Appendix V5-6L

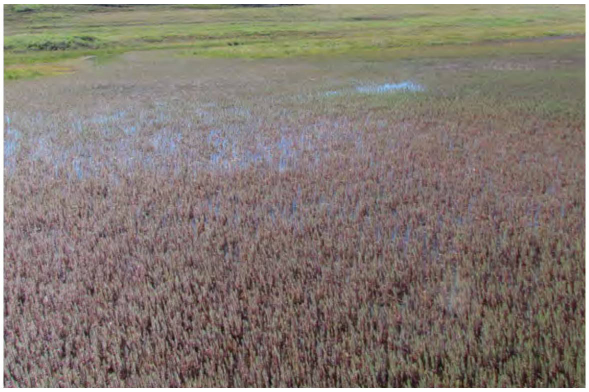
Doris North Project: 2013 Windy Lake Shoal Compliance Monitoring Report

TMAC RESOURCES

TMAC Resources Inc.

DORIS NORTH PROJECT
2013 Windy Lake Shoal Compliance Monitoring Report



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DORIS NORTH PROJECT

2013 WINDY LAKE SHOAL COMPLIANCE MONITORING REPORT

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Prepared for:

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Executive Summary

Executive Summary

The Doris North Project (the Project) is located within the Hope Bay Belt, an 80 by 20 kilometre property located along the south shore of Melville Sound in Nunavut. The property consists of a greenstone belt (the Hope Bay Belt) that contains three main gold deposits. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is at the southern end. The Project is located approximately 125 km southwest of Cambridge Bay on the southern shore of Melville Sound. The nearest communities are Umingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

TMAC Resources Inc. (TMAC) acquired the Hope Bay Belt Project from Newmont Corporation in March 2013. The acquisition included exploration and mineral rights over the Hope Bay Belt, including the Doris North Gold Mine and its permits, licences and authorizations for development received by previous owners. In late 2012, prior to the sale, the Hope Bay Belt Project was placed into care and maintenance, and the project was seasonally closed during the winter of 2012/2013. TMAC re-opened the Doris North Camp in March of 2013 for the purposes of conducting site water management, environmental compliance programs and to support exploration activities. The Doris North Project remains in care and maintenance although it will not be seasonally closed for the winter of 2013/2014.

The following compliance requirements for fish and fish habitat monitoring applicable to the Department of Fisheries and Oceans Fisheries Authorization (NU-02-0117.3) and the No Net Loss Plan approved under this authorization are as follows:

- to visually assess the stability of Compensation Shoals in Windy Lake; and
- to assess the successful utilization of Compensation Shoals relative to Natural Shoal reference sites and Fine Sediment reference sites during the open water season of 2013.

This report presents the results of the Windy Lake Shoal Monitoring Program following the second year after habitat construction (Year-2 post-construction) as outlined in the No Net Loss Plan (and modifications), as well as supporting information collected in 2013.

The overall objective of the Windy Lake Shoal Compliance Monitoring Program is to evaluate whether the Compensation Shoals provide quality cover and rearing habitat for juvenile Lake Trout in areas that were previously relatively featureless. In Windy Lake, there is a limited availability of shallow in-shore rearing areas with large substrate. Compensation Shoals were designed to increase the quantity and quality of juvenile Lake Trout rearing habitat by placing large rocky substrate in areas where fine sediment predominated.

Two years of post-construction monitoring indicate that the Compensation Shoals provide quality cover and rearing habitat available for rearing juvenile Lake Trout in Windy Lake. Habitat assessments show that Compensation Shoals have the greatest proportion of cover, compared to reference habitats. Compensation Shoals have been successfully colonized by periphyton and benthic macroinvertebrate communities similar to the abundances found at reference sites, which will provide forage opportunities for rearing juvenile Lake Trout. Fish capture and observation rates at all sites have been low in the two years following shoal construction and evidence of the use of Compensation Shoals by juvenile Lake Trout is limited at this time.

Acknowledgements

Acknowledgements

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Field-related logistics support was provided by TMAC, Great Slave Helicopters, Braden Burry Expediting, and Nuna Logistics.

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Glossary and Abbreviations

Glossary and Abbreviations

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

ALS	ALS Environmental Laboratories
ANOVA	Analysis of Variance
Chl *a*	Chlorophyll *a* (used as an estimate of algal biomass)
CI	95% Confidence Interval
CPUE	Catch-per-unit-effort
CS	Compensation Rock Shoal
DFO	Fisheries and Oceans Canada
ESR	Environment and Social Responsibility Department of TMAC
F	Fine Sediment Site
MMER	Metal Mining Effluent Regulations
NNLP	No Net Loss Plan
NS	Natural Rock Shoal
PCoA	Principal Coordinate Analysis (also known as Multidimensional Scaling)
QA/QC	Quality Assurance/Quality Control
ERM Rescan	ERM Consultants Canada Ltd.
SE	Standard Error
TIA	Tailings Impoundment Area
TMAC	TMAC Resources Inc.

1. Introduction

1. Introduction

1.1 PROJECT BACKGROUND

The Doris North Project (the Project) is located within the Hope Bay Belt, an 80 by 20 kilometre property located along the south shore of Melville Sound in Nunavut (Figure 1.1-1). The property consists of a greenstone belt (the Hope Bay Belt) that contains three main gold deposits. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is at the southern end. The Project is located approximately 125 km southwest of Cambridge Bay on the southern shore of Melville Sound. The nearest communities are Umingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

TMAC Resources Inc. (TMAC) acquired the Hope Bay Belt Project from Newmont Corporation in March 2013. The acquisition included exploration and mineral rights over the Hope Bay Belt, including the Doris North Gold Mine and its permits, licences and authorizations for development received by previous owners. In late 2012, prior to the sale, the Hope Bay Belt Project was placed into care and maintenance, and the project was seasonally closed during the winter of 2012/2013. TMAC re-opened the Doris North Camp in March of 2013 for the purposes of conducting site water management, environmental compliance programs and to support exploration activities. The Doris North Project remains in care and maintenance although it will not be seasonally closed for the winter of 2013/2014.

The compliance requirements for fish and fish habitat monitoring applicable to the Department of Fisheries and Oceans Fisheries Authorization (NU-02-0117.3) for the loss of fish habitat in Tail Lake and the No Net Loss Plan (NNLP) approved under this authorization are as follows:

1. Creation of a narrow channel through the Roberts Outflow boulder garden to improve access of fish, primarily Arctic Char (*Salvelinus alpinus*), to Roberts Lake to increase the productive capacity of the lake (completed in September 2012; Rescan 2012b; **addressed elsewhere**).
2. Creation of pool habitat in stream E09, a tributary to Roberts Lake, to increase the quantity and quality of nursery habitat for Arctic char (completed in July 2012; Rescan 2012b; **addressed elsewhere**).
3. Installation of four rock shoals in Windy Lake to increase the quantity and quality of juvenile Lake Trout (*Salvelinus namaycush*) rearing habitat (completed in April 2011; **addressed in the Windy Lake Shoal Monitoring Program**).

The Project's NNLP also provided a strategy to compensate for the loss of fish habitat in Tail Lake Outflow via:

1. Installation of two additional rock shoals in Windy Lake to further increase the quantity and quality of juvenile Lake Trout rearing habitat (completed in April 2011; **addressed in the Windy Lake Shoal Monitoring Program**).

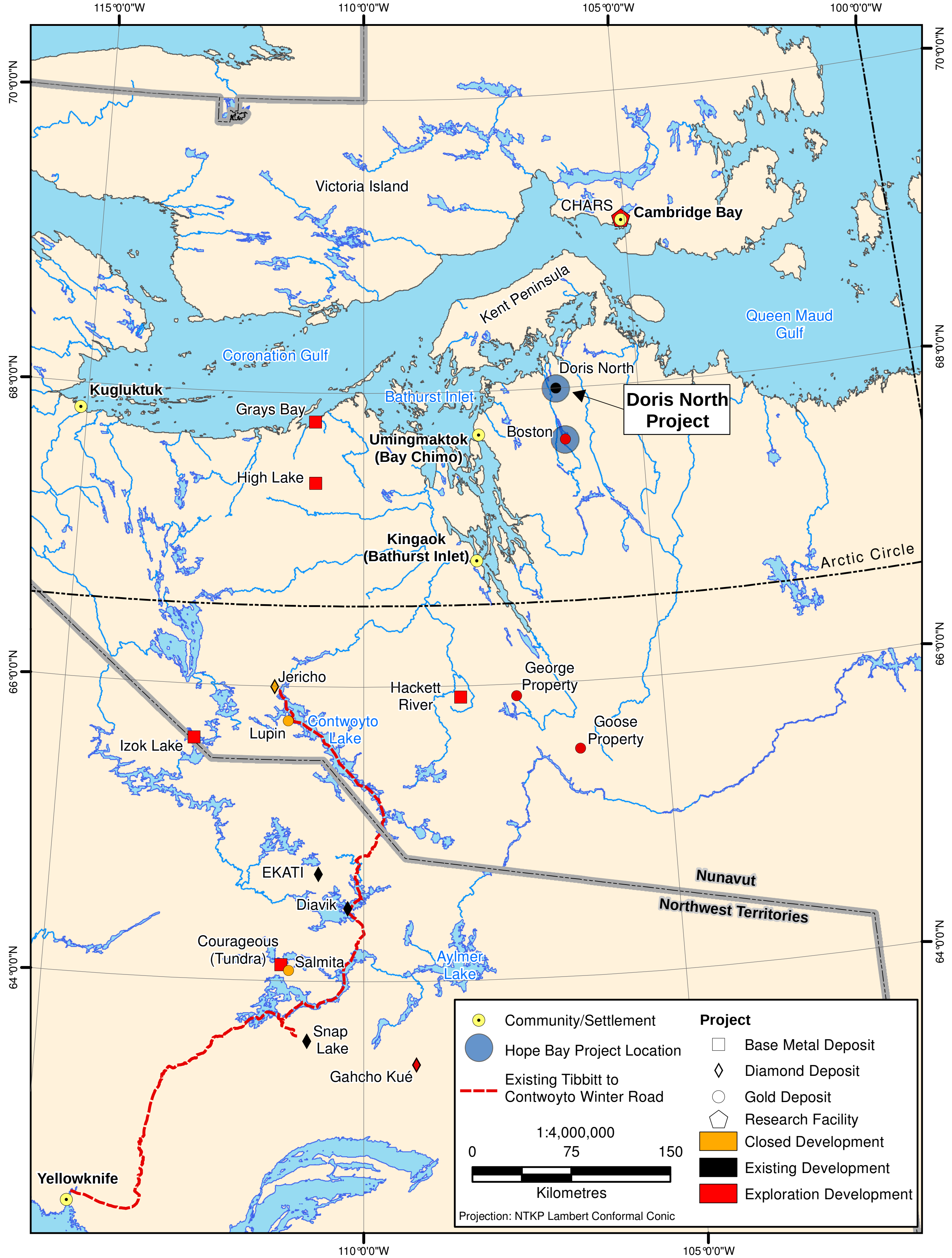

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Figure 1.1-1

Doris North Project Location

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The general goal of the No Net Loss principle is to balance habitat degradation or loss due to activities arising from economic development with the enhancement of existing habitat or the establishment of new habitat of ecological value to one or more impacted species (DFO 1986). To compensate for the loss of fish habitat caused by the construction of the Tailings Impoundment Area (TIA) in Tail Lake and Tail Lake Outflow, a total of six rock shoals were installed in Windy Lake in April of 2011 (Rescan 2011). Tail Lake was placed on Schedule 2 of the *Metal Mining Effluent Regulations* (MMER) on January 19, 2008. An approved *No Net Loss Plan* (Golder 2007), along with updates (Rescan 2010a, 2010b), exists for the loss of Tail Lake, and Fisheries and Oceans Canada (DFO) issued a Fisheries Authorization under the *Fisheries Act* (1985) for the loss of Tail Outflow on January 19, 2011 (DFO File No: 02-HCAA-CA7-000-000117, Authorization No: NU-02-0117.3). A fish-out was completed in Tail Lake in July-September, 2011 (Rescan 2012a), and the north dam, located across the upper section of Tail Outflow, was completed in 2012.

