MADRID-BOSTON PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT

Table of Contents

List of Figures

List of Tables

List of Appendices

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.

AEMP	Aquatic Effects Monitoring Program
AWR	All weather road
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRA	Commercial, Recreational, or Aboriginal
DFO	Fisheries and Oceans Canada
Doris Project	Existing Doris North Project
EEM	Environmental Effects Monitoring
EIS	Environmental Impact Statement
ERM	Environ mental Resource Management
FOP	Fisheries Offsetting Plan
FPP	Fisheries Protection Program
HBML	Hope Bay Mining Ltd.
Hope Bay Project	Comprises all aspects of Doris, Madrid-Boston and advance exploration projects associated with the Hope Bay Project
HTO	Hunters and Trappers Organization
HWM	High Water Mark
IIBA	Inuit Impacts and Benefits Agreement
IQ	Inuit Qaujimajatuqangit
KIA	Kitikmeot Inuit Association
LSA	Local Study Area
Miramar	Miramar Hope Bay Ltd./Hope Bay Joint Venture
MMER	Metal Mining Effluent Regulations
MOMB	Marine outfall mixing box
NIRB	Nunavut Impact Review Board
NLCA	Nunavut Land Claims Agreement

NTKP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
PAD	Permanent Alteration or Destruction of Fish Habitat
PDA	Project Development Area
PoE	Pathway of Effect
QA/QC	Quality Assurance/Quality Control
RSA	Regional Study Area
SARA	Species at Risk Act
t	tonne
The Project	the proposed Hope-Bay Project
TK	Traditional Knowledge
TMA	Dry-stack tailings management area at Boston
tpd	tonnes per day
VEC	Valued Ecosystem Component
WRR	Doris to Boston Winter Road Route

10. Marine Fish

The Project may interact with marine fish (inclusive of marine biological resources, fish habitat, and fish) through the development of Madrid-Boston infrastructure such as the cargo dock and the discharge pipe and diffuser in Roberts Bay. This section summarizes the sources of data, the methods of data collection, and the results from the sampling of marine biological resources, fish habitat, and fish community.

Fish habitat is defined in the federal *Fisheries Act* as “spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas, on which fish depend directly or indirectly in order to carry out their life processes.” In this section of the Environmental Impact Statement (EIS) it is divided into two components: biological resources and physical habitat. Biological resources include the abundance and taxonomy of lower trophic levels such as primary producers (phytoplankton) and secondary producers (zooplankton and benthic invertebrates). Physical habitat includes bathymetry, substrate size, gradients, and other physical characteristics.

The term “fish” in the *Fisheries Act* includes “parts of fish; shellfish, crustaceans, marine animals, and any parts of shellfish, crustaceans, or marine animals; and the eggs, sperm, larvae, spat, and juvenile stages of fish, shellfish, crustaceans, and marine animals”. In this section, fish includes fish species richness and the relative abundance of fish species.

Data on marine fish were collected in a nested series of areas. The Project Development Area (PDA) is the area which has the potential for infrastructure to be developed as part of the Madrid-Boston Project. It includes engineering buffers around the footprints of structures. The Local Study Area (LSA) is the area surrounding the PDA in which there is a reasonable potential for immediate effects on a Valued Environmental Component (VEC) due to an interaction with a Madrid-Boston Project component or physical activity. The marine fish LSA encloses Roberts Bay. The Regional Study Area (RSA) is the maximum extent of the area surrounding the LSA that may be directly or indirectly affected by Madrid-Boston development. It encloses Melville Sound, the western part of Elu Inlet, the northern part of Bathurst Inlet, and part of Coronation Sound. Details are provided in Section 10.2.

10.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

Traditional Knowledge (TK) information was gathered by the Kitikmeot Inuit Association (KIA) in a report titled *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (Banci and Spicker 2016) (hereafter referred to as the TK report). This report provides recorded and georeferenced TK pertaining to the Project by means of interviews conducted between 1997 and 2000, regional and site-specific studies, the *Inuit Land Use Occupancy Study* (Freeman 1976), focused workshops in Kugluktuk and Cambridge Bay in 2013, and studies of anadromous lake trout from Roberts Lake by Dr. Heidi Swanson of the University of Waterloo.

