiversity with minimum impact on human interests. Planning tools are typically also used to satisfy these criteria. This chapter reviews both the concepts and technical choices that underlie the development of these tools. Conservation planning problems can be formulated as optimization problems, and we evaluate the suitability of different algorithms for their solution. Finally, we also review some key issues associated with the use of these tools, such as computational efficiency, the effectiveness of taxa and abiotic parameters at choosing surrogates for biodiversity, the process of setting explicit targets of representation for biodiversity surrogates, and dealing with multiple criteria. The review concludes by identifying areas for future research, including the scheduling of conservation action over extensive time periods and incorporating data about site vulnerability.

Shepard, B. and J. Whittington. 2006. Response of Wolves to Corridor Restoration and Human Use Management. ***Ecology and Society*** 11:1.

<u>*Abstract taken directly from text*</u>
Corridor restoration is increasingly being used to connect habitat in mountainous areas where rugged topography and increasing human activity fragment habitat. Wolves (Canis lupus) are a conservation priority because they avoid areas with high levels of human use and are ecologically important predators. We examined how corridor restoration through a golf course changes the distribution of wolves and their prey in Jasper National Park, Alberta, Canada. We followed and recorded wolf paths in the snow both within the corridor and in the surrounding landscape before and after a corridor was re-established. Track transects were used to estimate prey abundance and snow depths, and trail counters measured human activity. We compared resources on wolf paths to available movement routes using conditional logistic regression and also compared resources used by wolves before and after restoration. We addressed potential confounding effects of prey abundance, snow depths, and levels of human use by testing for changes in these variables. Prior to restoration, wolves traveled around the golf course and used the mountainside to connect valley-bottom habitat. Conversely, elk (Cervus elaphus) densities were highest in the golf course. After restoration, wolves shifted most of their movement to the golf course corridor, whereas elk dispersed along the corridor and mountainside. When traveling through the study area, wolves selected for areas with high prey abundance, low elevations, and low levels of human activity. Corridor restoration increased the area of high quality habitat available to wolves and increased their access to elk and deer at low elevations. Our results corroborate other studies suggesting that wolves and elk quickly adapt to landscape changes and that corridor restoration can improve habitat quality and reduce habitat fragmentation.

Srivastava, D. S. and M. Vellend. 2005. Biodiversity-Ecosystem Function Research: Is It Relevant to Conservation? ***Annual Review of Ecology, Evolution, and Systematics*** 36:267-294.

<u>*Abstract taken directly from text*</u>
It has often been argued that conserving biodiversity is necessary for maintaining ecosystem functioning. We critically evaluate the current evidence for this argument. Although there is substantial evidence that diversity is able to affect function, particularly for plant communities, it is unclear if these patterns will hold for realistic scenarios of extinctions, multi-trophic communities, or larger spatial scales. Experiments are conducted at small spatial scales, the very scales at which diversity tends to increase owing to exotics. Stressors may affect function by many pathways, and diversity-mediated effects on function may be a minor pathway, except in the case of multiple-stressor insurance effects. In general, the conservation case is stronger for stability measures of function than stock and flux measures, in part because it is easier to attribute value unambiguously to stability and in part because stock and flux measures of functions are anticipated to be more affected by multi-trophic dynamics. Nor is biodiversity-ecosystem function theory likely to help conservation managers in practical decisions, except in the particular case of restoration. We give recommendations for increasing the relevance of this area of research for conservation.

The Nature Conservancy. 1997. ***Indicators of Hydrologic Alteration***. Arlington, Virginia.

Abstract not available [excerpts directly from text]
The Indicators of Hydrologic Alteration (IHA) program involves software that is a result of the efforts by The Nature Conservancy's Biohydrology Program to develop an easy-to-use tool for computing hydrologic regime characteristics, and to analyze changes in those characteristics over time. The method and software will work on any type of daily hydrologic data, such as stream flows or river stages, ground water levels, or lake levels. Many hydrologic systems have experienced a gradual, long-term accumulation of human impacts rather than a single point impact such as a dam. To assist in the analysis of such cumulative impacts, we have now provided for graphical analysis and linear regression on data from such systems.

The Nature Conservancy. 2000. ***Measures Across Sites, A Summary of Measures of Conservation Success & Site Conservation Information***. Arlington, Virginia. 23 pp.

Abstract taken directly from text
Measures of Conservation Success and Site Conservation information from 86 Capital Campaign conservation areas and three other areas were summarized and analyzed. The analysis looked for emerging patterns and trends as well as noteworthy findings in: the measures of success, target viability ranks, ranking of stresses to both targets and conservation areas, and ranking of critical threats at the conservation area level. The majority of Biodiversity Health measures are intermediate (fair and good). Sixty percent of conservation areas have acceptable Biodiversity Health ranks (good or very good). Threat Status measures show increasing frequency with increasing severity. There are more conservation areas with threats ranked very high and high. Less than one quarter of the conservation areas have acceptable Threat Status ranks (medium or low). Most Conservation Capacity measures are intermediate (medium and high). Most targets have intermediate (fair or good) viability ratings. The most commonly encountered stresses are: 1) habitat destruction or conversion, 2) habitat disturbance, 3) altered structure/composition, and 4) modification of aquatic regimes. Invasive species are by far, the most significant critical threats to the viability of focal targets at conservation areas. Invasive species are identified a critical threat at over ninety percent of the areas analyzed. Other critical threats across systems are: 1) development of roads or utilities, 2) recreational use, 3) home development, 4) fire suppression, and 5) forestry practices.

The Nature Conservancy. 2003. ***The Five-S Framework for Site Conservation. A Practitioner's Handbook for Site Conservation Planning and Measuring Conservation Success 1, Ed 3***. Arlington, Virginia.

Abstract not available [excerpts directly from text]
The Nature Conservancy initially developed the planning approach presented here for the "bioreserve" initiative, and called it the "Five S's": systems, stresses, sources, strategies, and success. Some people have added a sixth "S" (situation). Subsequently, the Five-S approach has been the basis for landscape-scale, community-based conservation workshops presented through the Center for Compatible Economic Development and Efroymson Fellowships. The Conservancy's Site Conservation Planning working group adapted it for the process known as site conservation planning. And most recently, it has become the foundation for the new measures of conservation success. The Five-S approach to site conservation integrates the experience and knowledge gained through these various applications into a single, unified site-based framework. While the approach continues to focus on the original five S's for site conservation planning—systems, stresses, sources, strategies, and success—it has been updated to meet the demands of our more sophisticated approach to site conservation under Conservation by Design. The five S's include:

Systems: the conservation targets occurring at a site, and the natural processes that maintain them, that will be the focus of site-based planning.

Stresses: the types of degradation and impairment afflicting the system(s) at a site.

Sources: the agents generating the stresses.

Strategies: the types of conservation activities deployed to abate sources of stress (threat abatement) and persistent stresses (restoration).

Success: measures of biodiversity health and threat abatement at a site.

Whittaker, R. J., K. J. Willis and R. Field. 2001. Scale and species richness: towards a general, hierarchical theory of species diversity. ***Journal of Biogeography*** 28:453-470.

<u>*Abstract taken directly from text*</u>

Aim: Current weaknesses of diversity theory include: a failure to distinguish different biogeographical response variables under the general heading of diversity; and a general failure of ecological theory to deal adequately with geographical scale. Our aim is to articulate the case for a top-down approach to theory building, in which scale is addressed explicitly and in which different response variables are clearly distinguished.

Location: The article draws upon both theoretical contributions and empirical analyses from all latitudes, focusing on terrestrial ecosystems and with some bias towards (woody) plants.

Methods: We review current diversity theory and terminology in relation to scale of applicability. As a starting point in developing a general theory, we take the issue of geographical gradients in species richness as a main theme and evaluate the extent to which commonly cited theories are likely to operate at scales from the macro down to the local.

Results: A degree of confusion surrounds the use of the terms alpha, beta and gamma diversity, and the terms local, landscape and macro-scale are preferred here as a more intuitive framework. The distinction between inventory and differentiation diversity is highlighted as important as, in terms of scale of analysis, are the concepts of focus and extent. The importance of holding area constant in analysis is stressed, as is the notion that different environmental factors exhibit measurable heterogeneity at different scales. Evaluation of several of the most common diversity theories put forward for the grand clines in species richness, indicates that they can be collapsed to dynamic hypotheses based on climate or historical explanations. The importance of the many ecological/ biological mechanisms that have been proposed is evident mainly at local scales of analysis, whilst at the macro-scale they are dependent largely upon climatic controls for their operation. Local communities have often been found not to be saturated, i.e. to be non-equilibrial. This is argued, perhaps counter-intuitively, to be entirely compatible with the persistence through time of macro-scale patterns of richness that are climatically determined. The review also incorporates recent developments in macroecology, Rapoport's rule, trade-offs, and the importance of isolation, landscape impedance and geometric constraints on richness (the mid-domain effect) in generating richness patterns; highlighting those phenomena that are contributory to the first-order climatic pattern, and those, such as the geometric constraints, that may confound or obscure these patterns.

Main conclusions: A general theory of diversity must necessarily cover many disparate phenomena, at various scales of analysis, and cannot therefore be expressed in a simple formula, but individual elements of this general theory may be. In particular, it appears possible to capture in a dynamic climate-based model and `capacity rule', the form of the grand cline in richness of woody plants at the macro-scale. This provides a starting point for a top-down, global-to-local, macro-to-micro scale approach to modelling richness variations in a variety of taxa. Patterns in differentiation/endemicity, on the other hand, require more immediate attention to historical events, and to features of geography such as isolation. Thus, whilst we argue that there are basic physical principles and laws underlying certain diversity phenomena (e.g. macro-scale richness gradients), a pluralistic body of theory is required that incorporates dynamic and historical explanation, and which bridges equilibrial and non-equilibrial concepts and ideas.

Whittaker, R. J., M. B. Araujo, P. Jepson, R. J. Ladle, J. E. M. Watson and K. J. Willis. 2005. Conservation Biogeography: assessment and prospect. ***Diversity and Distributions*** 11:3-23.

<u>*Abstract taken directly from text*</u>

There is general agreement among scientists that biodiversity is under assault on a global basis and that species are being lost at a greatly enhanced rate. This article examines the role played by biogeographical science in the emergence of conservation guidance and makes the case for the recognition of Conservation Biogeography as a key subfield of conservation biology delimited as: *the application of biogeographical principles, theories, and analyses, being those concerned with the distributional dynamics of taxa individually and collectively, to problems concerning the conservation of biodiversity.* Conservation biogeography thus encompasses both a substantial body of theory and analysis, and some of the most prominent planning frameworks used in conservation. Considerable advances in conservation guidelines have been made over the last few decades by applying biogeographical methods and principles. Herein we provide a critical review focused on the sensitivity to assumptions inherent in the applications we examine. In particular, we focus on four inter-related factors: (i) scale dependency (both spatial and temporal); (ii) inadequacies in taxonomic and distributional data (the so-called Linnean and Wallacean shortfalls); (iii) effects of model structure and parameterization; and (iv) inadequacies of theory. These generic problems are illustrated by reference to studies ranging from the application of historical biogeography, through island biogeography, and complementarity analyses to bioclimatic envelope modelling. There is a great deal of uncertainty inherent in predictive analyses in conservation biogeography and this area in particular presents considerable challenges. Protected area planning frameworks and their resulting map outputs are amongst the most powerful and influential applications within conservation biogeography, and at the global scale are characterized by the production, by a small number of prominent NGOs, of bespoke schemes, which serve both to mobilize funds and channel efforts in a highly targeted fashion. We provide a simple typology of protected area planning frameworks, with particular reference to the global scale, and provide a brief critique of some of their strengths and weaknesses. Finally, we discuss the importance, especially at regional scales, of developing more responsive analyses and models that integrate pattern (the compositionalist approach) and processes (the functionalist approach) such as range collapse and climate change, again noting the sensitivity of outcomes to starting assumptions. We make the case for the greater engagement of the biogeographical community in a programme of evaluation and refinement of all such schemes to test their robustness and their sensitivity to alternative conservation priorities and goals.

Whittington, J., C. C. St. Clair and G. Mercer. 2004. Path Tortuosity and the Permeability of Roads and Trails to Wolf Movement. ***Ecology and Society*** 9:4.