To comply with monitoring requirements under the authorization, TMAC contracted ERM Consultants Canada Inc. (ERM Rescan) to undertake monitoring activities at the site and to report on its findings. Selection of the six Windy Lake Compensation Shoal sites was based on the presence of a shallow water shelf at approximately three meters depth consisting of predominantly fine sediments. The surface areas of the designed shoals ranged from 621 to 1,040 m^2, providing a total of 4,789 m^2 of rocky habitat. Shoals were created using clean, well-graded shot rock (150—300 cm diameter), and shoal design restricted the vertical profile of each shoal to pile heights of no more than 1.5 m above the pre-existing lake floor. The resulting geometry of the new rock shoal habitat was designed to increase the amount of cover and refuge available to rearing juvenile Lake Trout, and to provide more foraging habitat for adults of this species.

This report presents the results following the second year of the Windy Lake Shoal Monitoring Program, which was set out in the Project's No Net Loss Plan and its modifications (Golder 2007; Rescan 2010a, 2010b).

1.2 OBJECTIVES

The objective of the Windy Lake Shoal Compliance Monitoring Program is to evaluate whether the Compensation Shoals are providing quality cover and rearing habitat for juvenile Lake Trout in areas that were previously relatively featureless. A control-impact study design was used and the following three specific tasks were set out to meet the overall objective of the monitoring program (Rescan 2012c):

1. To visually assess the stability of the Compensation Shoals.
2. To monitor the following three habitat types twice during the open water season of 2013:
   - six compensation rock shoals (Compensation Shoal sites; CS1-CS6);
   - six reference areas with natural rock shoals (Natural Shoal sites; NS1-NS6); and
   - six reference areas with fine sediments (Fine Sediment sites; F1-F6).
3. To collect the following from the compensation and reference habitats:
   - data on fish habitat: the amount of available cover, composition of available cover, and overall substrate composition;
   - data on primary producers: periphyton biomass (indicated by the concentration of chlorophyll *a*), cell density, and taxonomic composition;
   - data on benthic macroinvertebrates: density and taxonomic composition; and

- data on the fish community: number and taxonomic identity of fish directly observed using each habitat (from snorkel surveys); species richness and number of individuals captured and catch-per-unit-effort (CPUE) per species (from minnow traps and gillnetting); biological characteristics of each species, including size distributions (length and weight), condition, and growth rate (also from minnow traps and gillnetting).

2. Methods

2. Methods

Reference sites were selected to represent two habitat types, Fine Sediments and Natural Shoals, as required by the DFO fisheries authorization (NU-02-0117.3) and the No Net Loss Plan (Golder 2007). Fine Sediment sites were included as one reference habitat type because they most closely represent the ecological state of Compensation Shoal locations prior to installation. Natural Shoals, the second reference habitat type, represent complex physical habitat mainly composed of cobble, boulder, and bedrock substrates. The Compensation Shoals were designed to mimic the physical characteristics of these natural rocky shoals in Windy Lake.

2.1 VISUAL ASSESMENT

Visual assessments were completed at each Compensation Shoal, Natural Shoal, and Fine Sediment site by snorkel survey from July 12 to 20 and September 12 to 15, 2013 (Figure 2.1-1). Over the two sampling periods, a total of one hour of snorkel surveying was employed at each site to accomplish the following:

1. Inspect the stability of Compensation Shoals.
2. Quantify the amount of cover, type of cover, and type of substrate available to aquatic species.
3. Quantify the number of benthic macroinvertebrates observed at each site.
4. Enumerate the number of fish species and individuals within species observed at each site.
5. Estimate the fork length of each observed fish.

Compensation Shoal, Natural Shoal, and Fine Sediment sites established in 2012 (Rescan 2012c) were located using a handheld GPS unit. Two snorkelers then slowly swam in a zigzag pattern across the site and back over a 15-minute period, while maintaining a separation distance of at least 3 metres between them. Owing to the inshore bathymetry, Natural Shoal and Fine Sediment sites tended to be somewhat long and narrow. When snorkelers could not swim the zigzag pattern at such sites, they instead swam parallel to shore, following the depth contours, across the site and back for 15 minutes while maintaining the minimum separation distance between them. If the entire area of the site was surveyed prior to the 15 minute limit, the snorkelers continued swimming the zigzag pattern over the site until the full time expired. Sites were approximately 750 m^2 and, in general, the entire area was passed over twice during the 15 minute interval. Total site observation time equalled 30 minutes per sampling trip for a total of one hour for each site in 2013. Substrate size and composition was estimated based on methods described by Rescource Inventory Standards Committee (2001). Snorkeler observations of the habitat characteristics listed above were initially recorded on an underwater slate board and subsequently transcribed to a field notebook. Snorkel surveys were only conducted when the lake's visibility was greater than 3 m.

2.2 BIOLOGICAL SAMPLING

2.2.1 Community Ecology

Community structure was assessed for both primary producer (periphyton) and benthic macroinvertebrate communities at Compensation Shoals, Natural Shoals, and Fine Sediment sites. This was accomplished using artificial substrate samplers that were deployed in the lake and colonized by members specific to one of these communities (Klemm et al. 1990; Kirk and Perry 1994).

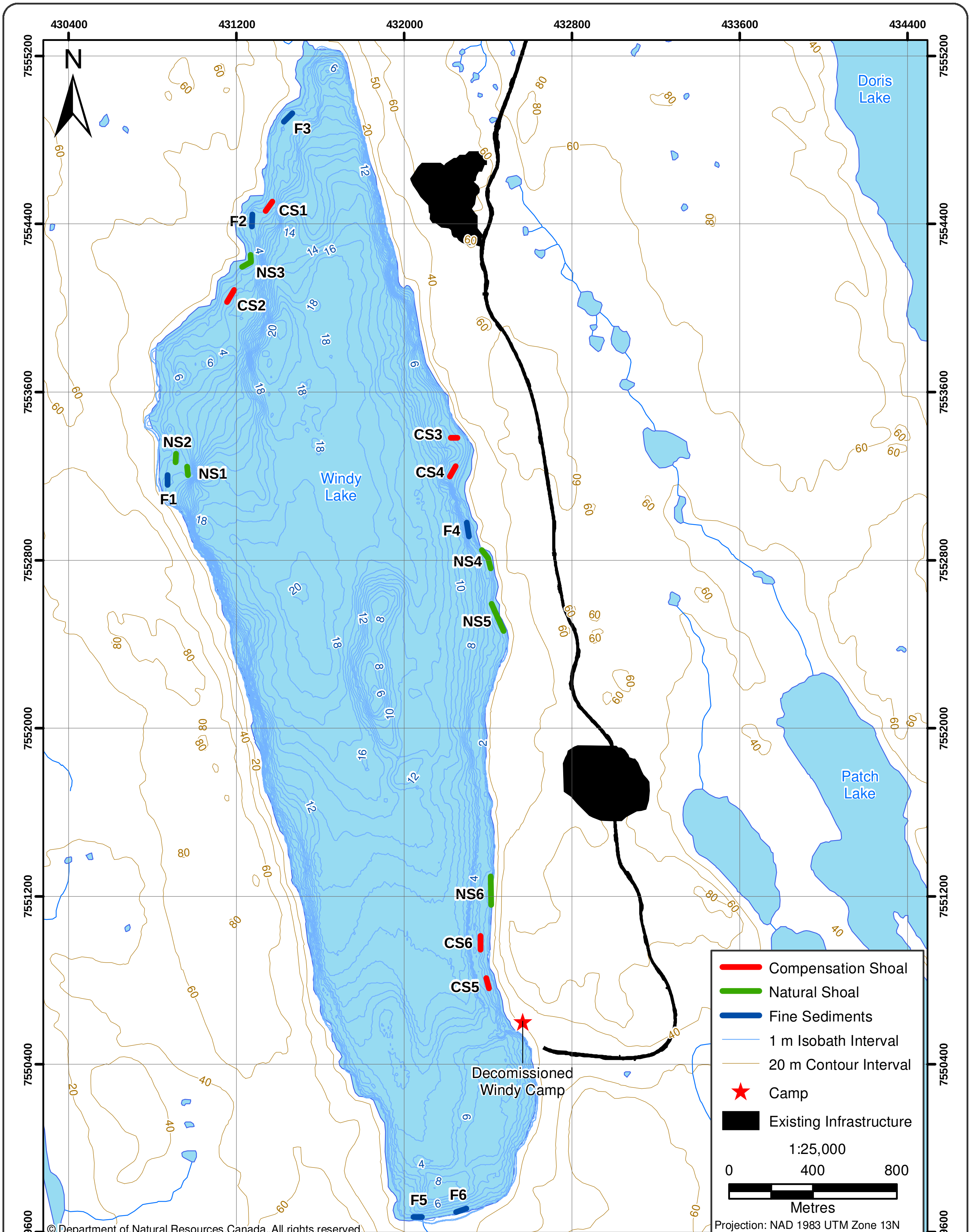


Figure 2.1-1

Windy Lake Compensation Shoal and Reference Sites, Doris North Project, 2013

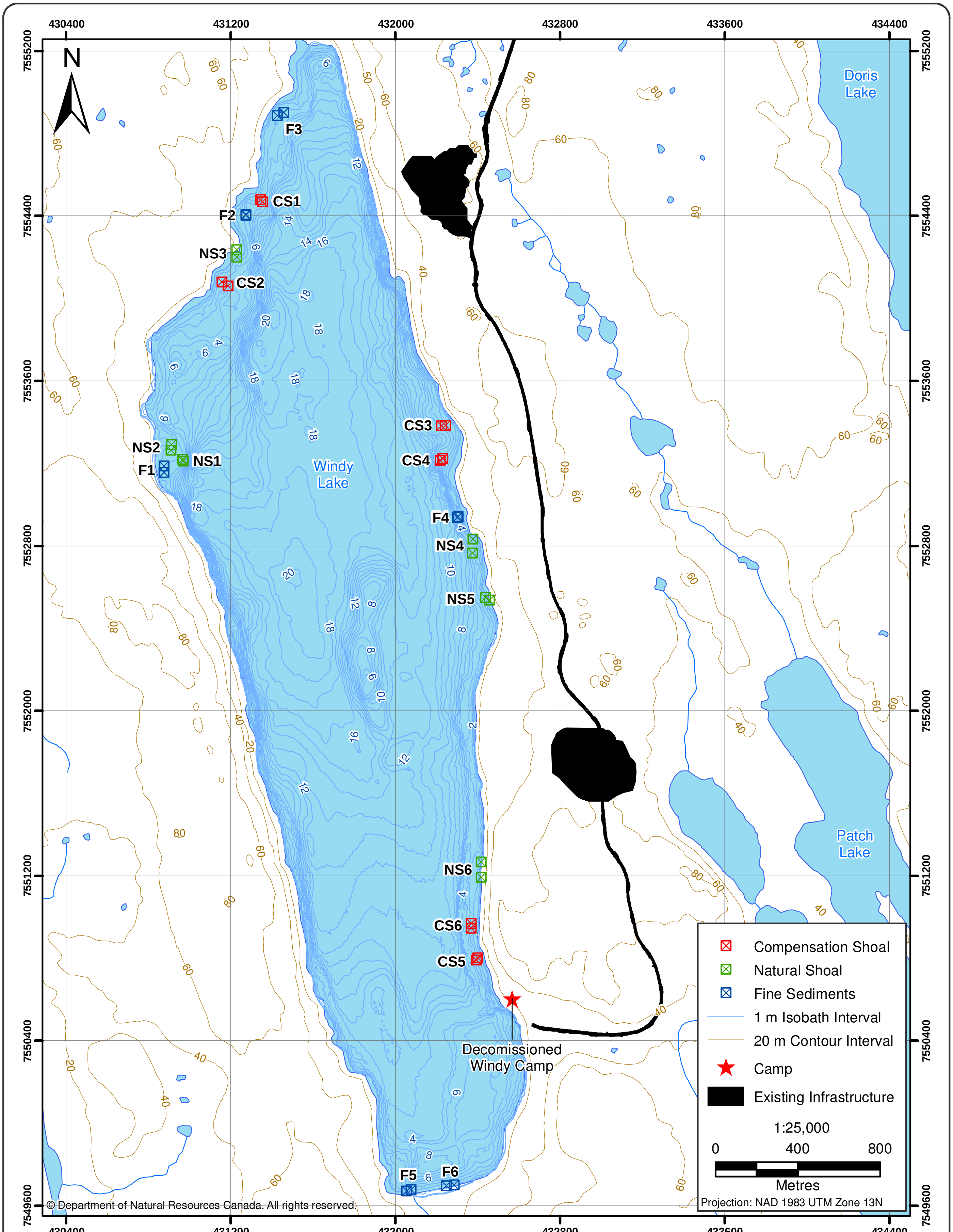
Rock trap samplers - the sole method used in 2012 to sample benthic macroinvertebrate community members - captured very few benthic macroinvertebrates overall that year. This included samplers at two sites that contained no macroinvertebrates despite being deployed for a 47-day colonization period (Rescan 2012c). Thus, in 2013 Hester Dendy macroinvertebrate samplers were added to verify if macroinvertebrate abundance was truly low, or if the results from 2012 were largely a result of the rock trap method itself.