A second source of TK is information on traditional land use presented in the baseline of the land use chapter of this EIS (Volume 6; Chapter 4). This information was obtained through a land use focus group conducted in November 2011 for the Project and interviews with representatives of local Hunter and Trappers Organizations (HTOs) (Land Use Focus Group 2011)). The focus group was attended by five elders and one younger hunter active in areas near to the Project, specifically Omingmaktok. Interviews included both structured and semi-structured questions, as well as resource mapping, to gather additional information on current use of land and resources to supplement the information collected from the focus group.

10.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

10.1.1.1 TK Report

The TK report was reviewed for existing environment and baseline information on marine fish and fish habitat. Fish were, and continue to be, an important component of the Inuit seasonal diet. They were essential during times of food shortage, particularly when caribou did not arrive because of a change in migration route or calving area. They were also important for feeding dog teams during winter trapping.

Inuit fished the ocean adjacent to the mainland and island coastlines, and at the mouths of major rivers. Fishing was conducted in the regions of Bathurst Inlet, Melville Sound, Elu Inlet, Roberts Bay, Ida Bay, Daniel Moore Bay, and scattered areas within the Coronation Gulf. Figure 21 of the TK report shows that most individual fishing places in the Project area were located along the coastline of Roberts Bay and the southern coastline of Melville Sound.

In the past, Inuit fished the ocean during the open-water season by jigging and sometimes with nets. In the spring they fished through the ice cracks. Fishing is now most commonly conducted using nets.

> *Inuit mostly fish inlets and bays. Sometimes we go out on the open ocean, deep water, too.*
>
> *You go out into the ocean to catch cod. Deep, deep water. They live right on the bottom of the ocean, more of bottom feeding fish. They are seldom seen on top, like charr. Charr always go on top. It will be up on top, feed on top of the water.*
>
> *They are all over this whole area, all of Bathurst Inlet. Kanayuk (sculpins), and natanik, turbot, flounders, they are all over. And eels, also eels. There are all types of ocean species, but we don't know what they all are.*
>
> *People fished the ocean by jigging mostly. Now they use a lot of gillnets. They ice fish today with fishing rods. There are Arctic charr and some trout close to the ocean. Some trout are really close to the ocean… In the ocean, there are whitefish, what they call the broad whitefish, lots of broad whitefish, and those flat fish called flounders, tomcod, Thompson eel, and sculpins ...*

Fish caught in the ocean included both anadromous and exclusively marine species. Section 6.1 of the TK report describes the results for the freshwater life stages of four major anadromous species: Arctic Char, Lake Trout, Arctic Cisco, and Broad Whitefish. Inuit caught all four species at the mouths of rivers and in shallow, coastline habitats with weirs, spears, and fish traps.

<u>Hiugyoktuk (Saffron Cod and Arctic Cod)</u>

Arctic Cod (*Arctogadus glacialis*) and Saffron Cod (*Eleginus gracilis*) are the main target species for Inuit marine fisheries. Saffron Cod are fished primarily in shallow inlets and bays and Arctic cod are fished primarily in deep ocean habitats. Both species are prized as food fish.

> *You pretty well find cod everywhere. There are two types of cod here (Arctic cod and saffron cod). They are all over the inlet (Bathurst Inlet) … They are all good eating. What we have*

noticed is that they are mostly the same, in abundance. This one (saffron cod) is found in inlets and bays, in more shallow waters … and this one (Arctic cod) is in deeper waters.

Arctic cod can grow really, really large … I remember catching one in the really deep part. And they said you're going to get tired trying to take that fish out. (I was fishing) by jigging … where it was really deep.

Capelin

Capelin (*Mallotus villosus*) was caught with baskets when they spawned on beaches. Spawning usually took place once or twice a year during the summer. Inuit ate capelin and also fed it to their dogs. No Inuit name for capelin was reported in the TK report.