<u>*Abstract taken directly from text*</u>

Few studies have examined the effects of human development on fine-scale movement behavior, yet understanding animal movement through increasingly human-dominated landscapes is essential for the persistence of many wild populations, especially wary species. In mountainous areas, roads and trails may be particularly deserving of study because they are concentrated in the valley bottoms where they can impede animal movement both across and between valleys. In this study, we tracked wolf (Canis lupus) movement in the snow for two winters in Jasper National Park, Alberta, Canada to examine how wolves navigate through or around human-use features. We quantified the effects of human development and topography on the tortuosity of wolf paths and then tested the permeability of roads, trails, and a railway line to wolf movement by comparing the frequency with which actual wolf paths and a null model of random paths crossed these features. Wolf path tortuosity increased near high-use trails, within areas of high-trail and road density, near predation sites, and in rugged terrain. Wolves crossed all roads, trails, and the railway line 9.7% less often than expected, but avoided crossing high-use roads more than low-use trails. Surprisingly, trails affected movement behavior of wolves equally, if not more, than roads. These results suggest that although roads and trails in this study were not absolute barriers to wolf movement, they altered wolf movements across their territories.

SECTION 8.0 - RESOURCE DEVELOPMENT

ABR, Inc. Environmental Research & Services. 2004. ***Marine Wildlife Surveys, Port Sites: 2004 Progress Report***. Pebble Gold-Copper Project, Environmental Baseline Studies, prepared for Northern Dynasty Mines Inc.

Abstract taken directly from text

We surveyed the distribution and abundance of marine-oriented birds and mammals in the proposed port area during two periods in 2004: summer and late fall–winter. During each sampling period, we determined densities of birds and mammals near or on the shoreline with near-shore surveys. We determined densities in deeper waters, in the centers of bays, and in the bight that encompasses both bays, with offshore surveys. Densities of birds on both near-shore and offshore surveys were considerably higher in the summer than in the late fall–winter. In addition, species-composition, species dominance, and distribution changed seasonally, with birds concentrating near the mouths of the bays in the summer but retreating into the bays in winter. Several species of birds also bred in the area, including (in order of abundance), Tufted Puffins, Pigeon Guillemots, Pelagic Cormorants, Horned Puffins, Glaucous-winged Gulls, Double-crested Cormorants, and Bald Eagles. Our surveys were designed to locate any threatened or endangered wildlife species that might occur in the port area. We recorded no Steller's Eiders in the summer, but recorded one pair in the fall–winter. We recorded no Kittlitz's Murrelets during either season, although it still is possible they may occur in the area in low numbers. We recorded high densities of Harlequin Ducks, which previously were proposed for listing. Densities of mammals on both near-shore and offshore surveys were considerably higher in the summer than in the late fall–winter. In addition, species-composition and species dominance changed seasonally, with harbor seals dominating numerically in the summer and sea otters dominating in the fall–winter. Preliminary review of the literature suggests that this is the highest concentration of harbor seals in Cook Inlet. We recorded no beluga whales or Steller sea lions during the surveys.

ABR, Inc. Environmental Reseach & Services. 2006. ***Chuitna Coal Project Plan: Proposed Baseline Terrestrial Wildlife and Marine Bird Studies, 2006-2007***. Prepared for Mine Engineer, Inc., Cheyenne, Wyoming and DRven Corporation, Anchorage, Alaska.

Abstract not available [excerpts directly from text]

This plan consists of two sections. The first section describes the proposed studies on terrestrial wildlife and marine birds to support the permitting requirements of the Alaska Surface Coal Mine Control and Reclamation Act. The second section describes the proposed studies that may be needed to be conducted for the impact assessments for the Supplemental Environmental Impact Statement for the Chuitna Coal Project. This work has a Proposed Budget of $765,646. Baseline studies will look at the footprints of all proposed mine-related facilities, such as the deposit area, any housing facilities, the export facility etc., and a 1-mile buffer surrounding these facilities. It will also look at the footprints of the proposed coal conveyor system corridor, any supporting roads, and a ½-mile buffer surrounding these facilities. Wildlife studies will look at bears, moose, raptors (including the Bald and Golden Eagle, Peregrine Falcon, Northern Goshawk, Red-tailed Hawk, Rough-legged Hawk, Osprey, and Great-horned Owl), landbirds (including the Blackpoll Warbler and Rusty Blackbird), shorebirds (including the Western Sandpiper, Hudsonian Godwit and Ruddy Turnstone), and marine bird species (various waterfowl species, loons, grebes, tubenoses, cormorants, herons, cranes, larids, kingfishers, and corvids). This report includes maps of the mine area and a table of the preliminary cost estimates and proposed budget.

Arc Wildlife Services Ltd. 1997. ***The Effects of Linear Developments on Wildlife: A Review of Selected Scientific Literature***. Prepared for Canadian Association of Petroleum Producers, Calgary, Alberta.

Abstract not available [excerpts directly from text]
Arc Wildlife Services Ltd. was contracted by the Canadian Association of Petroleum Producers, the Alberta Energy and Utilities Board, and Nova Corporation to conduct a review of the scientific literature describing the effects of linear developments on wildlife, especially large mammals. Of particular interest were the types of roads and linear developments created by the oil and pipeline industries in western Canada. Development corridors may affect wildlife in a wide variety of ways. The range of effects of any particular corridor is in part a function of the corridor itself. Corridors have both internal and external structure. Internal structure characteristics can be grouped into 3 categories: width characteristics, internal entities, and plant and animal community structure. Width characteristics include the Corridors function in 5 different ways for wildlife; they act as habitat, conduits, filters or barriers, sources, and sinks. Corridors are considered habitat when they provide wildlife with some requisites for survival such as food or shelter (e.g., grazing habitat for ungulates). A corridor is a conduit when wildlife moves along it (e.g., a wolf traveling along a packed seismic line in winter). Corridors may be filters or barriers when wildlife movements across or along them are hindered or blocked (e.g., roads with high traffic volumes). Corridors may be sources if wildlife living in the corridor spreads out into the surrounding habitat (e.g., mice) or they may be sinks if wildlife is attracted to the corridor and die as a result (roads and wildlife-vehicle collisions). Corridor structure plays a major role in determining the extent to which a corridor fulfills each of the 5 functions. The effects of development corridors on wildlife can be subdivided into 6 major categories: individual disruption, social disruption, habitat avoidance, habitat disruption or enhancement, direct and indirect mortality, and population effects. The presence or absence of any particular effect is dependent on the species of wildlife and the structure of the corridor. The disturbance corridor itself or activities associated with the corridor often disturb wildlife resulting in wildlife leaving the corridor area or altering patterns of use, responses that carry with them costs in terms of energy expenditure and possibly lost opportunities (individual disruption).

AREVA Resources Canada Inc. 2007. ***Appendix E Wildlife Mitigation and Monitoring Plan***. Kiggavik Sissons Project, Nunavut. 13 pp.

Abstract not available [excerpts directly from text]
This document provides the proposed wildlife mitigation, protection and monitoring plans for the Kiggavik-Sissons exploration program. The plans address the recommendations and questions regarding AREVA's application for a Land Use Permit by Durey (2007), the Government of Nunavut (GN), Department of Environment (GNDOE 2007), Environment Canada (EC 2007), and the Beverly Qamanirjuaq Caribou Management Board (BQCMB 2007). Mitigation and monitoring plans also were based on the experience and knowledge obtained from wildlife effects monitoring programs at the BHP Billiton Ekati Diamond Mine, Diavik Diamond Mine, and the De Beers Snap Lake Project in the Northwest Territories (NWT). The plans were designed to increase the current understanding of wildlife interactions with human development, and the effectiveness of mitigation measures. This document proposes way to mitigate potential impacts to caribou, raptors and other migratory birds. It includes a caribou monitoring plan, caribou aerial surveys and caribou behaviour observations.

AXYS Environmental Consulting Ltd. 2005. ***Jericho Diamond Project. Terrestrial Wildlife Mitigation and Monitoring Plan***. Prepared for Tahera Diamond Corporation, Toronto, Ontario. 185 pp.

Abstract taken directly from text
Tahera Diamond Corporation (Tahera), on behalf of Benachee Resources Inc. (a wholly owned subsidiary of Tahera Diamond Corporation), received approval in June 2004 from the Nunavut Impact Review Board (NIRB) to develop their Jericho Diamond Project (the Project). As part of the regulatory process, Tahera is required to develop and implement a Wildlife Mitigation and Monitoring Plan (WMMP). To meet this requirement, Tahera contracted AXYS Environmental Consulting Ltd. to prepare a terrestrial WMMP. This report provides details on the WMMP, including a general description of the Project, regulatory requirements, as well as specific aspects of both the mitigation and monitoring components. The Project is located at Tahera's Carat Lake site 30 km north of the Lupin Gold Mine, approximately

420 km northeast of the city of Yellowknife, 200 km southeast of Kugluktuk, and 350 km south of Ikaluktutiak (Cambridge Bay), Nunavut. The diamond deposit is contained in a multiple-phase land-based kimberlite pipe that is located about 1 km to the northeast of the proposed mining camp and processing plant. The initial plan will use open pit mining methods with underground mining methods possibly phased in during the operational phase. Mobilization of material and construction is scheduled throughout 2005, with full scale production to begin in 2006 and operate until 2014. The overall approach to developing the WMMP was based on a series of regulatory requirements. In general, mitigation plans were developed to eliminate, reduce, or control adverse effects of the Project. Monitoring plans were developed to measure predicted effects of the Project and assess the effectiveness of mitigation measures. The WMMP addressed three main types of potential Project effects: habitat change, wildlife mortality, and disruption to wildlife movements. These potential effects may occur during design, construction, operations, or closure phases of Project development. Species-specific mitigation is identified and monitoring plans developed for wildlife indicator species or species groups. The Monitoring plan focused on developing approaches for collecting data on wildlife indicators within two study area boundaries: local study area (Project footprint buffered by 500 m) and the regional study area (30 X 30 km area, centered on the mine). Wildlife indicators (and target species) were selected using various criteria and included: 1) ungulates – caribou, muskox, 2) carnivores - grizzly bear, wolverine, 3) raptors – peregrine falcon, gyrfalcon, and 4) migratory birds – passerines and waterbirds (various species). The study design used two approaches: experimental (before/after-control/impact; BACI) and correlative (i.e., repeated measures) designs. These designs will allow measurable parameters of selected wildlife indicators to be monitored over time, as well as controlling for potential sources of variation. For certain indicators and survey types, control areas will be established using zones of influence (ZOI) to differentiate between impacted and control sites. Where possible, thresholds will be used to trigger adaptive management.

Cumberland Resources Ltd. 2006. ***Meadowbank Gold Project Terrestrial Ecosystem Management***. Final Report. 149 pp.

<u>Abstract taken directly from text</u>
This report provides a comprehensive Terrestrial Ecosystem Management Plan (TEMP) for the Cumberland Resources Ltd. (Cumberland) Meadowbank Gold project. The project is located approximately 70 km north of Baker Lake, 300 km inland from the northwest coast of Hudson Bay. The Meadowbank area is above the tree line near the Arctic Circle in an area of permanently frozen ground (permafrost) that extends to a depth of 400 to 500 m. The local physiography is characterized by numerous lakes and low, rolling hills covered mainly by heath tundra. The purpose of the TEMP is to manage the interaction between the project and the terrestrial ecosystem so that residual impacts (i.e., effects that remain after mitigation has been implemented) to vegetation, wildlife, and wildlife habitats are acceptable. The TEMP has been written in association with the Terrestrial Ecosystem Impact Assessment (EIA), which identified potential residual effects to vegetation and wildlife. (Note: Unless otherwise specified, all references to an EIA in this document refer to the “Terrestrial Ecosystem Impact Assessment” and not the overall Project Environmental Impact Statement.) The EIA is based on a system of matrices that tabulate project components cross-referenced with potential effects, assessment of unmitigated effects, proposed mitigation, assessment of residual effects, and monitoring and management. Separate matrices have been prepared for each of seven terrestrial valued ecosystem components (i.e., vegetation [wildlife habitat], ungulates, predatory mammals, small mammals, raptors, waterfowl, and other breeding birds) for each of the three primary project phases (i.e., construction, operations, and closure and post-closure). Detailed matrices were not developed for the exploration, temporary closure, and long-term shutdown phases, but potential impacts during these phases are discussed within the EIA text. The TEMP follows the same basic format as those used in developing the matrices. For each potential unacceptable impact (described in detail in the EIA), mitigation measures are proposed to ensure that residual impacts (i.e., after mitigation) are acceptable. To ensure that residual impacts are indeed acceptable, a monitoring plan is presented which evaluates the response of vegetation communities and wildlife populations to the effects of the mine and mine-related activities. Where monitoring determines that unacceptable residual impacts exist, an adaptive management approach will be undertaken to ensure that further impacts are acceptable. Additional mitigation

measures will be the most likely means by which this will be accomplished. Adaptive management is an ongoing process that evolves throughout the life of the mine as better and more effective ideas are introduced in a process that is designed to be continually improving. Ongoing review of the TEMP and annual Wildlife Monitoring Summary Reports by regulatory agencies, technical reviewers, and stakeholders will further ensure that local and regional concerns have been adequately addressed. The general approach of the TEMP can be categorized in five steps:
1) Describe key valued ecosystem components (VECs).
2) Describe spatial and temporal boundaries.
3) Summarize key potential project interactions for each VEC.
4) Describe mitigation strategies for key potential interactions and propose contingency plans to address unforeseen impacts quickly and effectively.
5) Describe comprehensive long-term monitoring programs for wildlife habitat, and wildlife behaviour, movement, distribution, and abundance.