Each rock trap sampler consisted of a steel cage, filled with 1 L of graded rock (gravel 20 to 50 mm diameter) to capture macroinvertebrates, and with two 10 cm^2 Plexiglas® plates (one attached at each end of the sampler) to serve as substrates for periphyton colonization and community growth (Plate 2.2-1). Two replicate samplers were set at each site on July 11, 2013 (Figure 2.2-1, Appendix 2.2-1). Samplers remained immersed until they were retrieved on September 13 and 14, 2013, resulting in a sample immersion time of 64-65 days.

Plate 2.2-1. Rock Trap benthic macroinvertebrate sampler deployed in Windy Lake on July 11, 2013. Two Plexiglas® plates for collecting periphyton were attached horizontally at each end.

Each Hester Dendy trap consisted of 14 circular tempered Masonite® plates, each with a diameter of 75 mm and a thickness of 3 mm thick. The plates were separated by 5 mm-thick nylon spacers along a long eye bolt, held in place by a wing nut (Plate 2.2-2). Three traps were deployed in a gang spaced at three metre intervals at each site on July 11, 2013 and retrieved between September 11 and 14, 2013 (Figure 2.2-2, Appendix 2.2-1). Sampler immersion duration ranged from 62 to 65 days.

To avoid pseudoreplication (Hurlburt 1984), the three replicate Hester Dendy traps collected at each site were combined into a single Hester Dendy sample for that site. Similarly, the two replicate Rock Traps were combined into one Rock Trap sample for each site. Therefore, effectively six Hester Dendy and six Rock Trap samples were collected from each habitat type (Compensation Shoal sites CS1-CS6, Natural Shoal sites NS1-NS6 and Fine Sediment sites F1-F6).



Periphyton and Rock Trap Sampling Locations in Windy Lake, Doris North Project, 2013

Figure 2.2-1

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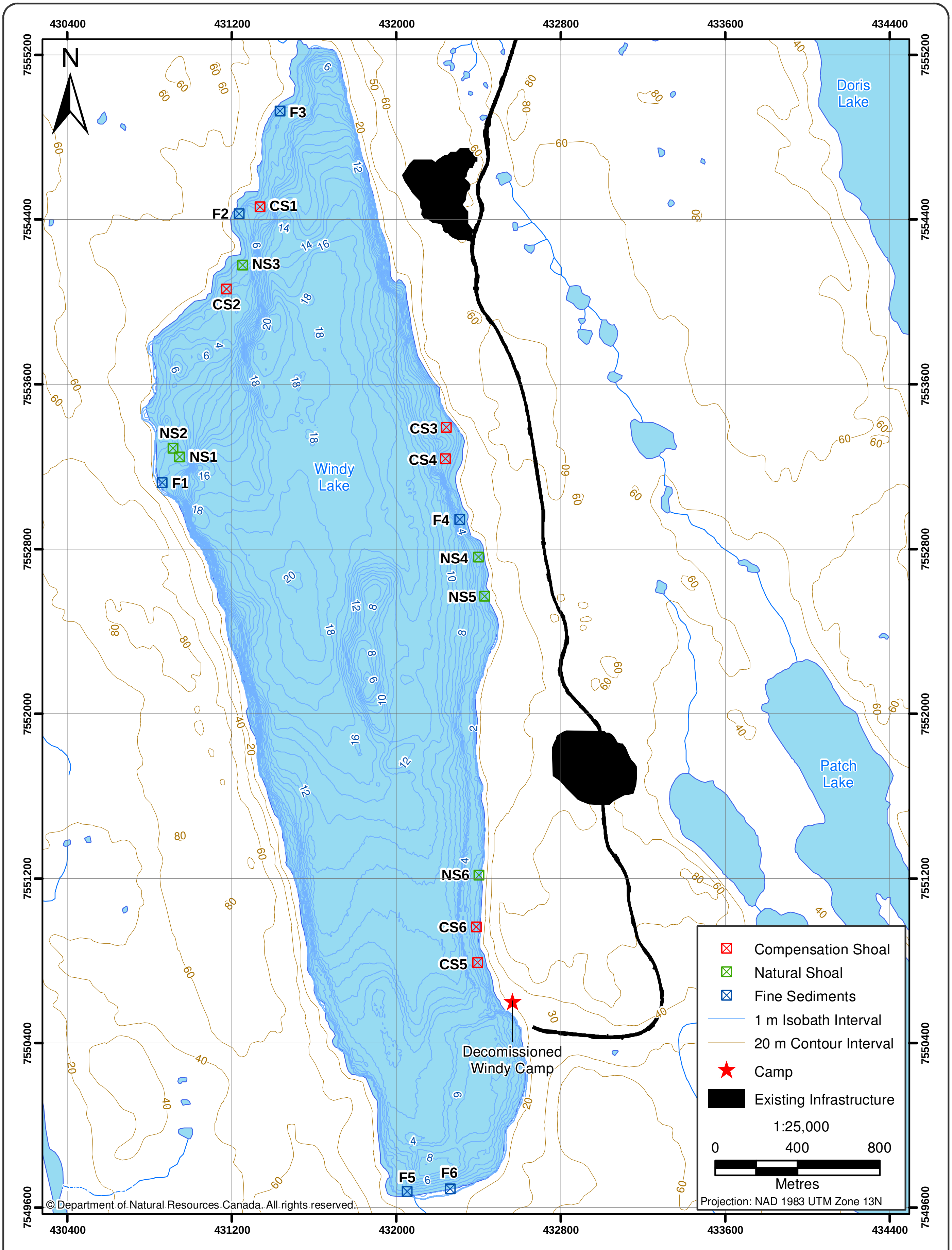

Figure 2.2-2

Hester Dendy Sampling Locations in Windy Lake, Doris North Project, 2013

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Plate 2.2-2. Hester Dendy sampler deployed in Windy Lake on July 11, 2013.

In addition to artificial substrate samplers, macroinvertebrate density was examined using incidental by-catch in minnow traps set for small-bodied fish. Three minnow traps were set for approximately 24 hours at each site during both the July and the September sampling periods. Upon retrieval, invertebrates in each trap were identified and enumerated prior to their release. Full minnow trap methods are presented in Section 2.2.2.

2.2.1.1 Primary Producers (Periphyton)

At each site four Plexiglas® periphyton plates were set; two plates were attached to each rock trap. Following retrieval, all four periphyton plates were scraped with a razor blade and rinsed into one 250 mL opaque plastic container to prevent exposure to light. This effectively pooled the periphyton on the four Plexiglas® plates per site into a single sample, reducing the variability among plates. Samples were then kept in a cool, dark place until they were processed at Doris North Camp.

At camp, samples were topped up to a standard volume with deionized water (200 ml or 400 ml, depending on initial sample volume), after which each sample was homogenized by vigorous shaking by hand and then split into two samples of equal volume. Primary producer biomass was estimated from one of these samples by measuring chlorophyll *a* concentration and periphyton taxonomy was estimated from the other sample through taxonomic counts. Each of the periphyton samples (biomass and taxonomy) represents sampling by two plates.

For measuring periphyton biomass, two aliquots were taken from the biomass sample and field-filtered through separate 0.45 μm nitrocellulose filters using a portable filter apparatus and hand-pump. Aliquot volume varied depending on the available sample volume and the concentration of the filtrate (mostly algae and sediment). Next, the two filters for each site were folded in half, wrapped together in aluminum foil, and labelled. All of these samples were frozen immediately, and were kept on ice and in darkness until analyzed by ALS Environmental Laboratories (ALS; Vancouver, BC).

ALS analyzed the chlorophyll *a* samples using standard methods (MOE 2003) with a detection limit of 0.0006 µg and a realized detection limit of 0.01 – 0.10 µg (Appendix 2.2-2).

Chlorophyll *a* in each sample was calculated as follows:

$$Total\ Chl\ \mathrm{a}\ (\mu g) = Chl\ \mathrm{a}\ in\ filters\ (\mu g)\ /\ volume\ of\ aliquot\ filtered\ (mL) * sample\ volume\ (mL)$$

Chlorophyll *a* was then standardized for the surface area of Plexiglas® plates (200 cm^2) and for the slight differences in immersion times (Appendix 2.2-2):

$$Chl\ \mathrm{a}\ (\mu g/cm^2/day) = Total\ Chl\ \mathrm{a}\ (\mu g)\ /\ surface\ area\ (cm^2)\ /\ immersion\ duration\ (day)$$

The sample taken for periphyton community composition (half the original combined periphyton sample at each site; equivalent to two periphyton plates) was retained in 250 mL opaque plastic jars, preserved with 10 to 15 drops of Lugol's iodine solution (to achieve a tea-coloured solution), and shipped to a taxonomic laboratory (EcoAnalysts Inc., Moscow, Idaho) for identification and enumeration to the lowest practical taxonomic level. Samples were processed for diatoms and soft body algae using standard EcoAnalysts protocols, which included the use of Utermöhl count chambers, magnification of 400 to 1200X, and the enumeration of a minimum of 300 algal units. Periphyton community composition was expressed as relative proportion of the community made up by an individual genus. Periphyton density (number of cells/cm^2/day) was standardized by the surface area of Plexiglas® plates and immersion time (Appendix 2.2-1).

2.2.1.2 Benthic Macroinvertebrates

Biomass and community composition of benthic macroinvertebrates were quantified using rock traps and Hester Dendy samplers (Kirk and Perry 1994; Hester and Dendy 1962). For rock traps, a 1 L sample of gravel rock was carefully raised to the water surface and transferred to a deep collection tray, after which the gravel was scrubbed by hand and rinsed to remove attached invertebrates. In the case of the Hester Dendy samplers, each sampler was dismantled and both sides of each of the 14 Masonite® plates composing the sampler were scrubbed into a tray with a nylon bristle periphyton brush. Finally, each resulting rock trap or Hester Dendy sample was transferred into a 500 µm sieve bucket and rinsed with site-specific water until free of sediments. The material retained by the sieve was placed into a 500 mL plastic jar, which was labelled accordingly, and preserved with 10% buffered formalin immediately upon our return to camp.