Capelin always stay in the ocean, in the deep ocean. They only come to the shallows to lay their eggs.

There are lots in the middle of July. They arrive maybe twice. Early July, and then again about two weeks later. Then they come back.

Capelin … These are ocean fish. They are always in the ocean. Summertime they come to shore to lay their eggs. Millions and millions of eggs on the shoreline. They have to have a certain type of place to lay their eggs, mostly sandy beaches. But sometimes they find rocky parts to lay their eggs.

Etok (Rainbow Smelt and Pacific Herring)

Rainbow smelt (*Osmerus mordax*) and Pacific herring (*Clupea pallasii*) are also summer shore spawners. Smelt spawn on sandy beaches and herring spawn on aquatic vegetation or bare rock if vegetation is not present. Inuit harvest them during the spawning period using traps and nets.

… The shiny little fish are called rainbow smelt. They are different from the capelin, really shiny.

They are a little smaller than the capelin.

Herring are different. They are bigger. There are herring in here too. Herring, etok. They are all over this ocean too. They tend to stay out in the ocean. They don't come ashore, they are mostly in the deep ocean.

Other traditionally harvested marine species include sculpins, flounders, wolfish, eels, crabs, oysters, and starfish.

10.1.1.2 Land Use Study

This section reports relevant TK shown in Chapter 4 (Land Use) of Volume 6 of this EIS.

Fish are harvested in winter, spring and summer. Fishing methods includes the use of weirs and nets (Land Use Focus Group 2011). While fishing occurs throughout the land use RSA, there are two prominent fishing areas located within the RSA and one within the LSA. The first frequented fishing area within the RSA is located approximately 25 km northwest of the Project on Kent Peninsula near a small lake at the edge of Melville Sound. The NTKP report indicates this lake is known as Naoyak or Tahikyoaknahik (Banci and Spicker 2016). Many people come to this lake from Cambridge Bay, especially to ice fish in the spring. There are two cabins near this fishing area (Land Use Focus Group 2011;

J. Avalak, pers. comm.). This location is used for fishing Arctic Char in the fall and fishermen set nets through the ice. Grizzlies frequent the area because of the Arctic Char (Land Use Focus Group 2011).

The second frequented area is Roberts Lake, which was also highlighted by Omingmaktok residents as having abundant fish (e.g., Whitefish, Char, Cod, Sculpins, and Flatfish). However, it is minimally used because of its proximity to the Doris area. Generally, Omingmaktok harvesters focus on Whitefish, Trout and Cod (Land Use Focus Group 2011). Larger lakes and rivers that connect to the ocean are important as they usually have an abundance of fish such as Arctic Char, Whitefish, and Trout. Local land users pile rocks in a particular formation to mark good fishing spots. When travelling the land, people follow big lakes and rivers and look for fish markers (Land Use Focus Group 2011). Currently, harvesters hunting and fishing in the area use the camp for short-term stays. One seasonal camp is located adjacent to Roberts Lake.

10.1.2 Incorporation of Traditional Knowledge for VEC Selection

The TK report and the land use information were reviewed to refine the potential Valued Ecosystem Component (VEC) list for marine fish. The marine and anadromous fish species identified in the TK report and other commercial and recreational fish and their habitats were considered as potential VECs for the effects assessment. In addition, Inuit traditional fishing places and known fish distribution/locations identified in the TK report were considered as potential VECs for the effects assessment. Traditional knowledge was combined with data from public consultation and baseline surveys to determine which valued components would potentially interact with the proposed Project, and should therefore be evaluated for inclusion in the candidate VEC list.

Saffron cod was chosen as the only exclusively marine fish VEC because of its importance of food fish for Inuit, in addition to being the single most common species of marine fish in inlets and shallow habitat near Madrid-Boston infrastructure in Roberts Bay (50.85% of all fish caught in Roberts Bay from 2000 to 2010) (See Section 10.2; Table 10.2-11).