The mitigation and monitoring procedures identified in this TEMP will be integrated into all stages of the project to ensure that development can proceed as scheduled while accommodating wildlife management needs. The TEMP will also outline strategies for identifying how natural changes in the environment can be distinguished from project-related impacts. Reporting of natural versus project-related impacts will be in the annual Wildlife Monitoring Summary Report.

De Beers Diamond Mining Inc. 2004. ***Wildlife Effects Monitoring Program***. Report, Snap Lake Diamond Project. 48 pp.

Abstract not available [excerpts directly from text]
De Beers Canada Mining Inc. (De Beers) owns and operates the Snap Lake Diamond Project (the Project). An Environmental Assessment Report (EAR) for the proposed mine (De Beers 2002a) was completed and submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) in February, 2002. The Board in turn completed a review, and recommended that the Project proceed subject to the implementation of measures to mitigate environmental impacts (MVEIRB 2003). The Board's report and recommendation was submitted to the Minister of Indian and Northern Affairs in July 2003 and received ministerial approval in October, 2003. De Beers has recently received the necessary Water Licence, Land Use Permit, and Environmental Agreement to begin construction and operation of the mine. The Project is located approximately 220 km northeast of Yellowknife, Northwest Territories (NWT), 30 km south of MacKay Lake, and 100 km south of Lac de Gras where the Diavik Diamond Mine, and the Ekati Diamond Mine are located. The principal purpose of the Wildlife Effects Monitoring Program (WEMP) for the Project is to meet Condition 36 of the Land Use Permit and to comply with relevant Articles in the Environmental Agreement (e.g., Articles VII and VIII) and related corporate commitments. To comply with the relevant terms and conditions stated in the Land Use Permit and Environmental Agreement, De Beers has designed the WEMP to include the following objectives:
1) verify the accuracy of impact predictions made in the EAR;
2) implement, through the Environmental Management System (EMS) (De Beers 2002b), operational practices that mitigate disturbance to wildlife and wildlife habitat, including migratory birds and their nesting areas, species at risk, and caribou;
3) determine the effectiveness of mitigation measures implemented through the EMS;
4) consider, and incorporate where possible, traditional knowledge;
5) establish action levels or triggers for early warning signs to implement adaptive management and mitigation measures where appropriate:
6) provide opportunities for the involvement and active participation of aboriginal parties in the implementation of the WEMP;
7) design studies and data collection techniques that are consistent with, and will contribute to, understanding and managing regional cumulative effects; and
8) develop and review the WEMP in collaboration with the Government of the Northwest Territories Department of Renewable Resources and Economic Development.

Denali National Park and Preserve. 2003. ***Wolf-Human Conflict Management Plan***. Report, Denali Park, Alaska.

<u>*Abstract not available [excerpts directly from text]*</u>
Maintaining a naturally regulated population as part of an intact ecosystem is Denali National Park and Preserve's primary management objective for all wildlife species. For wolves, we intend to achieve this through the existing management programs such as road use restrictions, the visitor transportation system, the backcountry permit system and closures around active den and rendezvous sites. Informing park visitors how to behave in a manner that does not promote fearless behavior in wolves is the first step. The Wolf Encounters Brochure (Appendix G) is part of the park's educational program. However, in cases where fearless wolf behavior develops, a more manipulative strategy to modify wolf behavior is required. Failure to keep the park free of unnaturally fearless wolves may ultimately result in their removal. Selecting an alternative from the list presented below is the first step in developing a plan to manage habituated wolf behavior in Denali National Park and Preserve.

Diavik Diamond Mines. Inc. 2005. ***2005 Annual Environmental Agreement Report***. 205 pp.

<u>*Abstract not available [excerpts directly from text]*</u>
This report is written each year to meet the needs of Article 12 of the Environmental Agreement. It gives information about Diavik Diamond Mine's activities in 2005 and plans for 2006, to the affected communities and to the Parties to the Environmental Agreement. Each year, Diavik is supposed to arrange meetings in the communities to talk about this report. This is written in the Environmental Agreement. The Environment The Diavik Diamond Mine site at Lac de Gras is about 100 km north of the treeline in the Northwest Territories. Lac de Gras is a large lake that empties into the Coppermine River, which flows north to the Arctic Ocean. The lake is 60 km long, and is an average of 16 km wide and 12 meters deep. At the deepest spot, it is 56 meters. Like many arctic lakes there are not many fish or plants in it. This is natural because there is not much food or light in the winter months because ice covers the lake for a long time, and the water is cold. There is not very much rain or snow here and the wind is calm on most days. The lake freezes up in October, and it thaws in late June or early July. The land near the Diavik mine site is the home for a lot of wildlife. There are 84 kinds of birds and 16 kinds of animals in this area. Some of them stay the whole year and some just come for the summer. Some of the ones that stay are wolverine, red fox, arctic hare, arctic ground squirrel, red-backed vole, brown lemming and rock ptarmigan. The Bathurst caribou herd travels in the area near Lac de Gras. Some of the herd passes through this area in the spring and fall during migration. Wolves following these caribou den in the area during summer. Grizzly bears also travel in this area. Diavik has different plans and programs to check how healthy the environment is in the area around the mine. Under the Environmental Agreement, Diavik conducts a Wildlife Monitoring Program. This program was created to collect information about animals in the area to see if they are affected by the mine being operated. Some of the things we noticed and concluded or recommended from monitoring in 2005 were:
1) During 2005, the area of vegetation and habitat lost due to the mine was 0.84 square kilometres. This was within the expected amount from the Environmental Assessment.
2) The habitat loss for caribou was within the expected amount in 2005, and no caribou died or were injured near the mine during the year. Diavik will keep doing aerial caribou surveys because the surveys give information about changes in behavior as well as movement and number of caribou in the area. In 2005, a total of 28 caribou were seen on East Island on 20 different occasions from April to September. They were always seen in groups of one or two animals.
3) The grizzly bear habitat lost was also within the predicted amount, and no bears were killed, injured, or relocated during the year. The number of bears on the Island reported to Environment staff from May to October 2005 was 60, but it is important to note that the actual number of bears on site is unknown because the same bears were observed more than once at different times.
4) Wolverines were still on East Island in 2005 and no wolverines died, were injured or moved because of mining in 2005. Diavik will keep checking wolverine tracks in the snow to see how many there are and where they travel. During 2005, 41 sightings were reported but many of these were the same animal being sighted at different times.

5) During 2005, no peregrine falcon nests were productive within the study area. A pair of peregrine falcons made a nest on the high wall of the A154 pit. No peregrine falcons died because of the mine in 2005.

EBA Engineering Consultants Ltd. 2001. ***Tibbitt to Contwoyto Winter Road Wildlife Habitat Assessment, 2001 Report***. Prepared for Tibbit to Contwoyto Winter Road Joint Venture, Yellowknife, NWT.

Abstract not available [excerpts directly from text]

During the summer of 2001, the Tibbitt to Contwoyto Winter Road Joint Venture retained EBA Engineering Consultants Ltd. (EBA) to conduct a comprehensive field study and obtain site specific environmental and cultural information for the Tibbitt to Contwoyto Winter Road (winter road) corridor. The objective of this program was to collect the information necessary to support ongoing planning, assessment and effective environmental management related to winter road operations. Results from the various studies were combined into a GIS-based management system for the winter road corridor. This report provides the background for the wildlife habitat assessment and illustrates the types of information available within the management system. To be both effective and useful, a wildlife management program for the winter road needs to be based on data that permits a manager to quickly determine the importance of any area along the winter road corridor for any species of concern, under a variety of environmental conditions. Most wildlife species are closely linked to specific habitat types, at least for some of their needs and during certain seasons. Although not all species have been studied to the same degree, considerable knowledge is available about these habitat relationships. It was our objective to develop a flexible tool for assessing the importance of habitats for wildlife along the winter road, a tool that was based on the best information and experience available. This tool would be incorporated within the road management system. Development of wildlife habitat ratings encompassed the following steps. Wildlife species that represented the variety of available habitats in the winter road corridor were selected. Our understanding of the relationship between wildlife and habitat was documented and any assumptions explicitly defined. The values of representative habitats for the selected wildlife species for all seasons that they occurred in the area were assessed in the field. This report describes these steps. In the final step these ratings are extrapolated to all unique habitats within the winter road corridor. This final “ratings table” then provides a tool for assessing the value of any habitat for certain species at a particular time of year.

Golder Associates. 2005. ***2005 Wildlife Monitoring Data Summary Jericho Diamond Project***. Prepared for Tahera Diamond Corporation, Yellowknife, NWT. 24 pp.

Abstract not available [excerpts directly from text]

The Jericho Diamond Project (the Project), operated by the Tahera Diamond Corporation, is scheduled to begin production during the 1st quarter of 2006. This project will be the third permitted diamond mine in Canada, and the first in Nunavut. Following an environmental assessment, a Project Certificate was issued by the Nunavut Impact Review Board on July 20, 2004, pursuant to Article 12.5.12 of the Nunavut Land Claim Agreement. This report is intended to provide a summary of the data collected during wildlife baseline studies in 2005. Wildlife habitat loss (or vegetation loss) due to development of the Project is not quantified here, but will be included in the 2006 wildlife monitoring report. All wildlife studies in 2005 were conducted in a Regional Study Area (RSA) of 42 km by 42 km, or 1,764 km^2. Surveys conducted in 2005 included the following, each of which are described in the following chapters: 1) aerial surveys for caribou and muskox, 2) falcon nest occupancy surveys, 3) upland bird point-counts, 4) wildlife sign surveys, and 5) incidental observations and wildlife incidents.

Golder Associates. 2006. ***Doris North Project Wildlife Mitigation and Monitoring Program***. Prepared for Miramar Hope Bay Ltd., North Vancouver, British Columbia.

Abstract not available [excerpts directly from text]
Miramar Hope Bay Ltd. plans to construct and operate the "Doris North Gold Mine Project" (the Project) 160 km north of the Arctic Circle. Baseline environmental studies and an Environmental Impact Statement have been conducted for the Project. One of the requirements of the approval process is the implementation of a Wildlife Mitigation and Monitoring Program, which this document describes. Based on the results of the environmental impact assessment and Section 1.2, and the comments and recommendations from elders, KIA and government, the following VECs were selected for mitigation and monitoring: 1) wildlife habitat, 2) caribou (Dophin-Union and Ahiak herds), 3) muskox, 4) grizzly bears, 5) wolverines, 6) upland breeding birds (migratory songbirds and shorebirds, and ptarmigan), 7) waterfowl (including sea ducks), and 8) raptors (e.g., falcons, eagles, hawks, ravens, and owls). Other wildlife species (e.g., wolves, foxes, hares, ground squirrels, and marine mammals) will also be included in monitoring and mitigation of direct mine-related incidents that can lead to injury or mortality. For each VEC, data on a number of biological (measured) indicators will be used to monitor for potential project-related effects.