Invertebrate samples were sent to Zloty Environmental Research & Consulting (Summerland, BC) for enumeration and identification. Prior to laboratory-based sorting, samples were stained with Rose Bengal. Samples were completely and systematically sorted in a gridded petri dish. Sorting was accomplished using a dissecting microscope at 7 to 10X magnification. Organisms were counted and identified to the lowest practical taxonomic level (genus, where possible) using current literature and nomenclature. Microscope slide mounts were prepared for taxa which required detailed microscopic examination for identification (e.g., chironomids). The most common taxa were usually distinguishable on the basis of gross morphology, requiring only a few mounts for quality control checks. Slide mounts were made for each of the less commonly occurring taxa.

Benthic macroinvertebrate community composition was expressed as relative proportion of the community made up by an individual taxon. Taxon density (number/m^2/day) was standardized by the surface area of the sampler and by day to account for samplers immersed for slightly different time periods (Appendix 2.2-1). The surface area of rocks in each rock trap was approximately 1,715 cm^2 and the surface area of each Hester Dendy sampler (each consisting of 14 plates) was 1,600 cm^2.

2.2.2 Fish Community

Minnow traps and gill nets were used to assess fish distributions in Windy Lake. Cylindrical minnow traps (43 cm long, 23 cm in diameter, with 6.5 mm mesh) were employed to sample small-bodied adults and juvenile fish present in Windy Lake — Lake Trout, Lake Whitefish (*Coregonus clupeaformis*), Arctic Cisco (*Coregonus autumnalis*), and Ninespine Stickleback (*Pungitius pungitius*) - during July and September 2013 (Rescan 2010c). Trap entrance diameter was approximately 3 cm, so only fish with a maximum cross-sectional diameter of less than this size could enter (i.e., small-bodied fish).

For every habitat type (Compensation Shoal, Natural Shoal and Fine Sediment), three minnow traps were randomly placed directly on the substrate at each replicate site (Figures 2.2-3 and 2.2-4; Appendix 2.2-3). Traps were baited with dry commercial crab bait and immersed for approximately 24 hours before being retrieved the following day.

Despite high levels of effort, no small-bodied fish were caught in minnow traps in 2012 (Rescan 2012c). To provide more information on fish use at each habitat type, additional attempts were made to capture fish species using two gill nets sets at each site between July 19 and 21, 2013. (Figure 2.2-5; Appendix 2.2-4).

Short, small-mesh gill nets were set for brief durations to minimize the risk of incidental mortalities. Sinking gill nets 15.2 m long and 2.4 m deep with a stretched mesh size of 25 mm were set for durations between 45 min and 90 min. Nets with small mesh sizes tend to entangle fish by their teeth and fins but rarely cause gill structure damage that is common with larger mesh sizes. Note the standard gill net gangs recommended by the Resources Information Standards Committee (RISC 1997) were not used as these have a broad range of mesh sizes and they are too long for these sample sites.

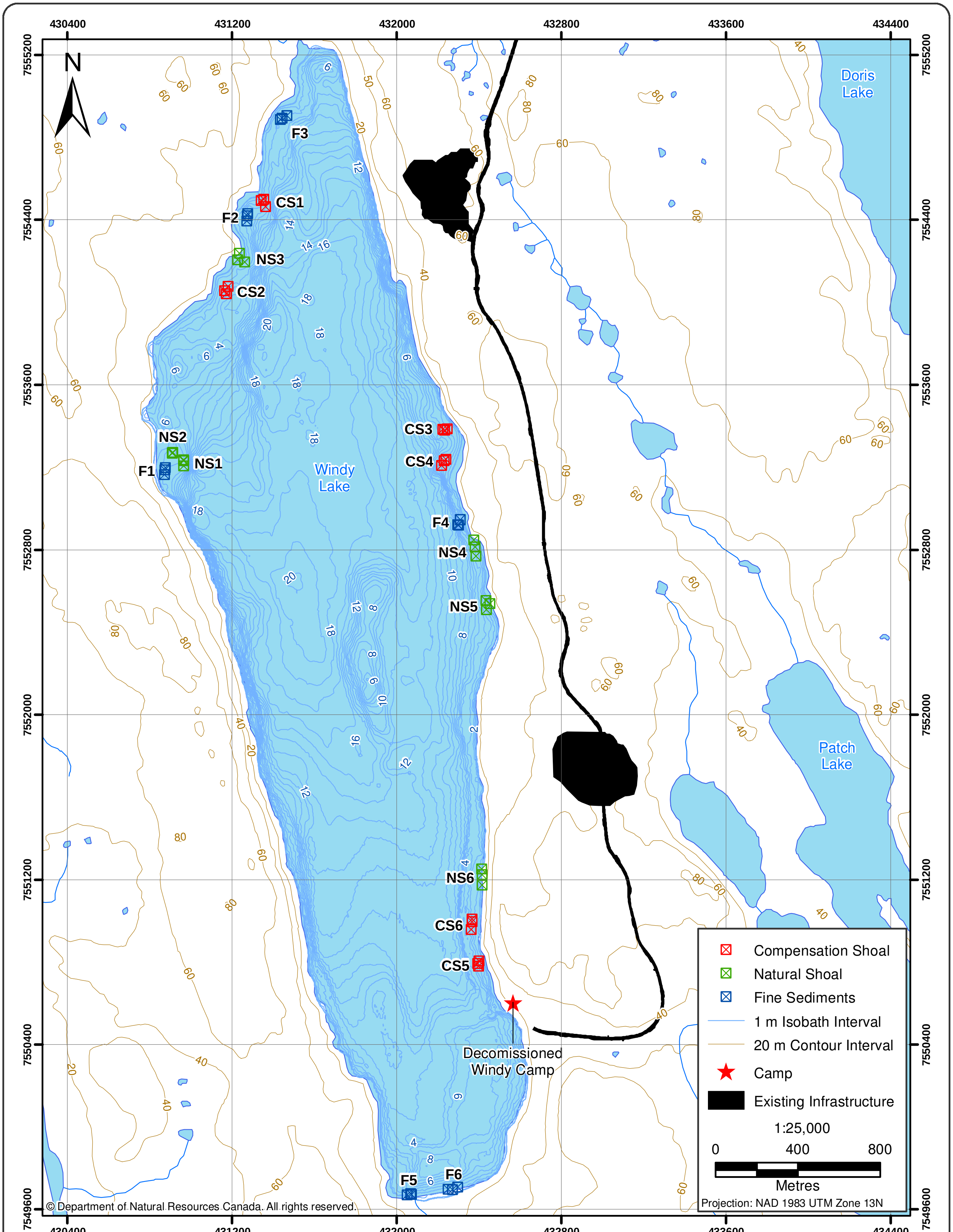
Small diameter gill net mesh may catch a broad size range of fish, as only the smallest can pass through and avoid entanglement. In Windy Lake, Lake Trout, Lake Whitefish, and Arctic Ciscoes have been historically captured in such gill nets.

Captured fish were identified to species, measured for fork length to the nearest 1 mm, and weighed to the nearest 1 g.

2.3 DATA ANALYSIS

2.3.1 Taxonomic Analysis

Density was calculated as the number of individuals (benthic macroinvertebrates) or cells (periphyton) per taxonomic unit after standardizing for the surface area and immersion time of the artificial sampler (number/area/day). Taxonomic richness and diversity were calculated from the relative abundance of each taxonomic unit. Richness is the simplest measure of biodiversity and is a total count of the number of taxa in a given area. Diversity indices are often used as a measure of overall ecosystem health, quantifying how evenly distributed different species are in terms of number of individuals, taking into account both richness and abundance. In Arctic environments, species richness and diversity are typically lower than in southern habitats (Rohde 1992) and may not be a good indicator of overall ecosystem health. For this report, these biodiversity indices are used to compare Compensation Shoals to reference sites, not as an overall indication of ecosystem heath.



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Locations of Minnow Traps Set in Windy Lake, Doris North Project, July 2013

Figure 2.2-3

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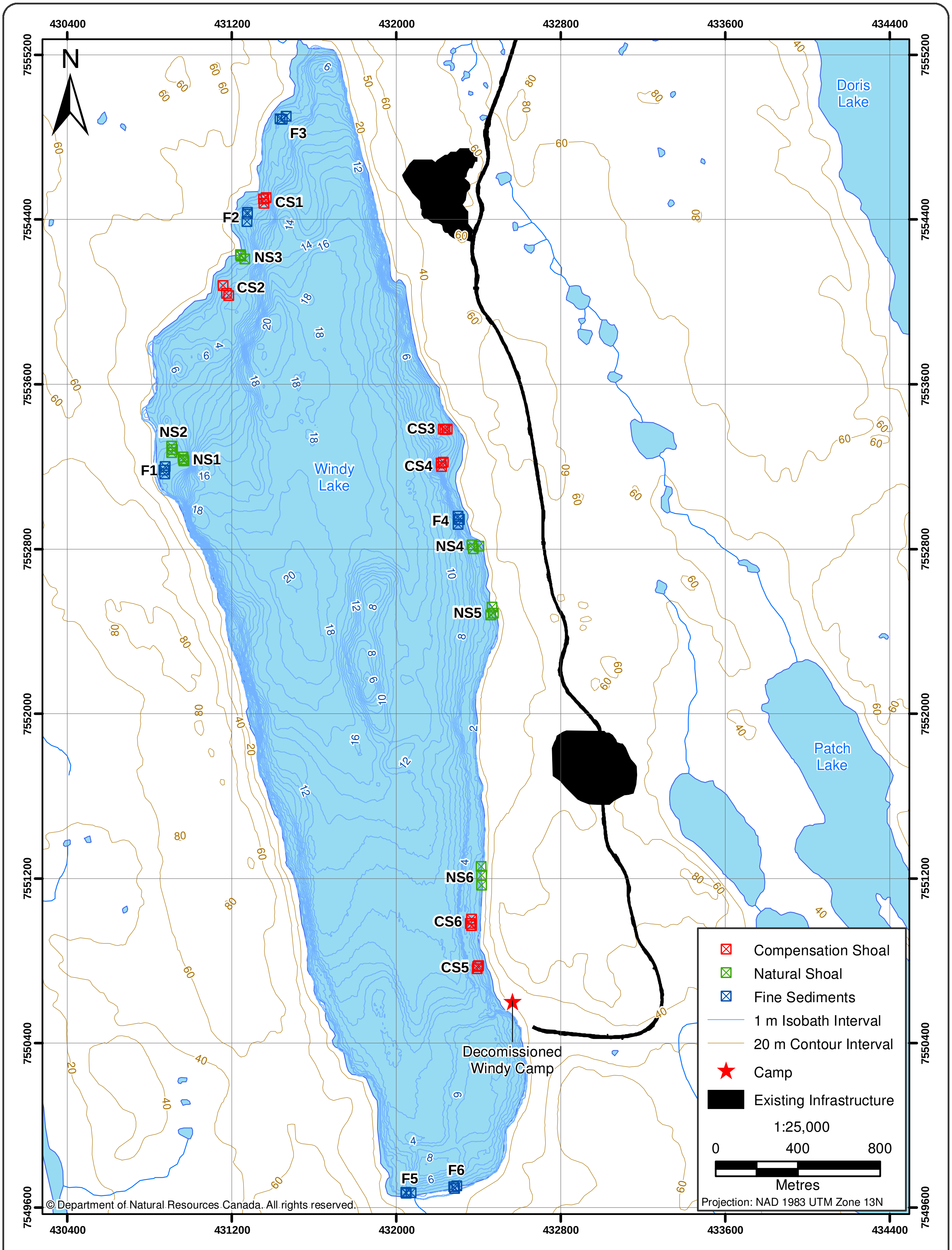