Although identified as being fished, Capelin was not chosen as a VEC because it is not common in Roberts Bay, although when it is present it is present in large numbers. Capelin was caught in only 3 of the 8 years that Roberts Bay was sampled from 2002 to 2010, and 98.5% of its total number (2,668) was caught in 2003 (See Section 10.2; Table 10.2-11). This suggests that Capelin uses habitat in Roberts Bay for only part of the year. Since Capelin has not been observed spawning on beaches in Roberts Bay, they were probably passing through Roberts Bay in 2003 on the way to beach spawning sites elsewhere in Melville Sound. A Capelin spawning event is highly visible because it attracts marine mammals such as seals and large flocks of noisy birds.

Arctic cod were not chosen as a VEC because they have not been caught in Roberts Bay, no doubt because of their preference for deep water habitat.

Rainbow smelt were not chosen as a marine fish VEC because they were rarely caught in Roberts Bay. Only a single specimen was captured in 2004 (See Section 10.2; Table 10.2-11).

Pacific herring were caught but in relatively small numbers (3.55% of all fish) compared to other species such as Saffron Cod (50.85%) (See Section 10.2; Table 10.2-11), indicating they are not a dominant member of the marine fish community. They are also not a popular food fish for Inuit. Hence they were not chosen as a marine fish VEC.

Flounders and sculpins were caught in Roberts Bay, as well as one wolffish and no eels. Numbers for these species were too low, and their value as food fish was too low, to justify selection as VECs.

The anadromous life stage of Arctic Char was chosen as the second marine VEC because the species was frequently caught in Roberts Bay (7 of 8 sampling years) (See Section 10.2; Table 10.2-11), and TK shows that it is a prized food fish. The results of baseline studies for this EIS confirmed that Arctic Char are present in the LSA and RSA of freshwater fish (See Section 10.2; Section 6.2.5.2) and that anadromous Arctic Char are present in the LSA of marine fish (See Section 10.2; Section 10.2.6.3).

In addition, Inuit traditional fishing places and known fish distribution/locations identified in the TK report and the land use chapter were considered as potential VECs for the effects assessment.

10.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The results of the TK report and land use study were considered when developing the spatial and temporal boundaries for the Project. The TK report showed that specific and general fishing locations extend along both shores of Melville Sound, but are concentrated along the southern shore extending both east and west of Roberts Bay. The land use study showed fishing for anadromous fish species such as Arctic Char in the Roberts Lake drainage. As a result, Roberts Bay was included within the boundaries of the LSA. The temporal boundaries of the assessment must extend into the indefinite future, as in the post-closure phase, because preservation of the productive capacity of the marine aquatic ecosystem, particularly the capacity to produce food fish and fishing opportunities, is a key value of Inuit culture.

10.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

The results of the TK report were considered when developing the effects assessment for marine fish. It is clear that Inuit value a suite of marine fish species, mainly the two species of cod plus the anadromous life stage of Arctic Char, as food fish and as key attributes of marine aquatic systems. Therefore, mitigation and adaptive management measures must focus on preserving the productive capacity of marine systems in the Project area so that these fish populations can continue to provide food and fishing opportunities into the indefinite future.

10.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

The TK report and land use study were considered when developing mitigation and adaptive management plans for freshwater fish and fish habitat. The Madrid-Boston Project has been designed such that infrastructure will not be located on important marine fishing habitat. Additional mitigation of Project-related effects may be achieved by the development of a Fish Offsetting Plan (FOP), which considers TK. Ongoing consultation with Fisheries and Oceans Canada (DFO), and future engagement with local Inuit, regarding the further development of the FOP, including the development of additional or alternative options that could provide value to the local communities, is intended through the life of the Project.

The two fish VECs considered in the marine fish assessment – Saffron Cod and the anadromous life stage of Arctic Char – use estuarine and coastal habitat within Roberts Bay and the RSA, hence conservation of that habitat is essential for preservation of productive populations. Productive marine ecosystems plus continued access to important feeding areas and spawning grounds are key requirements for both species.