Golder Associates. 2007. ***EA0607-003 Post Hearing Submission: Report on Qualitative Assessment of the Cumulative Effect from Ur-Energy's Exploration Program on the Beverly Caribou Herd***. Prepared for Mackenzie Valley Environmental Impact Review Board, Yellowknife, Northwest Territories.

Abstract not available [excerpts directly from text]
When Ur-Energy applied for a uranium exploration program, the Beverly Qamanirjuaq Caribou Management Board requested additional information on the potential cumulative effects from the proposed program on the Beverly caribou herd. Ur-Energy agreed to provide a qualitative assessment of the Beverly caribou herd, and look at factors that would drive changes in the distribution, movement, behaviour, demography, and ultimately the population persistence of this herd. Based on the findings, Ur-Energy decided to implement measures such as only operating the camp from January to April from 2007 to 2011 in order to avoid the northern and post-calving migratory movements. It was also decided that if caribou approach within 500 m of the drill rig, drilling will cease and the rig will shut down.

Golder Associates. 2007. ***Jericho Diamond Project, 2006 Wildlife Monitoring Program Data Summary, Final Report***. Prepared for Tahera Diamond Corporatoin, Yellowknife, NWT.

Abstract taken directly from text
The Jericho Diamond Project is a diamond mine owned and operated by Tahera Diamonds Inc. It is the third diamond mine in Canada and the first in Nunavut. NIRB issued a Project Certificate for the Jericho Diamond Project in July, 2004. The Project Certificate required Tahera to develop and undertake a wildlife effects monitoring program. As a result, a Wildlife Mitigation and Monitoring Plan was developed in November 2005, and has served as a guide for the wildlife effects monitoring at Jericho since submission. Construction of the Jericho Diamond Project began in early 2005 and operations began in early 2006. This report presents the results of wildlife monitoring during these two years, and recommendations for changes to wildlife monitoring in 2007. The WMMP stipulates that data reports be published annually to summarize the data collected to date, and that detailed analysis of the data be conducted every three years. As such, this report presents limited analysis of the data, and no interpretation. The first analysis report will include all data collected up to the end of 2008.

Gunn, A., J. Antoine, J. Boulanger, J. Bartlett, B. Croft and A. D'Hont. 2004. ***Boreal Caribou Habitat and Land Use Planning in the Deh Cho Region, Northwest Territories***. Manuscript Report No. 153. Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories, Yellowknife.

Abstract taken directly from text
Boreal caribou (*Rangifer tarandus*) are nationally listed as threatened. Land use jurisdictions, including communities and land claim organizations, will have to identify, steward and monitor boreal caribou

habitat both for land use planning in the Deh Cho Region (southern Northwest Territories (NWT)) and for recovery planning in the NWT. Mapping current distribution (occupation) and potential habitat use (occurrence) for boreal caribou is a first step for both land use planning and recovery planning. We modeled occurrence at the landscape scale using generalized additive model analysis and Akaike Information Criterion with habitat information from spectral classification and habitat attributes such as cutlines, fire -history and elevation. The Deh Cho First Nations database of lifetime harvest kill sites and sightings from an aerial survey in March 2002 revealed that boreal caribou occupation has not changed at the regional level. Observations of boreal caribou fit relatively well with occurrence predicted from the modeling. Boreal caribou were strongly associated with black spruce and lichen on uplands and in lowlands.

Harrison, C. 2006. Industry Perspectives on Barriers, Hurdles, and Irritants Preventing Development of Frontier Energy in Canada's Arctic Islands. ***Arctic*** 59:238-242.

Abstract taken directly from text
The Canadian Arctic Islands and intervening channels are known to be rich in hydrocarbon resources. The combined Hecla and Drake Point discoveries of Sabine Peninsula on Melville Island have recoverable and marketable natural gas reserves estimated at almost 9 trillion cubic feet (Tcf). Proven reserves for the western Sverdrup Basin, drilled and delineated by industry exploration between 1969 and the early 1980s, are 17.5 Tcf gas and 1.9 billion barrels (bbl) of oil while total resources for Sabine Peninsula and western Sverdrup basin are estimated at 44 to 50 Tcf gas and 3.5 to 5.5 billion bbl oil. The Canadian Energy Research Institute (CERI) has recently released a report which indicates that transportation of proven Melville Island gas is economically viable for development scenarios involving either liquefied natural gas (LNG) tanker shipments to the eastern seaboard of North America or compressed natural gas (CNG) vessels to a Mackenzie Valley pipeline. In spite of these findings, however, there is still significant industry reluctance to develop the gas resources of the Arctic Islands. This paper describes specific industry concerns with the development of Arctic Islands resources. Data were gathered during telephone interviews with exploration and development managers representing six medium-to-large domestic and multinational energy companies operating on the Arctic frontiers of North America. The issues discussed were identified in a Natural Resources Canada study entitled "Reducing the Geoscientific, Environmental and Regulatory Barriers to Exploration, Transportation and Development of Energy in the Arctic Islands." The approach taken for each interview was to provide some historical background on the topic, explain the purpose of the interview, and then ask respondents' opinions on which issues are most significant in accounting for the failure to renew exploration in Canada's Far North and the lack of progress on developing existing proven reserves. It became apparent with the first interview that some issues, such as the lack of development infrastructure and certain regulatory problems, could be considered true barriers to energy development in the Arctic Islands, but other issues were viewed as either hurdles or mere irritants. It also became very clear that the potential solutions available to government scientists and regulatory agencies cover a broad spectrum. The paper concludes with specific recommendations for future work.

Hik, D. S. and K. K. Sloan. 2004. Putting the Canadian Polar House in Order. ***Arctic*** 57:3-5.

Abstract not available [excerpts directly from text]
Northern Canada is facing unprecedented social, political, economic, environmental, and cultural changes. Unfortunately, attention to northern issues has typically been sustained for only short periods in response to external events, usually associated with interests in minerals, oil and natural gas reserves, or pipelines. Public policy needs to be supported by a strong knowledge base: the results of scholarly studies and various research and monitoring programs can help government to identify problems, set priorities, and implement solutions. The cumulative effect of inadequate federal funding has been to marginalize northern research, creating a crisis in capacity and knowledge that can no longer be ignored.

Hubert and Associates Ltd. 2002. ***Environmental Effects Assessment on Wildlife, Jericho Diamond Project***. Report Prepared for Tahera Corporation. 50 pp.

<u>Abstract taken directly from text</u>

The Jericho Diamond Project is located in the Willingham Hills, a rugged area of granite outcrop adjacent to the north end of Contwoyto Lake in the Kitikmeot Region of Nunavut. Baseline studies on wildlife and wildlife habitat in the area of the Jericho Diamond Project were conducted from 1995 to 2001. These studies included detailed ecosystem mapping, sampling for breeding birds, monitoring small mammal populations, locating nest sites and monitoring raptor productivity, monitoring carnivore dens, and conducting aerial surveys for large mammals and mapping caribou trails. Ecosystem mapping showed the normal diversity of tundra plant communities dominate the landscape of the Project area. Lowlands are dominated by wet sedge meadows, tundra heath covers dry slopes with dry land sedges and tufted plants occur on dry ridges and crests. No rare or endangered plant species were reported. The Project area supports a full complement of tundra wildlife species. Small mammals seem to be cyclic like elsewhere on the tundra. Passerine birds are present in normal abundance. Water fowl are relatively uncommon. Ground squirrels and Arctic hare are present. Carnivores were observed and fox and wolf dens were found. Muskox are present, but are not abundant. Caribou are common during spring migration and can be present in concentrated numbers for short periods of time (up to 24 hours) in the late-June through the mid-August period. The development schedule, layout, and operating plan of the Jericho Diamond Project were reviewed with a view to assessing potential Project effects on wildlife and wildlife populations in the Project area. Site development and operations will require the permanent alteration of approximately 222 ha of tundra habitat. Wildlife like small mammals and small birds may be displaced, but effects on their populations will be minor. Likewise, raptor nest sites close to the Project site may be displaced, but environmental effects at the population level will be minor and last only for the life of the Project, estimated to be about eight years. In terms of caribou, special attention was paid to the site plan in relation to mass caribou movements. The combination of mine site configuration and natural topography is such that large numbers of caribou will be able to continue to migrate past the Project site with little risk to individual caribou and no measurable effects on the Bathurst herd. It is believed that mitigative measures can be successfully undertaken to ensure the migration of caribou, in relation to the Jericho mine site. Specific recommendations for mitigation have been made within this report, which will aid in achieving this goal. Likewise, it is believed that the use of the Lupin winter road on Contwoyto Lake for bulk materials resupply will have no measurable effect on the Bathurst caribou herd. Overall, the Jericho Project will have only minor environmental effects on local wildlife populations with no cumulative environmental effects on wildlife and wildlife populations, operating in concert with other human activities in the region.

Johnstone, R. 2003. ***Submission of De Beers Snap Lake Diamond Project 2001 and 2002 Baseline and Interim Wildlife Monitoring Reports to the Public Registry***. Prepared by De Beers Mining Inc. for Environmental Assessment Office, Mackenzie Valley Environmental Impact Review Board, Yellowknife, NWT. 125 pp.

<u>Abstract not available [excerpts directly from text]</u>

This report presents the results of wildlife monitoring at the Snap Lake Diamond Project from 1999 through 2001. The environmental assessment for the Snap Lake Diamond Project predicted that the loss of any habitat type due to the mine footprint would be less than 1% of the study area, which is largely due to the small size of the mine footprint. Monitoring during construction and operation will determine if the amount of habitat loss is equal to that predicted in the environmental assessment. The Snap Lake Diamond Project is located on the migration route of the Bathurst caribou herd. The area is also occasionally used by caribou wintering north of the treeline. Information collected indicated that the number of caribou within the study area varies markedly between migration periods and years, and that 91% of groups observed contained fewer than 50 individuals. Results indicated that grizzly bears were present in the area. Fresh bear sign was found in 64% of the 42 plots surveyed. Wolverines, wolves, raptors, and upland birds were also studied.

Lines, S. 2007. ***Environmental Impact Assessment and Monitoring Guidelines for Differentiating Natural Variation from Development-related Impacts on Caribou***. Master's Thesis, University of Calgary.

<u>*Abstract not available [excerpts directly from text]*</u>

The purpose of this proposed study is to develop, using an ecology-based approach, scientifically rigorous guidelines for impact assessment and monitoring of caribou for the Mackenzie Valley Environmental Impact Review Board and Nunavut Impact Review Board (the Boards). This is being done so that the information collected by proponents allows for more reliable differentiation between natural variation in key aspects of caribou ecology and changes caused by development. The development of scientifically rigorous guidelines and their consistent implementation by the Boards for all projects would also contribute to more consistent and comparable data collection on a regional and transboundary level thus improving Cumulative Effects Assessment as well. Environmental Impact Assessment (EIA) is a powerful environmental safeguard in the project planning process but is often poorly carried out. This is certainly the case in northern Canada where a number of EIAs and the design of project monitoring have not been able to differentiate natural variation from development-related impacts on the terrestrial ecosystem. This issue is particularly significant when it comes to caribou, which is central to the cultural identity, spiritual well-being and traditional economy of northern communities. Objectives for this project are:

1) Review and document the authority and rules of practice and procedures of the Boards for issuing guidelines to proponents so that the guidelines developed are more likely to be effective for the Boards.
2) Determine which aspects of caribou ecology are most significant in EIA so that these key aspects can be included in the guidelines and used in part as criteria for evaluating current guidelines and practices in caribou impact assessment and monitoring.
3) Determine overall criterion for evaluating existing impact assessment guidelines and monitoring programs to establish current practices concerning caribou.
4) In addition to the guidelines evaluated above, identify ecological approaches to caribou impact assessment and monitoring which can differentiate natural variation from changes due to development-related impacts, and select the most suitable approach.
5) Identify a reasonable set of information and data requirements in order to use the selected ecological approach for caribou impact assessment and monitoring.
6) Determine preferred methodologies for collecting baseline and project monitoring data to support the information requirements of the ecological approach.
7) Evaluate how the guidelines can contribute on a regional level to meeting the requirements of Cumulative Effects Assessment legislation for the Boards in order to evaluate the broader implications of the guidelines.
8) Develop a reasonable set of comprehensive impact assessment and monitoring guidelines for caribou based on the ecological approach by integrating the information gathered. The guidelines will be intended to direct proponents on the collection of data required to implement the approach to differentiate natural variation from development-related impacts.
9) Present the caribou impact assessment and monitoring guidelines to the Boards and related industry in order to obtain feedback for consideration prior to finalizing the guidelines and delivery to the Boards for proposed implementation.