Figure 2.2-4

Locations of Minnow Traps Set in Windy Lake, Doris North Project, September 2013

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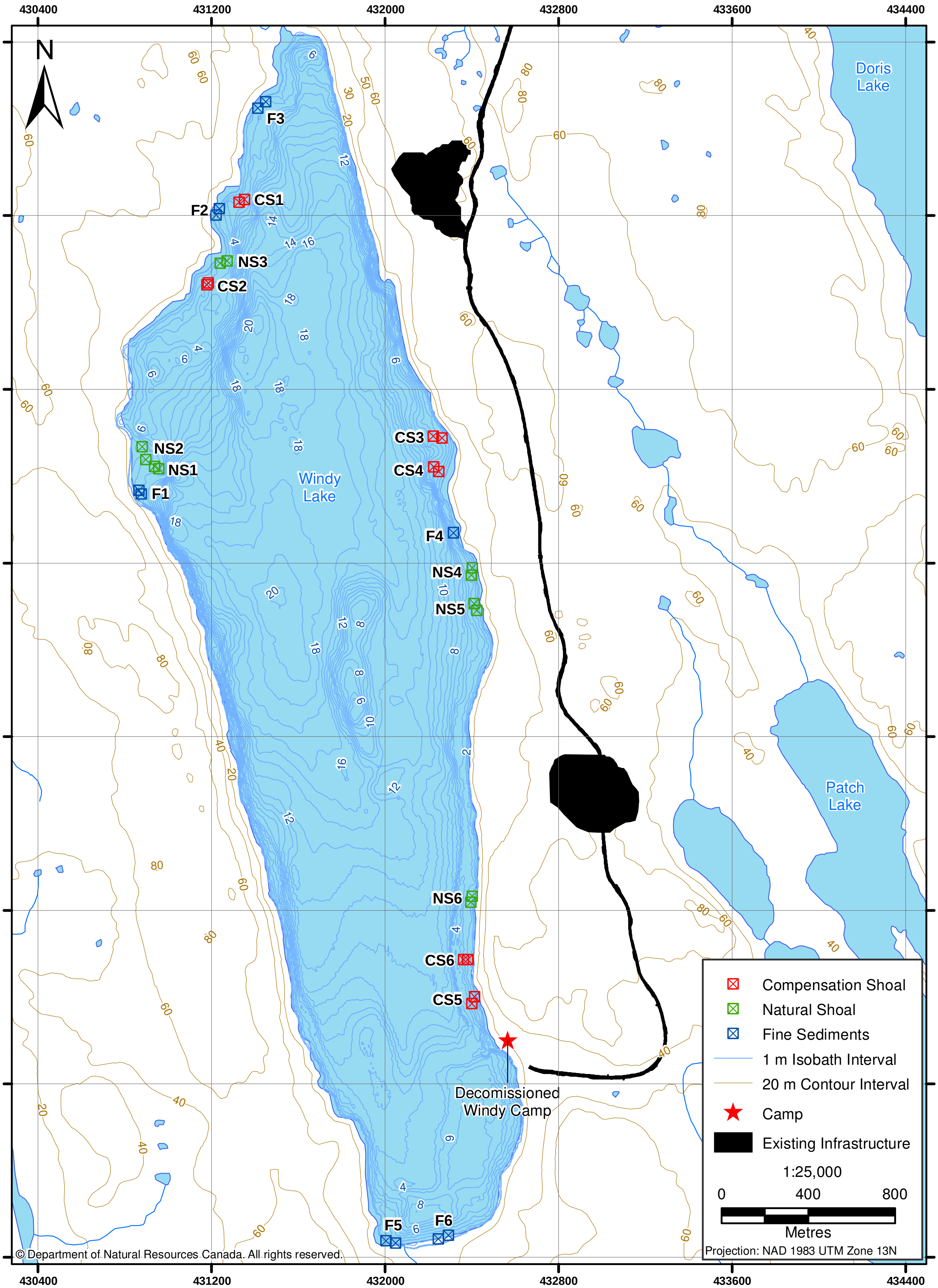

Figure 2.2-5

Locations of Gill Nets Set in Windy Lake, Doris North Project, July 2013

For the calculation of richness and diversity, taxa were grouped into their lowest unit (typically genus), and individuals from unknown taxa were excluded from the analysis. The Shannon Index, which was used as the measure of diversity for both periphyton and benthic macroinvertebrates, was calculated as follows:

$$\textit{Shannon Index } (H') = -\sum_{i=1}^{R} p_i \log p_i$$

where: p_i is the relative abundance of each taxonomic unit, calculated as n_i/N; n_i is the number of individuals in taxon i; N is the total number of all individuals sampled; and R is the total number of taxonomic units represented by all sampled individuals. Although Simpson's index of community evenness is commonly used to estimate community diversity (Begon, Harper, and Townsend 1996), the Shannon Index was employed here because of the presence of zero catch totals in the data. The calculation of Simpsons' index (1-*D*) yields an estimate of how equal the relative abundances are for each taxon in a community. Therefore, sites with zero catch totals for all taxa will result in a Simpsons' index value of 1 (i.e., all taxa have equal relative abundances). This is the highest possible Simpsons' Index value, which would erroneously suggest high diversity and a completely even taxonomic composition for sites with zero catch totals.

2.3.2 Statistical Analysis

2.3.2.1 Visual Assessment

Due to differences in depth and visibility among sites, there was a high degree of variability in the visual detection fish and benthic macroinvertebrates. Therefore, there exists uncertainty as to whether differences observed among sites are due to true differences in the number of individuals, or to differences in the ability to detect by sight. Due to the high variability, no formal statistical analysis was applied to the visual assessment data. These data were presented graphically, however, these graphs suffer from the same uncertainty and any patterns should be interpreted with caution.

2.3.2.2 Habitat

The classification of each site into habitat clusters was assessed using fuzzy c-means clustering (Borcard, Gillet and Legendre 2011). Fuzzy c-means clustering determines the strength of membership (in percentage) of any given site to each cluster. A site that is clearly linked to a given habitat cluster will show high membership percentage for that cluster and weak membership percentages for the other clusters. The expectation is that all sites from any given habitat type (only Compensation Shoal sites, only Natural Shoal sites, or only Fine Sediments sites) will cluster together.

The membership of each site to habitat groups was then visualized using Principal Coordinate Analysis (PCoA), which projected all variation in all habitat characteristics (total cover, cover type, and substrate type) onto just two PCoA Axes (Legendre and Legendre 1998), facilitating visual assessment of the overall pattern of habitat clustering. This technique also quantifies the degree to which each habitat variable distinguishes sites residing within the habitat clusters determined by the fuzzy c-means method. In other words, PCoA provided visual confirmation of the presence of distinct habitat clusters and reveals which habitat variables best distinguish the clusters.

2.3.2.3 Community Ecology

Differences in each community ecology parameter were tested among habitat types (Compensation Shoal, Natural Shoal, Fine Sediments) using one factor analysis of variance (ANOVA). The specific community ecology parameters tested were: 1) periphyton biomass (chlorophyll *a*), richness, and diversity; and 2) benthic macroinvertebrate density, richness, and diversity. Error variance for richness was modelled using a Poisson distribution. If ANOVA tests revealed significant differences among groups, pairwise multiple comparisons were performed using the False Discovery Rate (FDR) test to determine which pairs of habitat types differed significantly (Benjamini and Hochberg 1995).

Macroinvertebrates caught incidentally in minnow traps were compared among sites using catch-per-unit-effort (CPUE). Defined as the number of individuals captured per sampling device per unit time, this index of relative abundance can be used to compare populations sampled in different areas and/or years. CPUE for macroinvertebrates in minnow traps was calculated as the number of individuals captured per trap per 24 hour period.

2.3.2.4 Fish Community

Fish community composition was also characterized and compared among sites using CPUE, defined in the previous section. CPUE for gillnetting was calculated as the number of fish captured per 100 m^2 of net per hour, whereas CPUE for minnow trapping was calculated as the number of fish captured per trap per 24 hours.

To avoid pseudoreplication (Hurlburt 1984), the two replicate gill net sets retrieved at each site were combined into a single sample for that site. The gill nets were set simultaneously at each site in a relatively small area, so they were not sampling independently from each other. Similarly, the three minnow traps set at each site were combined to form one minnow trap sample for that site, as these traps also lacked complete statistical independence from each other. Where fewer than 10 sampling sets were conducted, CPUE data were bootstrapped to provide more accurate summary statistics.

2.3.2.5 Statistical Assumptions

Where appropriate, the underlying parametric assumptions of ANOVA were examined (normal distribution and equal variance among groups) using box and whisker plots and standardized residual plots. In cases where data did not meet these assumptions, appropriate data transformations were used to achieve near normality and equality of variances. All transformations are identified in the results section. In cases where the transformed data did not yield similar variances among groups or approximately normal distributions within groups, the non-parametric Kruskal-Wallis test was used in place of ANOVA, which is a parametric statistical procedure. If Kruskal-Wallis tests revealed significant differences among groups, non-parametric pairwise multiple comparisons were performed using the procedure outlined by Siegel and Castellan (1988). All statistical analyses were performed using R (R Core Team 2013).

2.3.2.6 Avoidance of Pseudoreplication

The control/impact design (Smith 2002) of the Windy Shoal Monitoring Program considered ‘site’ to be the unit of replication: six sites were replicated within each of three habitat types (Compensation Shoal, Natural Shoal, and Fine Sediment). Multiple samples collected within a single site (i.e., two rock traps, three Hester Dendy samplers, three minnow traps, or two gill nets) are considered pseudoreplicates (Hurlbert 1984) and, therefore, were either pooled within site prior to laboratory analysis, or averaged within site prior to statistical analysis.

2.4 QUALITY ASSURANCE/QUALITY CONTROL

All fish habitat and community survey results were reviewed at the end of each field day to ensure that sampling was complete and that the data were collected properly. Field notes were transcribed onto electronic spreadsheets once in the office, after which all such records were checked for accuracy against the field forms. Rare errors were corrected accordingly.

Chain of custody forms were used for periphyton samples as part of the QA/QC program. Laboratory QA/QC of periphyton taxonomic analysis included a re-count 10% of the whole community subsamples. Recounts were conducted by a second taxonomist. Percent similarity was calculated according to Washington (1984):

$$Percent\ Similarity = 100 - 0.5 \times \sum |pi1 - pi2|$$

where: *pi*1 is the proportion of the i^{th} taxon for the original taxonomist and *pi*2 is the proportion of the i^{th} taxon for the QA taxonomist. For QA/QC samples with percent similarities less than 85%, taxonomic discrepancies were to be resolved and the samples re-identified as necessary. In addition, a photographic reference collection of Project area periphyton was compiled by EcoAnalysts Inc.

For benthic macroinvertebrates, a re-sorting of randomly selected sample residues was conducted on 10% of the samples by a different technician to determine the level of sorting efficiency. The number of organisms initially recovered from the sample was expressed as a percentage of the total number after the re-sort (total of initial and re-sort count).

% sorting efficiency = [1-(# in QA/AC re-sort / (# sorted originally + # QA/QC resort))] 100*

For each sample, identified benthic macroinvertebrates were preserved with 70% isopropyl alcohol and archived in vials. All QA/QC results are found in Appendix 2.4-1.

3. Results and Discussion

3. Results and Discussion

3.1 VISUAL ASSESSMENT

The margins of each Compensation Shoal were located using the coordinates specified at their construction (Rescan 2011). No signs of instabilities, erosion or sediment accumulation were observed at any of the Compensation Shoal sites.

3.1.1 Habitat

Compensation Shoals, Natural Shoals, and Fine Sediment sites formed three distinct habitat types (Figure 3.1-1). Compensation sites had the greatest proportion of total cover, provided primarily by boulders. Natural shoals were more diverse with respect to the type of cover and had the most diverse substrate composition. As expected, Fine Sediment sites had the lowest percent cover, their substrate being predominantly fine sediment.