10.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

10.2.1 Regional Overview and Past Activities

The Hope Bay Project development is comprised of Approved Projects and the Madrid-Boston Project. The Madrid-Boston Project is situated within the Queen Maud Gulf Lowlands, approximately 125 km southwest of Cambridge Bay on the southern shore of Melville Sound in the West Kitikmeot region of Nunavut. The Madrid-Boston Project is located within the Hope Bay Property, which runs 80 km in a north-south direction with a width of approximately 20 km and a total area of 1,101 km^2. The Property encloses a greenstone belt with gold mineralization. The Property is located approximately 700 km northeast of Yellowknife and 150 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The nearest settlements are Umingmatok, located approximately 60 km to the west, and Kingaok (Bathurst Inlet), located 130 km southwest. The centre of the Property lies approximately 143 km above the Arctic Circle at 67º50' N latitude and 106 °30' W longitude.

The Hope Bay Project consists of three developments, with Doris being the northernmost, followed by Madrid in the north-central area, and Boston at the southern end (Figure 10.2-1). Marine infrastructure associated with the Hope Bay Project is located along the southern (68° 18' N, 106° 64' W) and western shoreline (68° 19' N, 106° 65' W) of Roberts Bay (Figure 10.2-2), a small inlet that empties into Melville Sound. Roberts Bay is bordered on the west by Hope Bay and on the east by Ida Bay (formerly known as Reference Bay; Figure 10.2-1). Current infrastructure in Roberts Bay includes a jetty, associated laydown areas, and an access road along it southern shoreline. A marine outfall berm and associated discharge pipeline has also been authorized to be constructed through the Doris Project Type A Water Licence 2AM-DOH1323 (the Type A Water Licence).

Sealift access to the Madrid-Boston Project is via the Arctic Ocean terminating at the dock/jetty sites in Roberts Bay (Volume 3 Project Description, Chapter 1). Sealift and fuel resupply will occur along the existing shipping route through the Northwest Passage. The common Northwest Passage sealift route starts in Nunavut at Lancaster Sound, and passes through Barrow Strait, Peel Sound, Victoria Strait, and the Queen Maud Gulf. Incoming ships would travel south into northern Bathurst Inlet, and enter from the west into Melville Sound terminating in Roberts Bay.

The marine fish RSA encloses Melville Sound, the western part of Elu Inlet, the northern part of Bathurst Inlet, and part of Coronation Sound (Figure 10.2-1). The marine fish LSA encloses Roberts Bay, consistent with the Doris Project. Roberts Bay has a maximum north-south length of 5 km, and an east-west width of 4 km, giving a total surface area of 14.3 km^2 (Figure 10.2-2). The total volume of the bay is approximately 5.1×10^8 m^3 with a mean depth of 36 m and maximum depth of 88 m at its mouth. The southernmost section of the inlet is shallow (<20 m), and deepens to between 40 m and 90 m towards Melville Sound.

Ida Bay is a true fjord that is long (10 km), narrow (1 km at entrance), deep (>65 m), with a shallow sill (20 m deep) at its mouth that impedes deep-water exchange with Melville Sound (Figure 10.2-1). Hope Bay is a broad inlet dotted with many small islands and islets with free connection to Melville Sound.

The physiography of the surrounding area is represented by broad, sloping uplands (primarily igneous outcrops) that reach approximately 300 m in elevation in the south, and subdued undulating plains near the coast. The region’s vegetation is characterized by shrub tundra vegetation such as dwarf birch (*Betula nana*), willow (*Salix* sp.), Labrador tea (*Ledum decumbens*), avens (*Dryas* sp.), and blueberries (*Vaccinium* sp.) (Rescan 2011d).