Lund, K. E. and K. Young. 2003. ***Contaminant in High Arctic Soils: A Tracer Experiment***. Poster, Department of Geography, York University.

<u>*Abstract taken directly from text*</u>

There is a need to understand how contaminants move in pristine High Arctic environments. Lithium can be used as a proxy for metal movement in soils. The objective of this study is to determine how soil properties affect lithium transport in High Arctic soils. The main conditions affecting transport are organic content, soil texture, topography, and moisture. A lithium chloride (LiCl) tracer experiment was set up at three study sites (Creswell Bay, Somerset Island; Resolute, Cornwallis Island; and Eastwind Lake, Ellesmere Island) in the summer of 2002. Plots were irrigated with 10 L of 0.2 M LiCl at each study site.

Each plot was sampled, extracted, and analyzed for vertical and lateral Li^+ movement in the summers of 2002 and 2003. It was found that all three sites experienced significant vertical and lateral losses of Li^+ over the spring snowmelt season. The greatest amount of Li^+ was transported at Creswell Bay and Resolute due to the low organic content, coarse soil texture, and sloping topography occurring at these sites. If used for a proxy for heavy metals (such as Cd or Pb), contaminants spilled on these soils would be relatively mobile. This tracer methodology could be used to select waste disposal sites in the Arctic.

Male, S. K. and E. Nol. 2003. ***Effects of Diamond Mining on the Breeding Distribution, Behaviour, and Reproductive Success of Arctic Passerines***. Poster, Trent University, Peterborough, Ontario.

Abstract taken directly from text

Activities associated with diamond mining in the arctic have the potential to degrade breeding habitat for arctic passerines, which must contain suitable nest sites and adequate resources to support both the parents and their young of the year. If the area is lacking in any necessary features, it may be completely avoided, or become a population sink for breeders of lower reproductive success. The purpose of this study was to determine the impacts of activities associated with the Ekati Dimaond Mine, NTW, on the breeding habitat, density, behaviour, and reproductive success of an arctic passerine, the Lapland Longspur (*Calcarius lapponicus*). Eight study plots were used in this study, four located within a kilometer of the mine and four located at least five kilometers from the mine. Lapland Longspurs were observed, and their nests tracked throughout the breeding season. Habitat in close proximity to the mine was found to be drier, have higher levels of dust deposition, and reduced ground cover. The species composition of the plant communities also changed at increasing distances from the mine. No significant differences were seen between densities, or reproductive success of Longspurs nesting adjacent to roads in comparison with those in control plots. Despite this, we suggest that due to the cumulative effects of activities associated with diamond-mining on arctic tundra plant communities, impacts may be observed in the near future.

Muller-Wille, L. 1987. Indigenous Peoples, Land-Use Conflicts, and Economic Development in Circumpolar Lands. ***Arctic and Alpine Research*** 19:351-356.

Abstract taken directly from text

Progressions in the contact between northern indigenous peoples and southern populations who seem to control sovereignty and economic development in the international circumpolar north are reviewed. Current issues surrounding modern, indigenous land-use patterns are seen in relation to the national, international, and global developments. The North is not isolated but rather intertwined with processes influenced by internal and external events. There are three competing and interfering land uses: (1) indigenous "traditional pursuits" based on renewable, mainly animal resources, i.e., herding, hunting, trapping, and fishing/sealing; (2) the introduced wage-labor and service sector based on the southern public services and facilities; and (3) the almost completely independent non-renewable resource extraction industry for export to production centers outside the North. The indigenous peoples have fully realized this process and know that choices have to be made in order to accommodate the different interests and goals in the north. However, their expectations center around: (1) sovereignty and territoriality; (2) control and decision making; (3) socioeconomic benefits for the North; and (4) cultural and linguistic survival.

Nelson, G. C., E. Bennett, A. A. Berhe, K. Cassman, R. DeFries, T. Dietz, A. Dobermann, A. Dobson, A. Janetos, M. Levy, D. Marco, N. Nakicenovic, B. O'Neill, R. Norgaard, G. Petschel-Held, D. Ojima, P. Pingali, R. Watson and M. Zurek. 2006. Anthropogenic Drivers of Ecosystem Change: an Overview. ***Ecology and Society*** 11:29.

Abstract taken directly from text

This paper provides an overview of what the Millennium Ecosystem Assessment (MA) calls "indirect and direct drivers" of change in ecosystem services at a global level. The MA definition of a driver is any natural or human-induced factor that directly or indirectly causes a change in an ecosystem. A direct driver unequivocally influences ecosystem processes. An indirect driver operates more diffusely by altering one or more direct drivers. Global driving forces are categorized as demographic, economic, socio-political, cultural and religious, scientific and technological, and physical and biological. Drivers in all categories other than physical and biological are considered indirect. Important direct drivers include changes in climate, plant nutrient use, land conversion, and diseases and invasive species. This paper does not discuss natural drivers such as climate variability, extreme weather events, or volcanic eruptions.

Northwest Territories Resources, Wildlife and Economic Development. 2000. ***Technical Review of the Environmental Assessment Report for the Sable, Pigeon, and Beartooth pipes, Ekati Mine, NWT***. Prepared for the Mackenzie Valley Environmental Impact Review Board, Yellowknife, NWT. 56 pp.

Abstract not available [excerpts directly from text]
The project under consideration includes the development of three new kimberlite pipes (Sable, Pigeon and Beartooth) within the Ekati Claim Block by BHP Diamonds Inc. These pipes were not included in the original mine plan reviewed during the initial Panel Review. This panel for the original Ekati Mine had Government of Northwest Territories representatives. The three new pipes will be mined by the same open pit methods currently used at the Panda pit. The Leslie Pipe, including in the original mine plan, was found to be uneconomic and was removed from the mine plan in 199. The removal of the Leslie Pipe decreased the operating life of the mine from 25 to 15 years. The addition of the Sable, Pigeon and Beartooth Pipes will provide an additional 3 years of reserves at the 18,000 tonne per day rate, extending the current mine life from 15 to 18 years.

Nunavut Impact Review Board. 2007. ***Comments from GN-DOE regarding the Doris North Project Wildlife Mitigation and Monitoring Program (Appendix A)***. Prepared for Miramar Hope Bay Ltd., North Vancouver, BC. 15 pp.

Abstract not available [excerpts directly from text]
Miramar Hope Bay Ltd. has proposed a number of mitigation measures aimed at reducing impacts of the project on the identified wildlife VECs; however, the proponent fails to provide actual thresholds for each monitoring program that would trigger additional mitigation actions. MHBL has opted to have the results of the monitoring reviewed yearly by appropriate regulators and communities which will be time consuming and potentially delay mitigation actions to allow the full extent of consultation described. In many instances the mitigation plans are poorly developed with little guidance on when and how they will be implemented. Accompanying each mitigation measure should be a plan of when and how it will be implemented, including thresholds for implementation i.e. number of animals, location, unanticipated impact etc. Additionally, the WMMP refers frequently to the need for adaptive management and review of mitigation measures if monitoring reveals that impacts are greater than predicted. In many instances, however, there are no triggers for such reviews or for the implementation of adaptive management techniques or even what those adaptive management techniques might be.
Overhead flights: Considering the necessary amount of wildlife monitoring required, we encourage the proponent to plan monitoring activities carefully in order to reduce the total amount of time spent in the field, especially when using aircrafts. For example, Grizzly bear habitat plots can be monitored at the same time some aerial surveys are conducted.

Reporting: DOE requests that NIRB require all wildlife reports to be forwarded to the appropriate regulatory agencies. Also, wildlife monitoring data should be forwarded to GN-DoE (not only the report but also the raw data with metadata).

Summary of proposed monitoring activities: To facilitate use of the WMMP by MHBL and regulators, DOE suggests the inclusion, as appendices, of a table summarizing the proposed monitoring activities. Such a table could include measurable parameters, impact prediction for each parameter, level of

confidence in the prediction, quantitative monitoring variables, thresholds for adaptive management, monitoring methods, frequency of monitoring and reporting.

Rey, L. 1987. The Arctic: Mankind's Unique Heritage and Common Responsibility. ***Arctic and Alpine Research*** 19:345-350.

<u>*Abstract not available [excerpts directly from text]*</u>
It is a common feature of public opinion to fuse together the Arctic and Antarctic into one single entity under the global heading of "Polar Regions." It goes even further since many research organizations claim competence on the polar regions of both hemispheres and train a large corps of "polar specialists" who demonstrate their expertise in meteorology, ice dynamics, high- atmosphere physics, oceanography, or low-temperature biology equally on austral or boreal lands and seas. Obviously there is some pertinence in this process since the Arctic and Antarctic share many common features: a polar and circumpolar astronomical and geographical setting, and a prevailing harsh cold climate which impedes the development of life on land, covers many areas with thick permanent ice shelves, and sheets the sea with a shore-fast or drifting ice pack. Polar regions are also far away from mid-latitude administrative, technical, and industrial decision-making centers as well as from major human settlements. For that very reason they have, indeed, been ignored for millenniums though, as early as the Ionian School (7th century B.C.), their existence has never been disputed from a pure logical and philosophical standpoint. However, because of their remoteness and adverse climatic conditions, it is only in fairly recent historical times that explorers and entrepreneurs managed to gain regular access to mysterious Antarctica and the gloomy Arctic. Nevertheless, whichever similitudes can be discovered, the boreal and austral frontiers have, indeed, very little in common and deserve specific individual consideration.

Robert Hornal and Associates, Ltd. 2003. ***A Socio-economic Impact Assessment of the Proposed Doris North Project in the Kitikmeot Region Nunavut***. Prepared for Miramar Hope Bay, Ltd. 31 pp.

<u>*Abstract taken directly from text*</u>
The purpose of this study is to identify the social and economic impacts of the proposed Doris North Project on the communities of the Kitikmeot Region of Nunavut (Kugluktuk, Cambridge Bay, Umingmaktok, Bathurst Inlet, Gjoa Haven, Taloyoak and Kugaaruk) and the community of Yellowknife in the Northwest Territories. The Doris North Project is a small mining project. It will generate a total of 400 person years of employment over three years. Six Valued Socio-Economic Components (VSECs) were identified for the Project, employment opportunities, education and training, contract and business opportunities, community health, crime and demographic impact. The impact of the Doris North Project on first three VSECs, employment opportunities, education and training and contract and business opportunities is expected to be moderately positive. The impact of the project on community health is expected to be moderate and could be either positive or negative depending on the mitigative measures applied. The impact of the Project on crime is expected to be moderately negative. The impact of the project on demographics is expected to be minor. Cumulative socio-economic impacts are expected to be neglible because of the small size of the Project and the mitigative measures available. A monitoring committee is recommended to assure that impacts are identified and managed.

Smith, A. C., J. A. Virgl, D. Panayi and A. R. Armstrong. 2005. Effects of a Diamond Mine on Tundra-breeding Birds. ***Arctic*** 58:295-304.

<u>*Abstract taken directly from text*</u>
Breeding birds (songbirds, shorebirds, and ptarmigan) were surveyed at the Ekati Diamond Mine in Canada's Northwest Territories from 1996 through 2003. Surveys were conducted on permanent, 25 ha mine and control plots. Five metrics (relative density of individual species, relative density of all birds, species richness using rarefaction curves, and species diversity using two indices) were used to assess potential impacts up to a distance of 1 km from the mine. Six species were more common on mine plots, and three were more common on control plots. Species diversity was slightly higher on mine plots when

measured with Fisher's alpha index. No other metrics suggested strong impacts. This study suggests that the mine has had a relatively limited impact on the upland breeding bird community within 1 km of the footprint but has provided habitat for at least one synanthropic bird species. Further monitoring of breeding birds on the tundra should include pre-development control data and demographic variables such as reproductive success and survival.

Stewart, E. J., D. Draper and M. E. Johnston. 2005. A review of tourism research in the Polar Regions. ***Arctic*** 58:383-394.