Cluster analysis confirmed that sites formed three distinct habitat clusters based on the habitat variables measured (Figure 3.1-2; Table 3.1-1; Appendix 3.1-1). The three clusters corresponded exactly to the three habitat types: Compensation Shoal, Natural Shoal, and Fine Sediment sites. Compensation Shoal sites clustered closely together (Cluster 1 in Figure 3.1-2) and were distinct from the other clusters by having a high proportion of total cover and a high proportion of boulders making up the substrate and cover type (Figures 3.1-1 and 3.1 2). The sites that were most similar to the Compensation Shoal sites were the Natural Shoal sites, yet the Natural Shoal sites formed a cluster with a more diverse set of habitat characteristics (Cluster 2 in Figure 3.1-2). This cluster was characterized by an intermediate amount of total cover, and a mix of cobble, gravel, and bedrock substrate (Figures 3.1-1 and 3.1-2). Fine Sediment sites were the most variable in terms of habitat characteristics, yet the sites still formed a distinct cluster in habitat (i.e., Principal Coordinate) space (Cluster 3 in Figure 3.1-2). Fine Sediment sites were characterized by having a low proportion of total cover and high proportions of fine sediments, vegetation, and small woody debris (Figures 3.1-1 and 3.1-2).

These habitat findings confirm that the physical structure and habitat characteristics of Compensation Shoals have remained as they were intended for two years following construction; they were designed to provide quality cover for fish in areas of fine sediment that previously provided little cover.

3.1.2 Observations of Benthic Macroinvertebrate and Habitat Use by Fish

Two benthic macroinvertebrate groups, isopod and mysid crustaceans, were observed occupying both Compensation and Reference habitats, whereas caddisfly larvae were observed only at Reference habitats (Figure 3.1-3). Isopods were observed in similar numbers at Natural Shoal and Fine Sediment sites; about twice as many isopods were observed at these sites compared to Compensation Shoal sites (Figure 3.1-3). Mysids were observed in similar numbers at Natural Shoal and Fine Sediment sites, but very few were observed on Compensation Shoals (Figure 3.1-3). Caddisflies were observed at two sites; one Natural Shoal site and one Fine Sediment site (Figure 3.1-3).

Benthic macroinvertebrate counts, particularly of mysids were highly variable among sites of the same habitat type. Much of this variability was likely due to differences in depth and visibility among sites, which result in a high degree of variance in the ability to visually detect small-bodied macroinvertebrates while snorkeling. As a result, any difference in observed numbers of individuals among habitat types should be interpreted with caution.

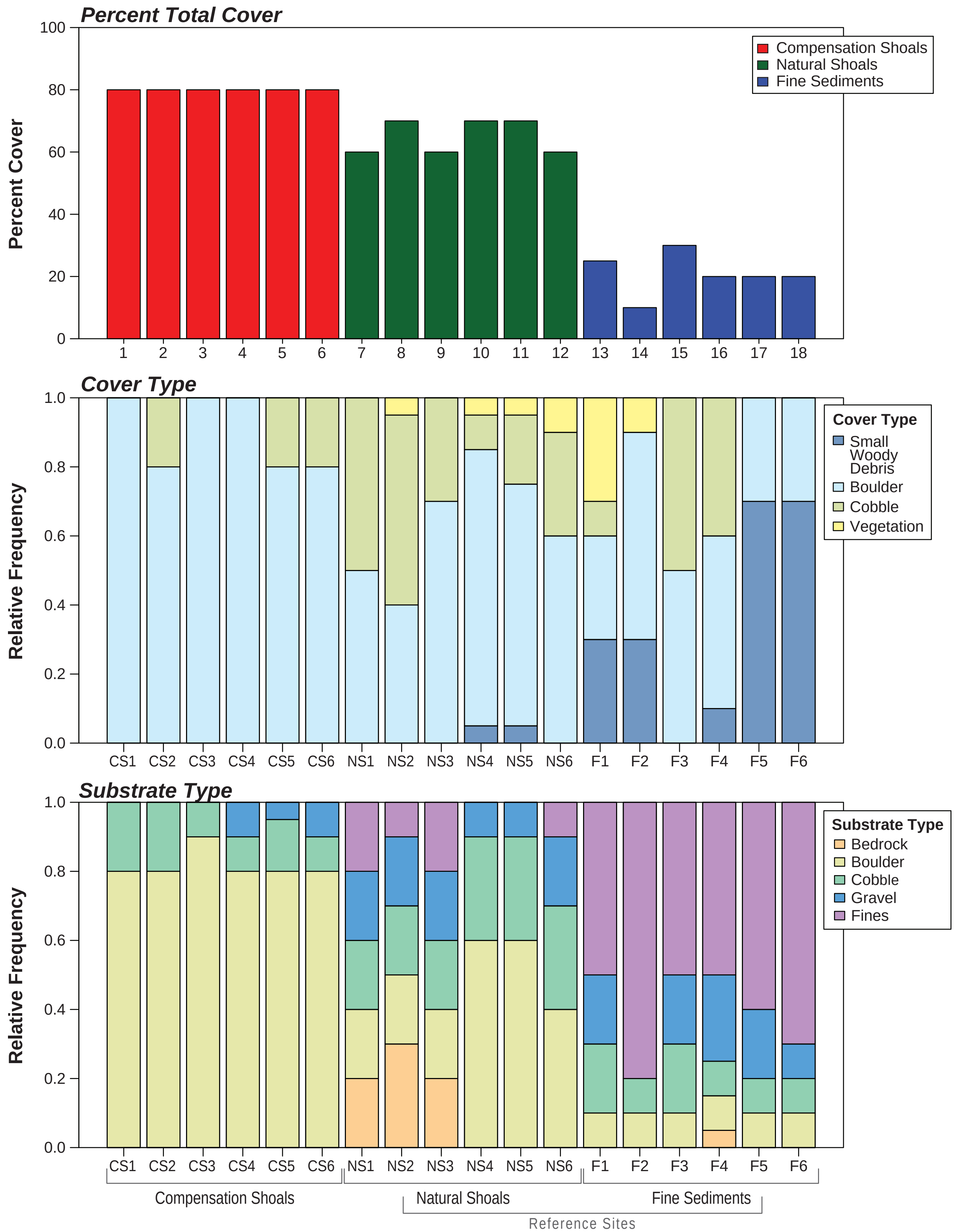

Figure 3.1-1

Percent Cover, Relative Frequency of Cover Type, and Substrate Type Observed at Compensation Shoals and Reference Sites in Windy Lake, Doris North Project, 2013

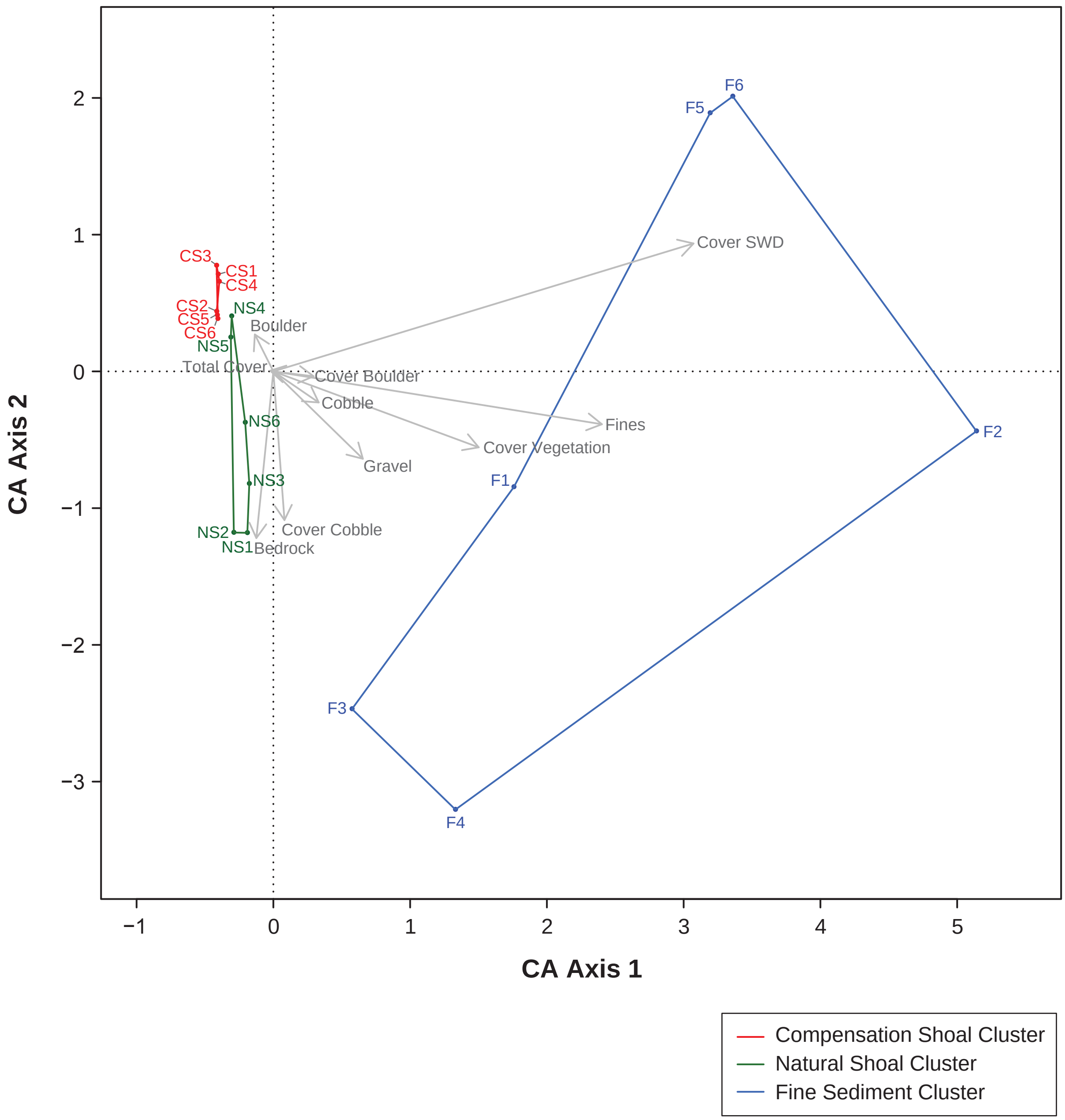

Figure 3.1-2

Principal Coordinate Analysis of Compensation Shoals and Reference Sites in Windy Lake, Doris North Project, 2013

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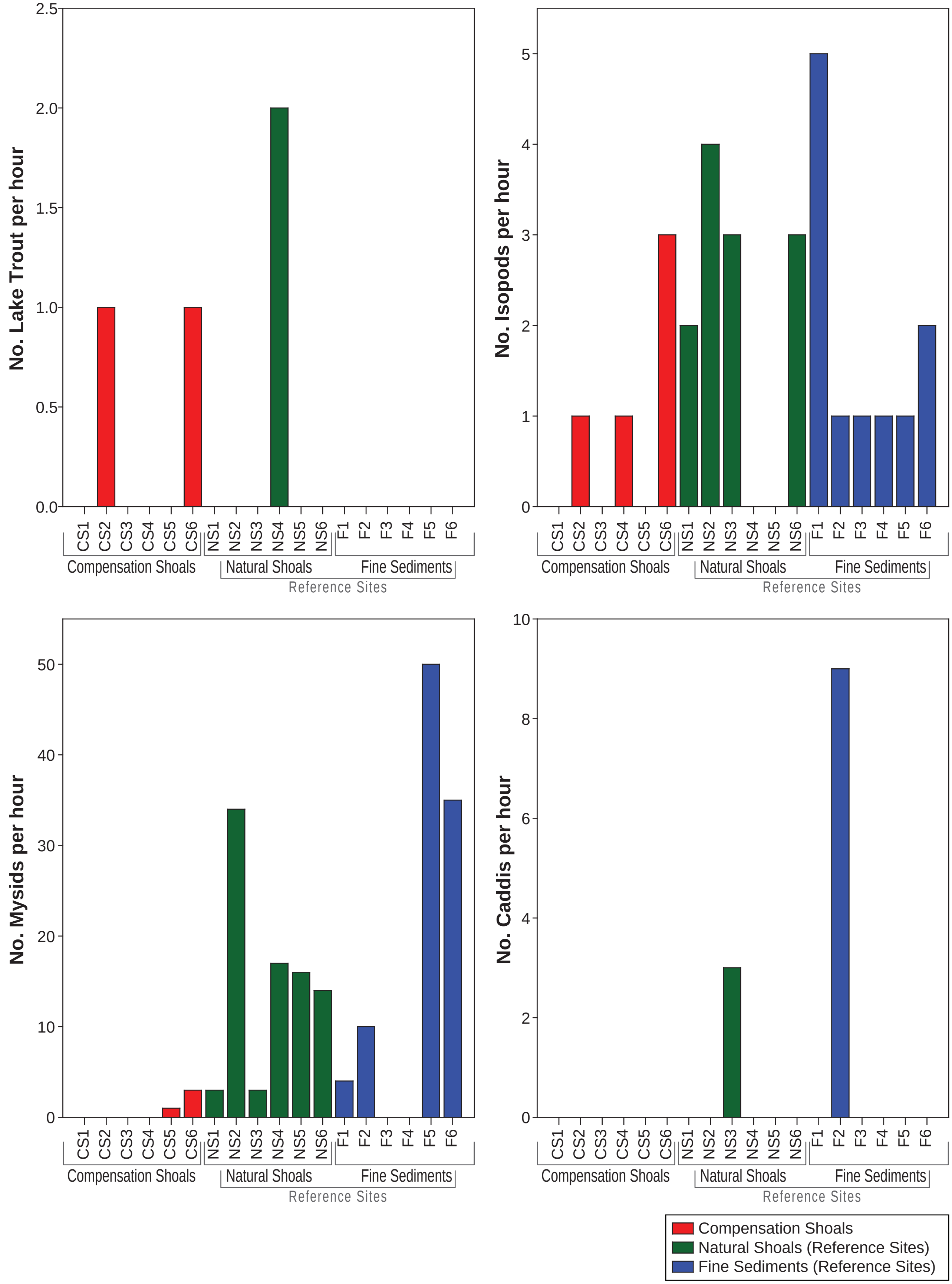

Snorkeling Observations at Compensation Shoals and Reference Sites in Windy Lake, Doris North Project, 2013

Figure 3.1-3

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Table 3.1-1. Results from Fuzzy C-Means Clustering of Habitat Variables Showing the Percent Membership of each Site to One of Three Possible Clusters, 2013

Habitat	Site	Cluster 1	Cluster 2	Cluster 3	Membership
Compensation Shoal	CS1	99.8	0.1	0.0	Cluster 1
	CS2	99.8	0.1	0.0	Cluster 1
	CS3	99.8	0.2	0.0	Cluster 1
	CS4	99.8	0.2	0.0	Cluster 1
	CS5	99.8	0.1	0.0	Cluster 1
	CS6	99.8	0.1	0.0	Cluster 1
Natural Shoal (Reference)	NS1	2.1	97.4	0.5	Cluster 2
	NS2	36.3	62.4	1.3	Cluster 2
	NS3	2.1	97.4	0.5	Cluster 2
	NS4	36.5	62.1	1.3	Cluster 2
	NS5	36.5	62.2	1.3	Cluster 2
	NS6	2.1	97.4	0.5	Cluster 2
Fine Sediments (Reference)	F1	0.6	1.3	98.1	Cluster 3
	F2	2.2	3.9	93.9	Cluster 3
	F3	3.2	7.2	89.6	Cluster 3
	F4	0.0	0.0	99.9	Cluster 3
	F5	0.0	0.0	99.9	Cluster 3
	F6	0.0	0.0	99.9	Cluster 3

Very few fish were observed while snorkelling in Windy Lake in July and September, 2013 (Figure 3.1-3). Over the course of the two surveys in 2013, which totalled 18 hours of in-water snorkeling time (1 hour per site), only four individual Lake Trout were observed (Table 3.1-2). Of these fish, two were seen on Compensation Shoals (CS2 and CS6), and two were spotted on Natural Shoals (both at NS 4). All Lake Trout sightings in 2013 were made during the July sampling period, and Lake Trout were never observed on Fine Sediment sites. Estimated sizes of the observed Lake Trout ranged from 400 mm to 500 mm.

Altogether, only eight Lake Trout have been observed in two years of monitoring in Windy Lake. Though these fish observations are not amenable to statistical analysis owing to their scarcity, the qualitative pattern of observations in 2013 matched that found in 2012, when all Lake Trout sightings were also made during the July sampling period (Rescan 2012c). In 2012, two Lake Trout were seen making use of Compensation Shoal sites, while two Lake Trout were seen on Natural Shoal sites (Rescan 2012c). No fish were observed over Fine Sediment sites in that first year of monitoring, just as in 2013.

Importantly, in each year of sampling, half of the observed fish were recorded at Compensation Shoal sites, indicating a consistent pattern of Compensation Shoal use by Lake Trout (sub-adults and adults based on the 350-550 mm size range) across two years of sampling.

Table 3.1-2. Snorkelling Observations at Compensation Shoals and Reference Sites in Windy Lake, 2013

Habitat	Site	Date of Sampling	UTM Coordinates						Number of Lake Trout Observed	Size of Lake Trout (mm)	Number of Isopods Observed	Number of Mysids Observed*	Number of Caddis Observed
			Outer Margin 1			Outer Margin 2							
			Zone	Easting	Northing	Zone	Easting	Northing					
Compensation Shoal	CS1	20-Jul	13 W	431371	7554505	13 W	431339	7554462	0	-	0	0	0
	CS2	19-Jul	13 W	431190	7554087	13 W	431156	7554029	1	500	1	0	0
	CS3	19-Jul	13 W	432254	7553382	13 W	432222	7553382	0	-	0	0	0
	CS4	19-Jul	13 W	432245	7553245	13 W	432218	7553198	0	-	0	0	0
	CS5	12-Jul	13 W	432393	7550809	13 W	432405	7550759	0	-	0	0	0
	CS6	12-Jul	13 W	432364	7551010	13 W	432365	7550944	1	500	3	1	0
Natural Shoal (reference sites)	NS1	12-Jul	13 W	430965	7553244	13 W	430969	7553203	0	-	2	0	0
	NS2	12-Jul	13 W	430911	7553306	13 W	430909	7553265	0	-	3	18	0
	NS3	20-Jul	13 W	431227	7554197	13 W	431267	7554254	0	-	3	3	0
	NS4	12-Jul	13 W	432371	7552848	13 W	432413	7552762	2	400 and 500	0	1	0
	NS5	12-Jul	13 W	432475	7552462	13 W	432417	7552592	0	-	0	1	0
	NS6	12-Jul	13 W	432415	7551159	13 W	432414	7551294	0	-	0	2	0
Fine Sediments (reference sites)	F1	12-Jul	13 W	430872	7553156	13 W	430872	7553203	0	-	5	4	0
	F2	20-Jul	13 W	431275	7554387	13 W	431277	7554444	0	-	0	0	3
	F3	19-Jul	13 W	431427	7554886	13 W	431468	7554927	0	-	1	0	0
	F4	12-Jul	13 W	432299	7552978	13 W	432310	7552914	0	-	0	0	0
	F5	20-Jul	13 W	432045	7549672	13 W	432085	7549671	0	-	0	0	0
	F6	20-Jul	13 W	432248	7549694	13 W	432296	7549712	0	-	2	0	0
Compensation Shoal	CS1	15-Sep	13 W	431371	7554505	13 W	431339	7554462	0	-	0	0	0
	CS2	15-Sep	13 W	431190	7554087	13 W	431156	7554029	0	-	0	0	0
	CS3	12-Sep	13 W	432254	7553382	13 W	432222	7553382	0	-	0	0	0
	CS4	12-Sep	13 W	432245	7553245	13 W	432218	7553198	0	-	1	0	0
	CS5	15-Sep	13 W	432393	7550809	13 W	432405	7550759	0	-	0	1	0
	CS6	15-Sep	13 W	432364	7551010	13 W	432365	7550944	0	-	0	2	0
Natural Shoal (reference sites)	NS1	15-Sep	13 W	430965	7553244	13 W	430969	7553203	0	-	0	3	0
	NS2	15-Sep	13 W	430911	7553306	13 W	430909	7553265	0	-	1	16	0
	NS3	15-Sep	13 W	431227	7554197	13 W	431267	7554254	0	-	0	3	3
	NS4	12-Sep	13 W	432371	7552848	13 W	432413	7552762	0	-	0	16	0
	NS5	12-Sep	13 W	432475	7552462	13 W	432417	7552592	0	-	0	15	0
	NS6	15-Sep	13 W	432415	7551159	13 W	432414	7551294	0	-	3	12	0
Fine Sediments (reference sites)	F1	15-Sep	13 W	430872	7553156	13 W	430872	7553203	0	-	0	0	0
	F2	15-Sep	13 W	431275	7554387	13 W	431277	7554444	0	-	1	10	6
	F3	15-Sep	13 W	431427	7554886	13 W	431468	7554927	0	-	0	0	0
	F4	12-Sep	13 W	432299	7552978	13 W	432310	7552914	0	-	1	0	0
	F5	12-Sep	13 W	432045	7549672	13 W	432085	7549671	0	-	1	50	0
	F6	12-Sep	13 W	432248	7549694	13 W	432296	7549712	0	-	0	35	0

** where the number of Mysids exceeds 20 the count is an estimate*

3.2 BIOLOGICAL SAMPLING

3.2.1 Community Ecology

3.2.1.1 Primary Producers (Periphyton)

Compensation Shoals were constructed in April 2011 (Rescan 2011). Since that time, the shoals have begun to develop resident ecological communities of organisms through colonization, *in situ* growth and reproduction, and ecological succession. Periphyton density and diversity indices showed little difference among habitat types (Figures 3.2-1 and 3.2-2), indicating that in the period of time since the construction of the Compensation Shoals (2 years) there has been development of a primary producer community.

Biomass, Density, Richness, and Diversity

Periphyton biomass (measured as chlorophyll *a* concentration) did not differ significantly among habitat types (Kruskal-Wallis, $K_{(2,15)}$ = 3.52, $P = 0.172$). Though not significant, there was a general trend in which Compensation Shoals had visibly lower mean periphyton biomass than Fine Sediment sites, as well as a slightly lower mean periphyton biomass value than the Natural Shoal sites (Figure 3.2-1).

Differences in periphyton densities among habitat types were not statistically significant at $\alpha = 0.05$ (ANOVA, $F_{(2,15)}$ = 3.52, $P = 0.06$, data were Ln transformed). Periphyton density showed a similar pattern to biomass, in which Compensation Shoals tended to have lower densities than the two reference habitat types (Figure 3.2-2). This pattern suggests the presence of slight lag in periphyton community development at Compensation Shoals after two years post-construction, but that compensation and reference communities are largely similar.