<u>*Abstract taken directly from text*</u>
Polar travel has grown dramatically in the last two decades and in recent years has become the focus of academic inquiry. Using a model initially developed for understanding the nature of culture, action, and knowledge in the development of human geography, we explore the nature, scale, and scope of research related to tourism in the Arctic and the Antarctic. We take a comparative approach to highlight the tourism issues that are largely similar in the two Polar Regions. Polar tourism research appears to cluster around four main areas: tourism patterns, tourism impacts, tourism policy and management, and tourism development. By assessing these emerging research clusters, we identify research gaps and potentially fruitful lines of inquiry.

Tahera Corporation. 2003. ***Environmental Management Plan, Jericho Project.*** Toronto, Ontario. 111 pp.

<u>*Abstract not available [excerpts directly from text]*</u>
Environmental management plans are the minimum commitments by Tahera Corporation for environmental protection. Plans have been made sufficiently flexible so that changes to the mining operation or other external changes can be responded to and accommodated appropriately. Annual evaluation of the Environmental Management Plan, evaluation of response if accidents occur, and continual evaluation of ways to reduce pollution at source will be integral management functions at the Jericho Mine. Feedback and suggestions from employees and the community liaison committee will be key tools in pollution prevention analysis. The mine safety committee will also be charged with evaluation of environmental issues and responses. This plan will look at rehabilitating the land, what to do with waste rock and processed kimberlite, domestic and industrial wastes, water management, fish habitat compensation, noise, air emissions, and wildlife management.

U.S. Department of the Interior. 2003. ***Cook Inlet Planning Area. Oil and Gas Lease Sales 191 and 199. Volume I - III***. Final Environmental Impact Statement, U.S. Department of the Interior, Minerals Management Service, Alaska Outer Continental Shelf.

<u>*Abstract taken directly from text*</u>
This environmental impact statement (EIS) assesses two lease sales in the Final 2002-2007 5-
Year Oil and Gas Leasing Program for the Cook Inlet Outer Continental Shelf (OCS) Planning Area. The Department has scheduled Sale 191 for 2004 and Sale 199 for 2006. The proposed sales include consideration of 517 whole or partial lease blocks in the Cook Inlet Planning Area, covering about 2.5 million acres (1.01 million hectares). The area considered for the Proposed Action (Alternative I) is located seaward of the State of Alaska submerged lands boundary in the Cook Inlet and extends from 3-30 miles in water depths ranging from 30 feet to more than 650 feet. For each alternative, the EIS evaluates the effects to the human, physical, and biological resources from routine activities and from the unlikely chance of a large oil spill. Other alternatives include Alternative II (No Lease Sale), which means cancellation of the sale; and two deferral alternatives (Alternatives III and IV), which would eliminate various subareas from leasing. A cumulative-effects analysis evaluates the environmental effects of the proposed action with past, present, and reasonably foreseeable future OCS lease sales, as well as non-OCS activities. MMS evaluated four standard lease Stipulations and six standard Information to Lessee (ITL) clauses as part of the proposed action. The EIS also evaluates an optional ITL.

U.S. Environmental Protection Agency. 1990. ***Diamond Chuitna Coal Project. Final Environmental Impact Statement, Vols. I & II***. U.S. Environmental Protection Agency, Water Division, Seattle, Washington. 656 pp.

Abstract not available [excerpts directly from text]
Volume I: The actions to be considered are the approvals of federal permits for the proposed Diamond Chuitna Coal Project located on the west side of Cook Inlet in southcentral Alaska. The project would consist of a surface coal mine, haul road, a method of transporting coal to a port facility on Cook Inlet, dock facilities, and other ancillary facilities. Three action alternatives and a no action alternative are discussed in detail. Rationale for eliminating various options is given. The preferred alternative would include construction of a port site at Ladd, an eastern transportation corridor, development of a housing facility at Lone Creek, and a conveyor system which would parallel the haul road and transport coal to the port site. The impacts of the proposed project are considered in terms of vegetation, fish, wildlife, wetlands, water quality and hydrology (both surface and subsurface), physical and chemical oceanography, air quality, visual resources, cultural resources, subsistence, socioeconomics, recreation, technical feasibility, and future uses of facilities.

Volume II: The second volume of the Diamond Chuitna Coal Project Environmental Impact Statement has the report appendices. These include the terrestrial habitat evaluation and the U.S. Fish and Wildlife Service Mitigation Statement, and a number of maps and figures of the proposed project area.

Knight Piésold CONSULTING

APPENDIX B

BIRD HABITAT SUITABILITY REPORT

(Pages B-1 to B-20)

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Cont. No.:NB10-00584

November 22, 2010

Matthew Pickard
Manager, Sustainable Development
Baffinland Iron Mines Corporation
1016 - 120 Adelaide Street West
Toronto, Ontario
Canada, M5H 1T1

Dear Matthew,

Re: Habitat Suitability Modelling for Peregrine Falcon, Red-Throated Loon, Snow Geese and Eider for the Mary River Project, North Baffin Island, Nunavut, Canada

Introduction

A quantitative ecological land classification (ELC) utilizing 45 variables related to wildlife habitat in the Mary River regional study area (RSA) was developed as a necessary precursor to the modeling of avian VEC habitat suitability (Knight Piésold Ltd. 2010). Avian VECs included Peregrine Falcon (nesting and foraging), Red-Throated Loon, Snow Geese, and Eider. The Mary River Project ELC report (Knight Piésold Ltd. 2010) provides details describing the development of this GIS-based model. In addition to the ELC model, a variety of other methods were used to produce these bird habitat suitability maps (e.g., see Franklin 2009). These habitat suitability maps were used to quantify potential project impacts on avian VEC habitat.

Methods

Initially, an avian biologist provided suitability ratings of the terrestrial habitat variables in the RSA for each of the four bird VECs during the growing season. These variables included plant species/guilds (e.g., lichens, saxifrage, etc.), land cover types (e.g., wetlands, sparsely vegetated bedrock, etc.), and physical habitat characteristics (e.g., slope, elevation, etc.) (see Appendix A for a list of the habitat variables). Using these habitat ratings and the ELC as inputs, the VEC habitat suitability models generated terrestrial habitat suitability map for each bird VEC.

Terrestrial habitat variables (abiotic variables and ELC vegetation variables) were transformed into habitat suitability ratings by using a lookup and replace procedure of creating the habitat suitability map for each VEC. Based on the suitability ratings, raw terrestrial habitat variables were replaced with a 0-1 or 0-100 suitability rating if they were within certain ranges of the terrestrial habitat variables values. The separate habitat variable suitability maps were combined using a composite weighted sum of all the habitat variables, these were rescaled to a 0-100 interval. The composite VEC habitat suitability map was categorized into four intervals based on an equal area allocation of all habitat suitability values including high, medium, low, and nil habitat suitability classes.

In addition to using terrestrial habitat, three of the four bird VECs (Red-Throated Loon, Snow Geese and Eider) also utilize various portions of aquatic habitats. In order to build an aquatic habitat component into the ELC model, use of aquatic habitat by the three aquatic bird species was rated by an avian biologist and the aquatic spatial database was integrated with the terrestrial spatial database. The steps required to do this were as follows.

- Within the RSA, bodies of freshwater (lakes and large rivers) were classified into five size categories and one category for marine areas
- Raster datasets that estimated the distance from shoreline within the six waterbody categories were created
- A seabird expert produced habitat rating tables for each waterbody category that defined the relative preference (0-100) of the three aquatic bird VECs for distance categories
- Each distance raster dataset was re-classed to the relative preference for the distance from shore for each VEC and all the relative preference raster datasets were combined together to produce a single relative preference raster dataset of waterbodies and marine areas for the VEC
- The preferences were converted to a scalar from 0 to 1, which was multiplied by the maximum terrestrial VEC suitability. These were further adjusted down using the elevation preference lookup tables originally developed for the terrestrial VEC suitability modeling.
- Finally, for each VEC, the data layer for VEC suitability within waterbodies and marine areas was overlaid onto the terrestrial VEC suitability data layer to produce a single VEC suitability theme covering the entire RSA

The accuracy of the habitat suitability maps for each bird VEC was evaluated using the field data collected for the Mary River Project Bird Baseline Program. This was done by quantifying the number of observations located within each of the four classes of habitat suitability: high, medium, low, and nil, with each class representing roughly 25% of the RSA. The greater the percentage of observations within the medium and high habitat suitability categories, the more accurate the model was judged to be.

Due to low accuracy of the original Peregrine Falcon foraging and nesting habitat suitability models, the field data for this species were used in a binary logistic regression analysis to identify the independent variables that contribute significantly to predicting Falcon foraging and nesting presence. The results of the logistic regression analysis were then used to create a linear model of peregrine foraging habitat suitability and a linear model of peregrine nesting habitat suitability. The magnitude of the coefficients of each significant independent variable was used to weight the abiotic and ELC variables and combine them into a weighted sum. The resulting values were rescaled between 0-100 and categorized into the four habitat suitability categories. The accuracy of the revised habitat suitability models was also evaluated using the Mary River bird field data.

Results

The bird VEC habitat suitability maps created by this work are presented in the bird habitat impact analysis as part of the Mary River Project draft Environmental Impact Statement (in preparation).

<u>Peregrine Falcon</u>

Nesting

The original and revised habitat ratings for Falcon nesting are provided in Appendix A. The accuracy of the original Falcon nesting habitat suitability model was only 73.6% (see Table 1). Using the results of the logistic regression (see Appendix B), the accuracy of the model was increased to 87.9% (see Table 2).

Table 1 - Accuracy of Original Peregrine Falcon Nesting Habitat Suitability Model

Habitat Suitability Category	Accuracy	
	Frequency of Observations	%
3 (high)	112	41.0
2 (medium)	89	32.6
1 (low)	39	14.3
0 (nil)	33	12.1
all	273	100

Table 2 - Accuracy of Revised Peregrine Falcon Nesting Habitat Suitability Model

Habitat Suitability Category	Accuracy	
	Frequency of Observations	%
3 (high)	187	68.5
2 (medium)	53	19.4
1 (low)	10	3.7
0 (nil)	23	8.4
all	273	100

Foraging

The original and revised habitat ratings for Falcon foraging are provided in Appendix A. The accuracy of the original Falcon foraging habitat suitability model was only 41.7% (see Table 3). Using the results of the logistic regression (see Appendix B), the accuracy of the model was increased to 83.4% (see Table 4).

Table 3 - Accuracy of Original Peregrine Falcon Foraging Habitat Suitability Model

Habitat Suitability Category	Accuracy	
	Frequency of Observations	%
3 (high)	61	22.5
2 (medium)	52	19.2
1 (low)	111	41.0
0 (nil)	47	17.3
all	271	100

Table 4 - Accuracy of Revised Peregrine Falcon Foraging Habitat Suitability Model

Habitat Suitability Category	Accuracy	
	Frequency of Observations	%
3 (high)	161	59.4
2 (medium)	65	24.0
1 (low)	18	6.6
0 (nil)	27	10.0
all	271	100

Red-Throated Loon

The original and revised habitat ratings for Red-Throated Loon are provided in Appendix A. The accuracy of the Red-Throated Loon habitat suitability model was 89.9% (see Table 5).

Table 5 - Accuracy of Red-Throated Loon Habitat Suitability Model

Habitat Suitability Category	Accuracy	
	Frequency of Observations	%
3 (high)	660	56.2
2 (medium)	396	33.7
1 (low)	89	7.6
0 (nil)	29	2.5
all	1174	100

Snow Geese

The original and revised habitat ratings for Snow Goose are provided in Appendix A. The accuracy of the Snow Goose habitat suitability model was 82.5% (see Table 6).

Table 6 - Accuracy of Snow Geese Habitat Suitability Model

Habitat Suitability Category	Accuracy	
	Frequency of Observations	%
3 (high)	1812	53.9
2 (medium)	962	28.6
1 (low)	370	11.0
0 (nil)	217	6.5
all	1174	100

Eider

The original and revised habitat ratings for Eider are provided in Appendix A. The accuracy of the Eider habitat suitability model was 89.3% (see Table 7).