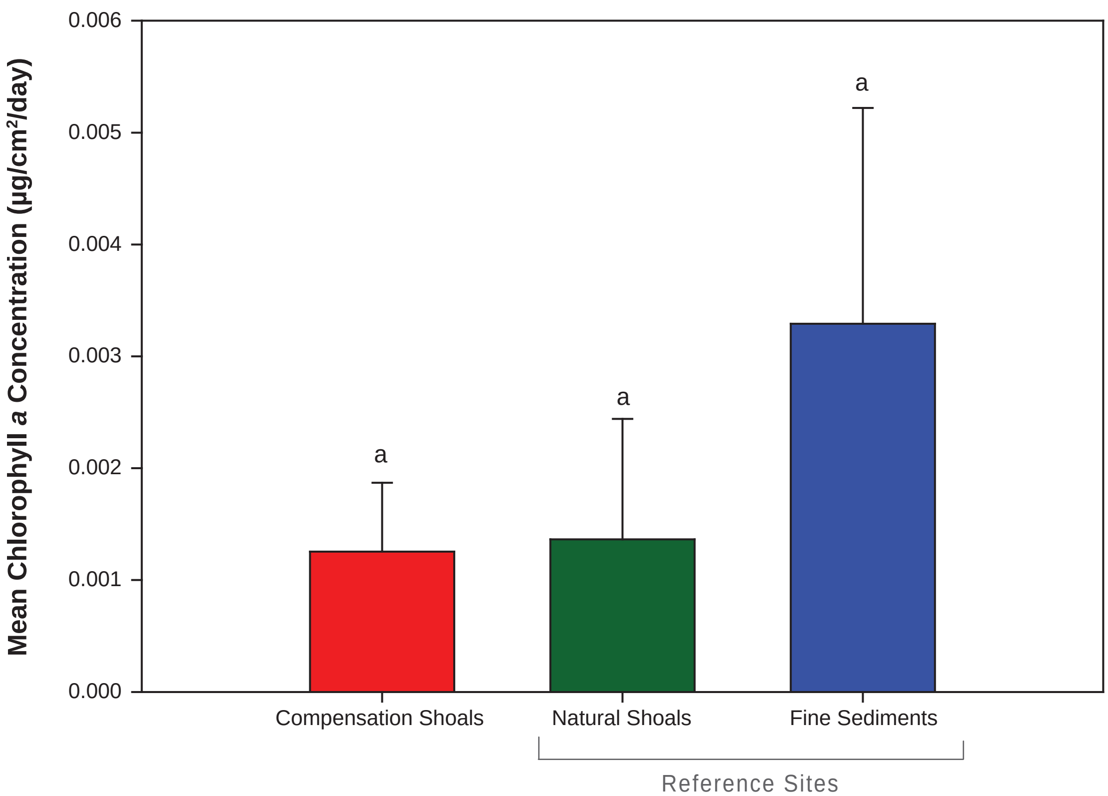
The taxonomic richness of periphyton communities did not differ significantly among habitat types (ANOVA, $F_{(2,15)}$ = 1.34, $P = 0.29$). This lack of a statistically significant difference and the finding that Compensation Shoals had the highest mean value for this index, are consistent with the interpretation that periphyton communities at Compensation Shoals are developing quickly and are similar to those on the Natural Shoal reference sites. Results for periphyton diversity were similar to richness, lending additional support to this interpretation. The average Shannon's Diversity Index for periphyton was highest on Compensation Shoals (Figure 3.2-2), but did not differ significantly among the three habitat types (ANOVA, $F_{(2,15)}$ = 0.69, $P = 0.52$).

Comparison to 2012

To evaluate the effects of year and habitat type on periphyton indices, data from 2012 and 2013 were incorporated into a Two Factor (Year, Habitat) ANOVA. Analysis revealed no significant interaction ($P > 0.6$; Appendix 3.2-1) between year and habitat type for any of the periphyton indices (density, biomass, richness, diversity) allowing for direct comparisons of the main effects of Year and Habitat.

Year Effects

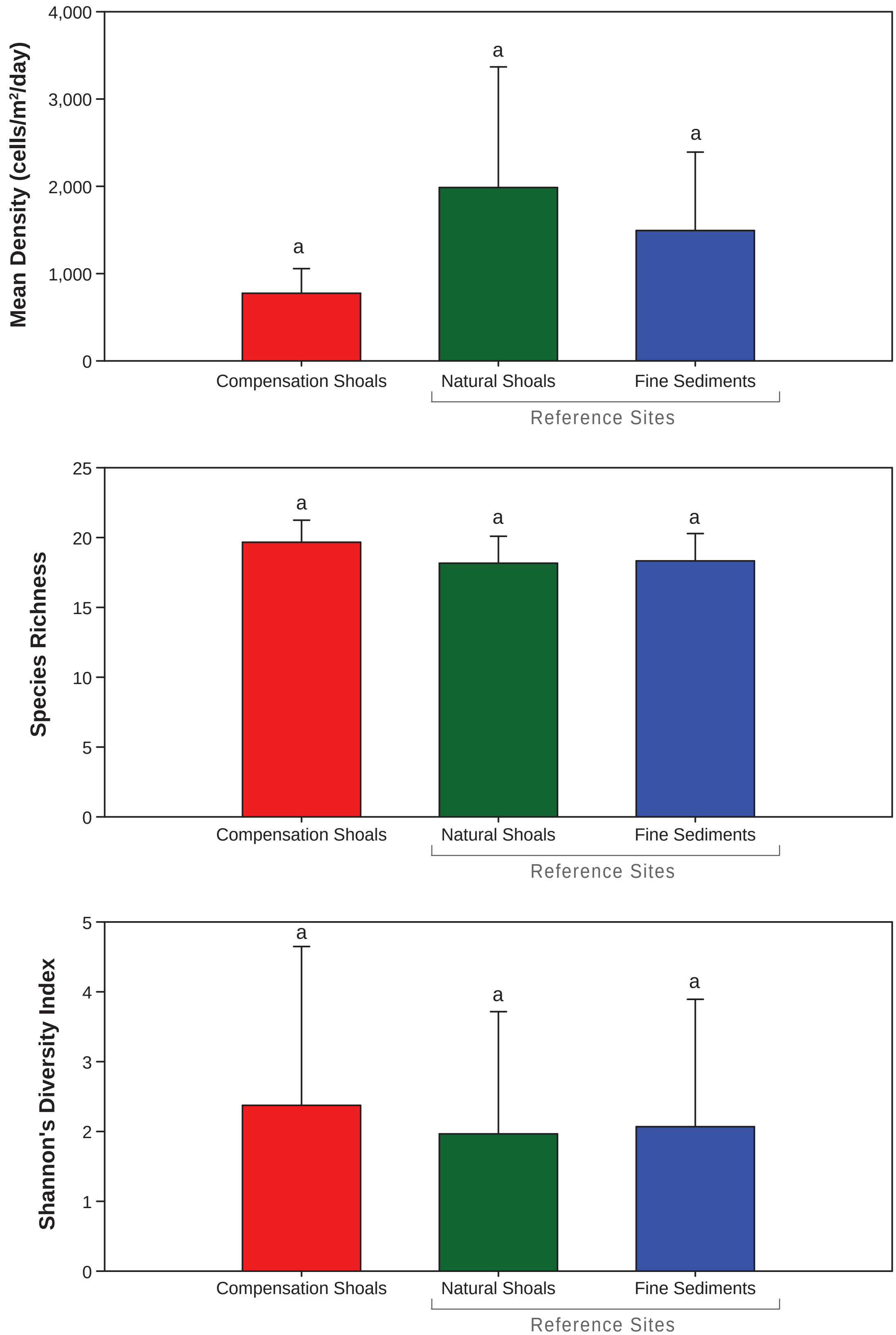
Year was a significant main effect for each periphyton index ($P < 0.01$; Appendix 3.2-1). Mean values of all indices at all habitat types (Compensation Shoals and reference sites) increased consistently between 2012 and 2013 (Figure 3.2-3 to 3.2-6). A similar increase in periphyton indices between 2012 and 2013 was found at other, unconnected water bodies in the Project area (Rescan 2013). This temporal pattern shared between Compensation Shoals and natural sites within the project area (including Natural Shoals and Fine Sediments sites in Windy Lake) suggests that the periphyton community at Compensation Shoals responds similarly to natural changes in the environment over time.



Note: Error bars represent the 95% confidence interval.
Groups that share the same letter are not significantly different at α = 0.05.

Chlorophyll *a* Concentration at Compensation Shoals and Reference Sites in Windy Lake, Doris North Project, 2013

Figure 3.2-1



Notes: Error bars represent the 95% confidence interval.
Groups that share the same letter are not significantly different at α = 0.05.

Periphyton Density, Richness, and Diversity at Compensation Shoals and Reference Sites in Windy Lake, Doris North Project, 2013

Figure 3.2-2

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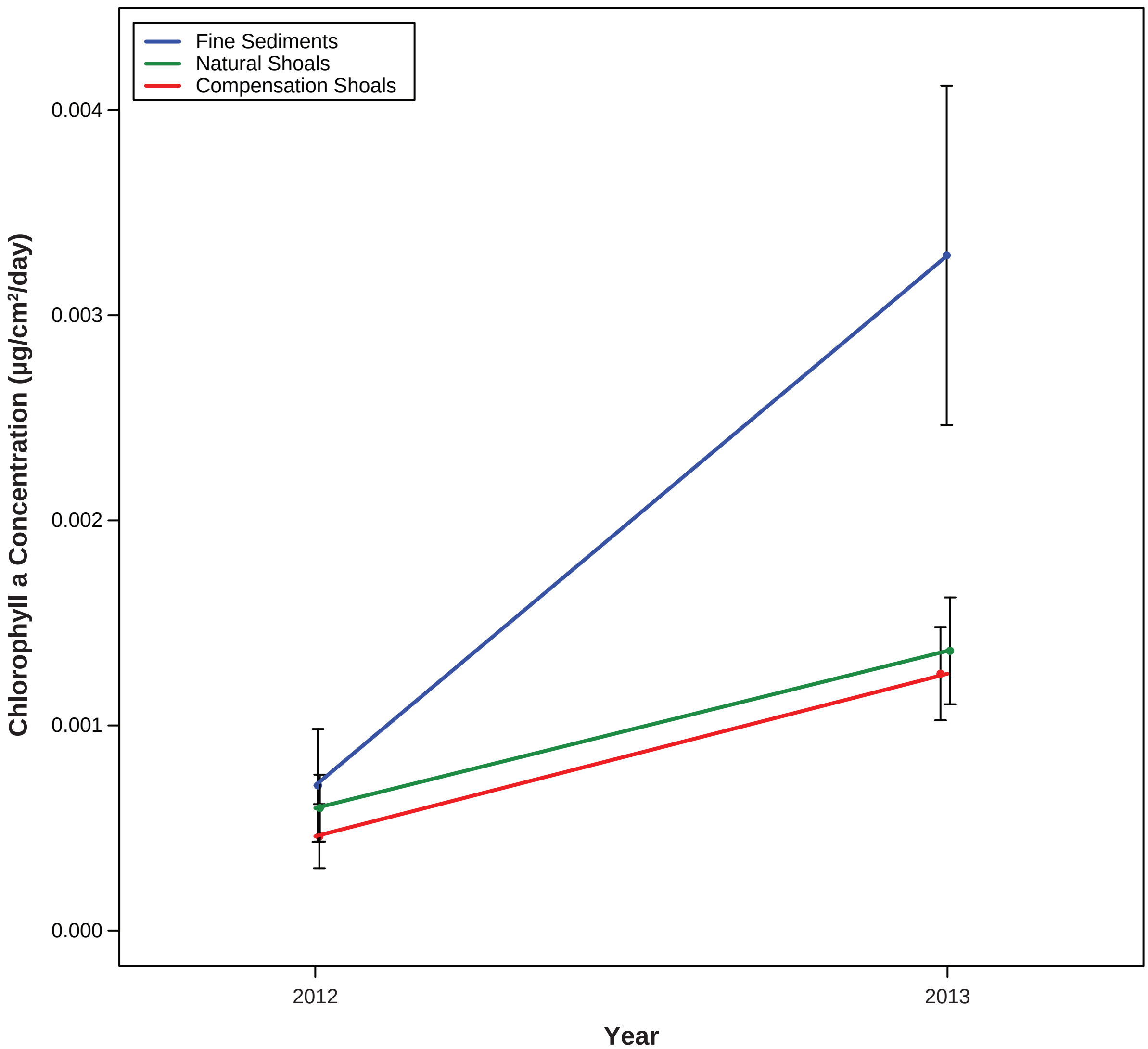

Note: Error bars represent Standard Error of the Mean and some points are slightly offset in time to show error bars.

Figure 3.2-3

Trend in Chlorophyll *a* Concentration at Compensation Shoals and Reference Sites (2012 to 2013)