Table 7 - Accuracy of Eider Habitat Suitability Model

Habitat Suitability Category	Accuracy	
	Frequency of Observations	%
3 (high)	147	68.4
2 (medium)	45	20.9
1 (low)	9	4.2
0 (nil)	14	6.5
all	215	100

Summary

A quantitative ELC utilizing 45 variables related to terrestrial and aquatic wildlife habitat in the Mary River RSA was developed as a necessary precursor to the modeling of avian VEC habitat suitability. These avian VECs included Peregrine Falcon (nesting and foraging), Red-Throated Loon, Snow Goose, and Eider. Using the ELC, habitat ratings (expert opinion), field data, and regression analysis, habitat suitability maps were generated. A ranking of these models from most to least accurate includes the following: Red-Throated Loon habitat at 89.9%, Eider habitat at 89.3%, Falcon nesting habitat at 87.9%, Falcon foraging habitat at 83.4%, and Snow Goose habitat at 82.5%. The habitat suitability maps generated from this work were subsequently used to quantify potential project impacts on avian VEC habitat, which are addressed in a separate report.

References

1. Baffinland Iron Mines Corporation.(in preparation). **Mary River Project - Draft Environmental Impact Statement**. Knight Piésold Ltd., North Bay, Ontario.

2. Franklin, J. 2009. ***Mapping Species Distributions***. Cambridge University Press, New York. 320 pp.

Yours truly,
KNIGHT PIESOLD LTD.

Signed: ______________________ Approved: ______________________

Peter Quinby, Ph.D. & Cert. Sen. Ecol.
Senior Environmental Scientist

Ken D. Embree, P.Eng.
Managing Director

Attachments:

Appendix A	Bird Habitat Suitability Ratings
Appendix B	Results of the Binary Logistic Regression Relating Habitat Variables to Peregrine Falcon Foraging Locations
Appendix C	Results of the Binary Logistic Regression Relating Habitat Variables to Peregrine Falcon Nest Locations

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Knight Piésold CONSULTING

APPENDIX A

BIRD HABITAT SUITABILITY RATINGS

(Pages A-1 to A-8)

NB10-00584
November 22, 2010

Species Acronyms

carea	***Carex atrofusca***
cares	***Carex scirpoidea***
cgr	**cotton grasses and rushes**
drya	***Dryas integrifolia*** **(avens)**
grass	**grasses and sedges**
ledu	***Ledum palustris*** **(Labrador tea)**
lich	**non-rock lichens**
luzuc	***Luzula confusa***
luzun	***Luzula nivalis***
moss	**mosses**
oxyt	***Oxyria digyna*** **(mountain sorrel)**
rock	**rock lichens**
salix	**willows**
saxi	***Saxifraga oppositifolia (purple mountain saxifrage)***
vacc	***Vaccinium uliginosum*** **(blueberry)**

Species	Peregrine Falcon - Nesting (original)

Plant Species/Guilds	carea	cares	cgr	drya	grass	ledu	lich	luzuc	luzun	moss	oxyt	rock	salix	saxi	vacc
Weightings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Vegetation Cover Types	Unknown	Tussock Graminoid Tundra	Wet Sedge	Prostrate Dwarf Shrub	Wetlands	Moist to Dry Non-Tussock	Sparsely Vegetated Bedrock	Sparsely Vegetated Till	Barren	Ice/Snow	Water	Dry Graminoid	Bare Soil with Cryptogam
Weightings	0	70	50	0	40	70	0	0	10	0	50	70	0

Small Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	80	50	0

Large Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	80	50	0

Lakes 0-0.25 ha	0-1	1-50	50-100	100-150	150-140000
Weighting	80	80	80	50	0

Lakes 0.25-1.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	80	50	0

Lakes 1.0-5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	80	50	0

Lakes >5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	80	50	0

Aspect	-1	0-45	45-135	135-225	225-315	315-360
Weightings	0	0	0	80	0	0

Slope	0-0.01	0.01-0.1	0.1-0.4	0.4-1
Weightings	0	0	0	100

Terrain Roughness Index	-0.001-0.063	0.063-0.126	0.126-0.189	0.189-0.252	0.252-0.33
Weightings	0	0	0	0	0

Elevation	-140-166	166-332	332-498	498-665	665-1500
Weighting	0	0	0	0	0

Moisture	smooth scaling of 0-100 moisture ratings (not rated)
Weightings	

Categories	Plant Spp/Guilds	Slope	Veg Cover Types	Moisture	Aspect	Terrain Roughness Index	Elevation	Lakes	Rivers
Weightings	0	100	50	0	80	0	0	80	80

Large Rivers - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0-0.25 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0.25-1.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 1.0-5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes >5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Marine - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Species	Peregrine Falcon - Nesting (revised)

Plant Species/Guilds	carea	cares	cgr	drya	grass	ledu	lich	luzuc	luzun	moss	oxyt	rock	salix	saxi	vacc
Weightings	-0.8555	0	0	0.05735	0	0	0.2414	0	0	0	0	0	-0.07683	0	0

Vegetation Cover Types	Unknown	Tussock Graminoid Tundra	Wet Sedge	Prostrate Dwarf Shrub	Wetlands	Moist to Dry Non-Tussock	Sparsely Vegetated Bedrock	Sparsely Vegetated Till	Barren	Ice/Snow	Water	Dry Graminoid	Bare Soil with Cryptogam
Weightings	0	0	0	0	0	0	0	0	0	0	0	0	0

Small Rivers		
Weightings	-0.000584	(treated as a continuous variable)

Large Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Lakes 0-0.25 ha		
Weighting	-0.000261	(treated as a continuous variable)

Lakes 0.25-1.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Lakes 1.0-5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Lakes >5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Aspect	-1	0-45	45-135	135-225	225-315	315-360
Weightings	0	0	0	0	0	0

Slope		
Weightings	0.15513	(treated as a continuous variable)

Terrain Roughness Index	-0.001-0.063	0.063-0.126	0.126-0.189	0.189-0.252	0.252-0.33
Weightings	0	0	0	0	0

Elevation		
Weighting	-0.006242	(treated as a continuous variable)

Moisture	
Weightings	smooth scaling of 0-100 moisture ratings

Categories	Plant Spp/Guilds	Slope	Veg Cover Types	Moisture	Aspect	Terrain Roughness Index	Elevation	Lakes	Rivers
Weightings	0	0	0	0	0	0	0	0	0

Large Rivers - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0-0.25 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0.25-1.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 1.0-5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes >5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Marine - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Species	Peregrine Falcon - Foraging (original)

Plant Species/Guilds	carea	cares	cgr	drya	grass	ledu	lich	luzuc	luzun	moss	oxyt	rock	salix	saxi	vacc
Weightings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Vegetation Cover Types	Unknown	Tussock Graminoid Tundra	Wet Sedge	Prostrate Dwarf Shrub	Wetlands	Moist to Dry Non-Tussock	Sparsely Vegetated Bedrock	Sparsely Vegetated Till	Barren	Ice/Snow	Water	Dry Graminoid	Bare Soil with Cryptogam
Weightings	0	70	50	0	40	70	0	0	10	0	50	70	0

Small Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	70	50	50

Large Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	70	50	50

Lakes 0-0.25 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	70	50	50

Lakes 0.25-1.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	70	50	50

Lakes 1.0-5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	70	50	50

Lakes >5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	80	80	70	50	50

Aspect	-1	0-45	45-135	135-225	225-315	315-360
Weightings	0	0	0	0	0	0

Slope	0-0.01	0.01-0.1	0.1-0.4	0.4-1
Weightings	100	100	0	0

Terrain Roughness Index	-0.001-0.063	0.063-0.126	0.126-0.189	0.189-0.252	0.252-0.33
Weightings	90	80	40	0	0

Elevation	-140-166	166-332	332-498	498-665	665-1500
Weightings	80	80	20	0	0

Moisture	smooth scaling of 0-100 moisture ratings (not rated)
Weightings	

Categories	Plant Spp/Guilds	Slope	Veg Cover Types	Moisture	Aspect	Terrain Roughness Index	Elevation	Lakes	Rivers
Weightings	100	50	100	0	0	0	50	50	0

Large Rivers - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0-0.25 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0.25-1.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 1.0-5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes >5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Marine - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Species	Peregrine Falcon - Foraging (revised)

Plant Species/Guilds	carea	cares	cgr	drya	grass	ledu	lich	luzuc	luzun	moss	oxyt	rock	salix	saxi	vacc
Weightings	0	0	0	100	0	0	100	0	0	100	100	0	0	0	0

Vegetation Cover Types	Unknown	Tussock Graminoid Tundra	Wet Sedge	Prostrate Dwarf Shrub	Wetlands	Moist to Dry Non-Tussock	Sparsely Vegetated Bedrock	Sparsely Vegetated Till	Barren	Ice/Snow	Water	Dry Graminoid	Bare Soil with Cryptogam
Weightings	0	70	50	0	40	70	0	0	10	0	50	70	0

Small Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Large Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Lakes 0-0.25 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	0	100	70	30	10

Lakes 0.25-1.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	0	100	70	30	10

Lakes 1.0-5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Lakes >5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	0	0	0	0	0

Aspect	-1	0-45	45-135	135-225	225-315	315-360
Weightings	0	0	0	0	0	0

Slope	0-0.01	0.01-0.1	0.1-0.4	0.4-1
Weightings	20	60	100	100

Terrain Roughness Index	-0.001-0.063	0.063-0.126	0.126-0.189	0.189-0.252	0.252-0.33
Weightings	0	0	0	0	0

Elevation	-140-166	166-332	332-498	498-665	665-1500
Weightings	100	80	20	0	0

Moisture	
Weightings	smooth scaling of 0-100 moisture ratings

Categories	Plant Spp/Guilds	Slope	Veg Cover Types	Moisture	Aspect	Terrain Roughness Index	Elevation	Lakes	Rivers
Weightings	100	50	100	0	0	0	50	50	0

Large Rivers - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0-0.25 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 0.25-1.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes 1.0-5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Lakes >5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Marine - Dist from Shore	-1-200	200-500	500-120000
Weightings	0	0	0

Species	Red-throated Loons

Plant Species/Guilds	carea	cares	cgr	drya	grass	ledu	lich	luzuc	luzun	moss	oxyt	rock	salix	saxi	vacc
Weightings	20	20	30	20	20	20	0	10	10	85	5	0	80	5	25

Vegetation Cover Types	Unknown	Tussock Graminoid Tundra	Wet Sedge	Prostrate Dwarf Shrub	Wetlands	Moist to Dry Non-Tussock	Sparsely Vegetated Bedrock	Sparsely Vegetated Till	Barren	Ice/Snow	Water	Dry Graminoid	Bare Soil with Cryptogam
Weightings	0	60	80	50	100	60	0	0	0	0	100	60	0

Small Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	50	50	45	40	35

Large Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	50	50	45	40	35

Lakes 0-0.25 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	10	5	0

Lakes 0.25-1.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	10	5	0

Lakes 1.0-5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	10	5	0

Lakes >5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	10	5	0

Aspect	-1	0-45	45-135	135-225	225-315	315-360
Weightings	1	1	1	1	1	1

Slope	0-0.01	0.01-0.1	0.1-0.4	0.4-1
Weightings	100	0	0	0

Terrain Roughness Index	-0.001-0.063	0.063-0.126	0.126-0.189	0.189-0.252	0.252-0.33
Weightings	80	0	0	0	0

Elevation	-140-166	166-332	332-498	498-665	665-1500
Weightings	80	20	10	10	10

Moisture	
Weightings	smooth scaling of 0-100 moisture ratings

Categories	Plant Spp/Guilds	Slope	Veg Cover Types	Moisture	Aspect	Terrain Roughness Index	Elevation	Lakes	Rivers
Weightings	80	100	100	50	0	0	0	100	50

Large Rivers - Dist from Shore	-1-200	200-500	500-120000
Weightings	30	30	30

Lakes 0-0.25 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	100	100	100

Lakes 0.25-1.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	80	80	80

Lakes 1.0-5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	60	60	60

Lakes >5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	60	60	60

Marine - Dist from Shore	-1-200	200-500	500-120000
Weightings	100	100	0

Species	Snow Goose

Plant Species/Guilds	carea	cares	cgr	drya	grass	ledu	lich	luzuc	luzun	moss	oxyt	rock	salix	saxi	vacc
Weightings	100	100	100	20	100	20	20	80	80	100	20	0	0	20	0

Vegetation Cover Types	Unknown	Tussock Graminoid Tundra	Wet Sedge	Prostrate Dwarf Shrub	Wetlands	Moist to Dry Non-Tussock	Sparsely Vegetated Bedrock	Sparsely Vegetated Till	Barren	Ice/Snow	Water	Dry Graminoid	Bare Soil with Cryptogam
Weightings	0	100	100	20	100	100	0	0	0	0	100	100	0

Small Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	45	45	35	25	15

Large Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	50	50	40	30	20

Lakes 0-0.25 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	90	60	40

Lakes 0.25-1.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	90	60	40

Lakes 1.0-5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	90	60	40

Lakes >5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	90	60	40

Aspect	-1	0-45	45-135	135-225	225-315	315-360
Weightings	1	1	1	1	1	1

Slope	0-0.01	0.01-0.1	0.1-0.4	0.4-1
Weightings	1	1	1	1

Terrain Roughness Index	-0.001-0.063	0.063-0.126	0.126-0.189	0.189-0.252	0.252-0.33
Weightings	80	80	50	0	0

Elevation	-140-166	166-332	332-498	498-665	665-1500
Weightings	1	1	1	1	1

Moisture	
Weightings	smooth scaling of 0-100 moisture ratings

Categories	Plant Spp/Guilds	Slope	Veg Cover Types	Moisture	Aspect	Terrain Roughness Index	Elevation	Lakes	Rivers
Weightings	40	0	80	100	0	0	0	100	50

Large Rivers - Dist from Shore	-1 - 50	-1-200	200-500	500-120000
Weightings	50	50	50	50

Lakes 0-0.25 ha - Dist from Shore	-1 - 50	-1-200	200-500	500-120000
Weightings	100	100	100	100

Lakes 0.25-1.0 ha - Dist from Shore	-1 - 50	-1-200	200-500	500-120000
Weightings	100	100	100	100

Lakes 1.0-5.0 ha - Dist from Shore	-1 - 50	-1-200	200-500	500-120000
Weightings	100	100	100	100

Lakes >5.0 ha - Dist from Shore	-1 - 50	-1-200	200-500	500-120000
Weightings	100	100	100	100

Marine - Dist from Shore	-1 - 50	-1-200	200-500	500-120000
Weightings	100	100	50	10

Species	Eider

Plant Species/Guilds	carea	cares	cgr	drya	grass	ledu	lich	luzuc	luzun	moss	oxyt	rock	salix	saxi	vacc
Weightings	20	20	10	0	20	0	0	0	0	20	40	0	20	40	40

Vegetation Cover Types	Unknown	Tussock Graminoid Tundra	Wet Sedge	Prostrate Dwarf Shrub	Wetlands	Moist to Dry Non-Tussock	Sparsely Vegetated Bedrock	Sparsely Vegetated Till	Barren	Ice/Snow	Water	Dry Graminoid	Bare Soil with Cryptogam
Weightings	0	20	100	10	100	10	0	0	0	0	100	0	0

Small Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	50	50	20	10	0

Large Rivers	0-1	1-50	50-100	100-150	150-140000
Weightings	50	50	20	10	0

Lakes 0-0.25 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	70	10	0

Lakes 0.25-1.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	70	20	0

Lakes 1.0-5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	70	30	0

Lakes >5.0 ha	0-1	1-50	50-100	100-150	150-140000
Weightings	100	100	70	30	0

Aspect	-1	0-45	45-135	135-225	225-315	315-360
Weightings	1	1	1	1	1	1

Slope	0-0.01	0.01-0.1	0.1-0.4	0.4-1
Weightings	100	100	0	0

Terrain Roughness Index	-0.001-0.063	0.063-0.126	0.126-0.189	0.189-0.252	0.252-0.33
Weightings	60	70	90	70	0

Elevation	-140-166	166-332	332-498	498-665	665-1500
Weightings	100	100	40	0	0

Moisture	
Weightings	smooth scaling of 0-100 moisture ratings

Categories	Plant Spp/Guilds	Slope	Veg Cover Types	Moisture	Aspect	Terrain Roughness Index	Elevation	Lakes	Rivers
Weightings	70	30	90	100	0	30	20	100	30

Large Rivers - Dist from Shore	-1-200	200-500	500-120000
Weightings	25	25	25

Lakes 0-0.25 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	30	30	30

Lakes 0.25-1.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	50	50	50

Lakes 1.0-5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	100	100	100

Lakes >5.0 ha - Dist from Shore	-1-200	200-500	500-120000
Weightings	100	50	20

Marine - Dist from Shore	-1-200	200-500	500-120000
Weightings	100	50	20

APPENDIX B

RESULTS OF THE BINARY LOGISTIC REGRESSION RELATING HABITAT VARIABLES TO PEREGRINE FALCON FORAGING LOCATIONS

(Pages B-1 to B-2)

Results of the Binary Logistic Regression Relating Habitat Variables to Peregrine Falcon Foraging Locations (using MINITAB, Release 13, Minitab Inc., 2000; probabilities >/= .10 are highlighted)

Response Information

Variable	Value	Count	
PresAbs	1	268	(Event)
	0	269	
	Total	537	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-2.462	3.808	-0.65	0.518			
Aspect	-0.000300	0.001314	-0.23	0.819	1.00	1.00	1.00
Elevatio	-0.005757	0.001567	-3.67	0.000	0.99	0.99	1.00
DistLk1	-2.351E-04	0.00006834	-3.44	0.001	1.00	1.00	1.00
DistLk2	-0.0003844	0.0002141	-1.80	0.073	1.00	1.00	1.00
DistLk3	0.0002926	0.0002118	1.38	0.167	1.00	1.00	1.00
DistLk4	-0.0000868	0.0001055	-0.82	0.411	1.00	1.00	1.00
Moist	-0.03184	0.01984	-1.61	0.108	0.97	0.93	1.01
DistLgRi	-1.614E-06	0.00003356	-0.05	0.962	1.00	1.00	1.00
DistSmRi	-0.0003529	0.0003673	-0.96	0.337	1.00	1.00	1.00
Rough	286.5	211.0	1.36	0.174	*	0.00	*
Slope	0.16882	0.03089	5.47	0.000	1.18	1.11	1.26
SolRad	0.00001573	0.00001740	0.90	0.366	1.00	1.00	1.00
CarexA	-0.5861	0.3187	-1.84	0.066	0.56	0.30	1.04
CarexS	-0.0059	0.2522	-0.02	0.981	0.99	0.61	1.63
Dryas	0.07687	0.03762	2.04	0.041	1.08	1.00	1.16
Grass	0.01007	0.04222	0.24	0.812	1.01	0.93	1.10
Ledu	-0.01735	0.07854	-0.22	0.825	0.98	0.84	1.15
Lichen	0.3070	0.1029	2.98	0.003	1.36	1.11	1.66
LuzuC	0.1593	0.2787	0.57	0.568	1.17	0.68	2.03
LuzuN	0.0670	0.1081	0.62	0.535	1.07	0.87	1.32
Moss	0.08759	0.04017	2.18	0.029	1.09	1.01	1.18
Oxy	0.25676	0.09787	2.62	0.009	1.29	1.07	1.57
RockLich	-0.08738	0.08628	-1.01	0.311	0.92	0.77	1.09
Salix	-0.03614	0.03508	-1.03	0.303	0.96	0.90	1.03
Saxifrag	-0.4479	0.2178	-2.06	0.040	0.64	0.42	0.98
Vaccin	0.00448	0.01874	0.24	0.811	1.00	0.97	1.04
CottGras	-0.00074	0.09988	-0.01	0.994	1.00	0.82	1.22

Log-Likelihood = -230.711
Test that all slopes are zero: G = 283.015, DF = 27, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	591.550	493	0.001
Deviance	461.423	493	0.843
Hosmer-Lemeshow	16.639	8	0.034

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group										
Value	1	2	3	4	5	6	7	8	9	10	Total
1											
Obs	1	3	6	12	31	41	35	40	47	52	268
Exp	0.5	3.8	10.2	16.8	24.6	31.5	36.5	42.7	48.8	52.6	
0											
Obs	52	51	48	41	23	14	18	13	7	2	269
Exp	52.5	50.2	43.8	36.2	29.4	23.5	16.5	10.3	5.2	1.4	
Total	53	54	54	53	54	55	53	53	54	54	537

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	63587	88.2%	Somers' D	0.77
Discordant	8419	11.7%	Goodman-Kruskal Gamma	0.77
Ties	86	0.1%	Kendall's Tau-a	0.38
Total	72092	100.0%		

Knight Piésold
CONSULTING

APPENDIX C

RESULTS OF THE BINARY LOGISTIC REGRESSION RELATING HABITAT VARIABLES TO PEREGRINE FALCON NEST LOCATIONS

(Pages C-1 to C-2)

NB10-00584
November 22, 2010

Results of the Binary Logistic Regression Relating Habitat Variables to Peregrine Falcon Nest Locations (using MINITAB, Release 13, Minitab Inc., 2000; Probabilities >/= .10 are highlighted)

Response Information

Variable	Value	Count	
PresAbs	1	268	(Event)
	0	268	
	Total	536	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	95% CI Upper
Constant	-5.426	3.695	-1.47	0.142			
Aspect	0.000243	0.001273	0.19	0.849	1.00	1.00	1.00
Elev	-0.006242	0.001547	-4.03	0.000	0.99	0.99	1.00
DistLk1	-2.616E-04	0.00006503	-4.02	0.000	1.00	1.00	1.00
DistLk2	-0.0002503	0.0001984	-1.26	0.207	1.00	1.00	1.00
DistLk3	0.0002520	0.0001927	1.31	0.191	1.00	1.00	1.00
DistLk4	-0.0001419	0.0001050	-1.35	0.177	1.00	1.00	1.00
Moist	0.02544	0.02139	1.19	0.234	1.03	0.98	1.07
DistLgRv	0.00001982	0.00003102	0.64	0.523	1.00	1.00	1.00
DistSmRi	-0.0005842	0.0003506	-1.67	0.096	1.00	1.00	1.00
Rough	45.6	164.6	0.28	0.782	6.24E+19	0.00	*
Slope	0.15513	0.03717	4.17	0.000	1.17	1.09	1.26
SolRad	0.00002561	0.00001731	1.48	0.139	1.00	1.00	1.00
CarexA	-0.8555	0.3301	-2.59	0.010	0.43	0.22	0.81
CarexS	0.2550	0.2566	0.99	0.320	1.29	0.78	2.13
Dryas	0.05735	0.03546	1.62	0.106	1.06	0.99	1.14
Grass	-0.01363	0.03836	-0.36	0.722	0.99	0.92	1.06
Ledu	0.04673	0.05967	0.78	0.434	1.05	0.93	1.18
Lichen	0.2414	0.1016	2.38	0.017	1.27	1.04	1.55
LuzuC	-0.4136	0.2996	-1.38	0.167	0.66	0.37	1.19
LuzuN	0.0177	0.1045	0.17	0.866	1.02	0.83	1.25
Moss	0.05693	0.04497	1.27	0.206	1.06	0.97	1.16
Oxy	0.07632	0.09743	0.78	0.433	1.08	0.89	1.31
Salix	-0.07683	0.03680	-2.09	0.037	0.93	0.86	1.00
Saxifrag	-0.1600	0.1938	-0.83	0.409	0.85	0.58	1.25
Vaccin	-0.01325	0.01623	-0.82	0.414	0.99	0.96	1.02
CottGras	0.1279	0.1018	1.26	0.209	1.14	0.93	1.39

Log-Likelihood = -259.439
Test that all slopes are zero: G = 224.176, DF = 26, P-Value = 0.000

Goodness-of-Fit Tests

Method	Chi-Square	DF	P
Pearson	562.121	469	0.002
Deviance	518.878	469	0.055
Hosmer-Lemeshow	10.475	8	0.233

Table of Observed and Expected Frequencies:
(See Hosmer-Lemeshow Test for the Pearson Chi-Square Statistic)

	Group										
Value	1	2	3	4	5	6	7	8	9	10	Total
1											
Obs	0	5	14	18	24	33	43	42	42	47	268
Exp	1.1	5.5	12.1	20.4	26.6	31.4	35.4	41.4	44.9	49.2	
0											
Obs	53	49	39	36	30	21	10	13	12	5	268
Exp	51.9	48.5	40.9	33.6	27.4	22.6	17.6	13.6	9.1	2.8	
Total	53	54	53	54	54	54	53	55	54	52	536

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	60626	84.4%	Somers' D	0.69
Discordant	11064	15.4%	Goodman-Kruskal Gamma	0.69
Ties	134	0.2%	Kendall's Tau-a	0.35
Total	71824	100.0%		