Figure 10.2-1
Local and Regional Study Areas for Marine Fish

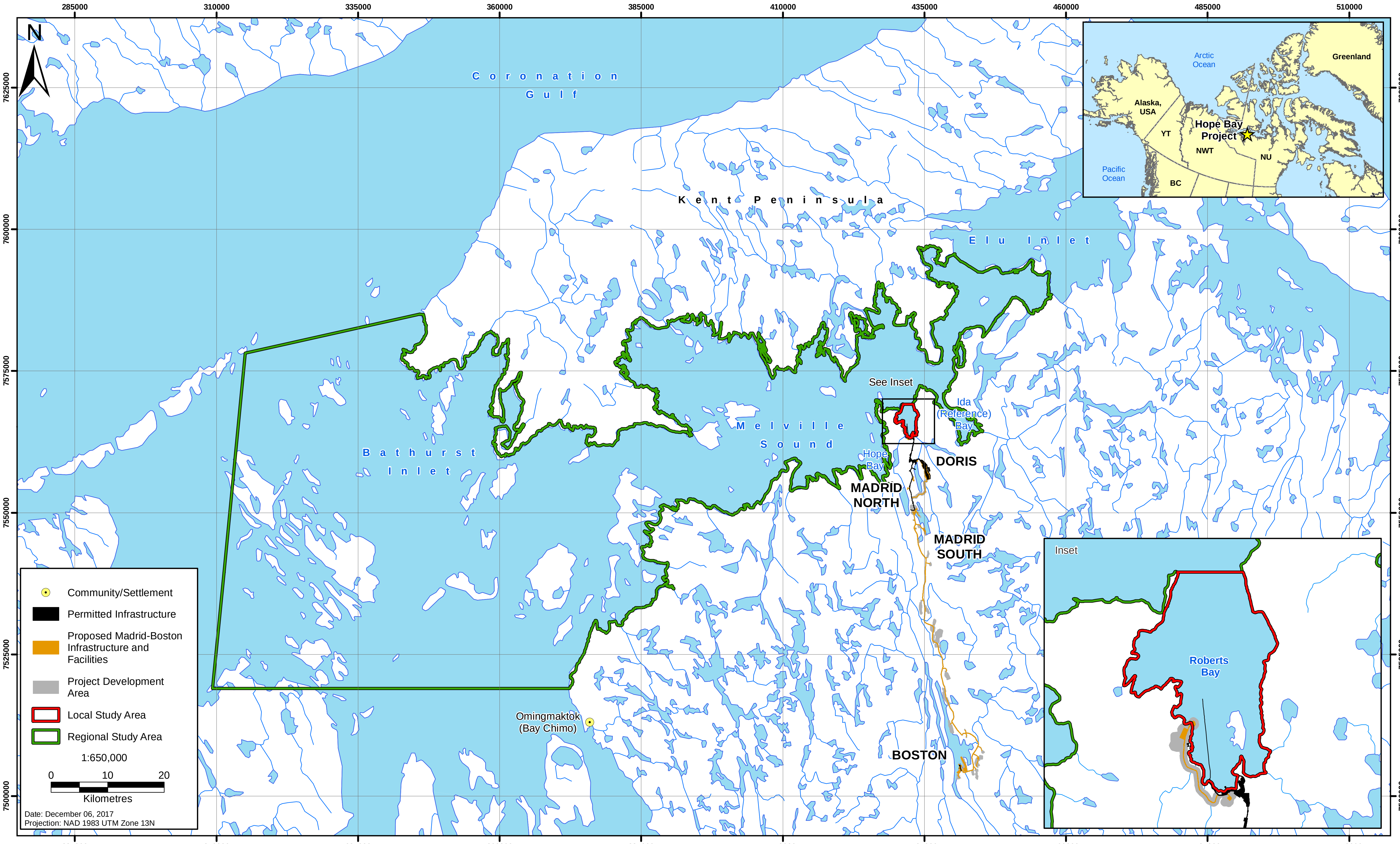
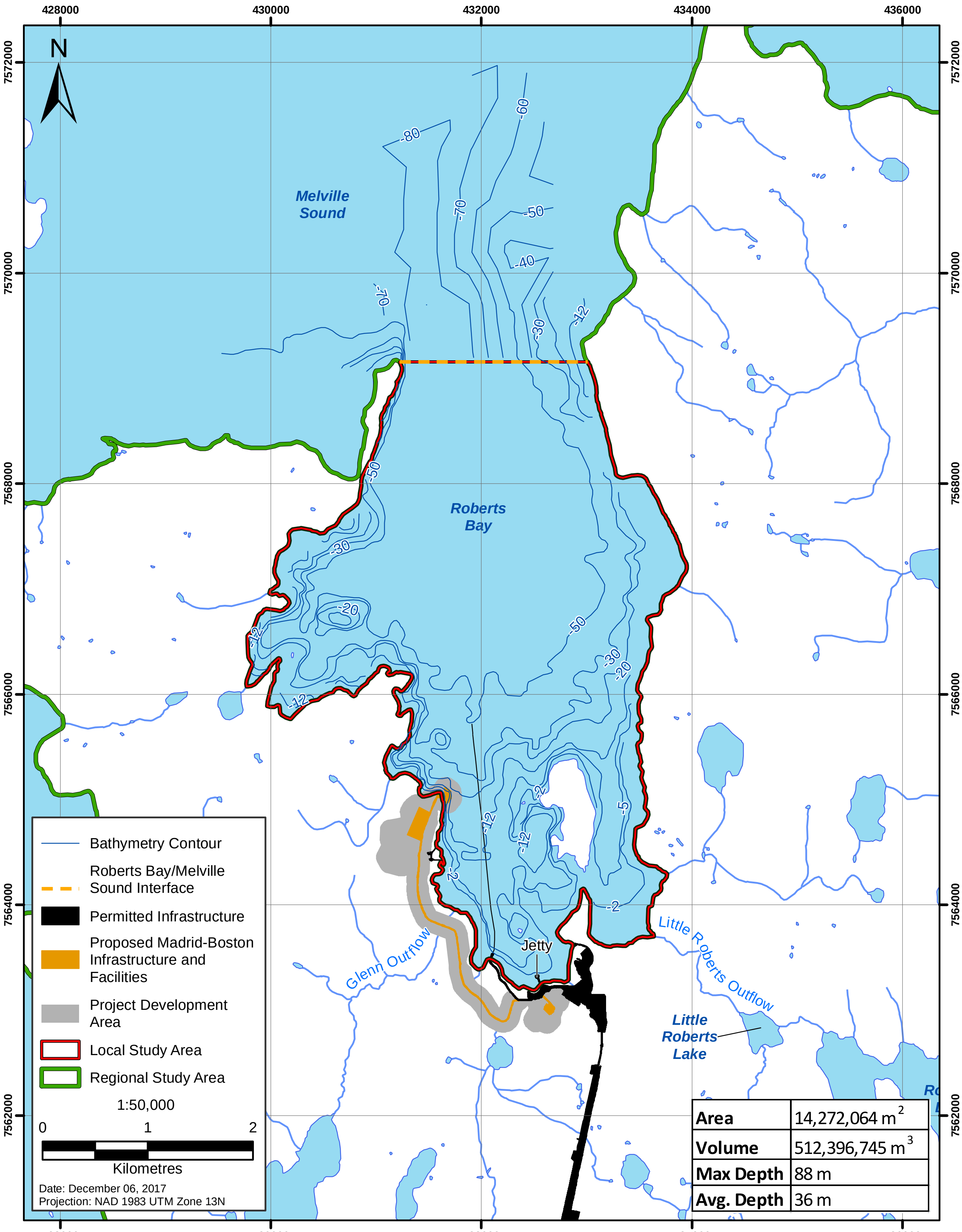


Figure 10.2-2
Roberts Bay



Area	14,272,064 m^2
Volume	512,396,745 m^3
Max Depth	88 m
Avg. Depth	36 m

Water in Roberts Bay has free exchange with Melville Sound because there is no sill present in the inlet. Water exchange between the two waterbodies occurs primarily during the summer months when winds drive the upper freshwater layer towards the shoreline of Roberts Bay, and deeper waters move into Melville Sound (Rescan 2012b). The bay is typically ice covered from October to June, most of that time with land-fast ice that is about 1.5 m thick. During ice cover, the waters of the bay are isolated from wind stress and the exchange of waters between Roberts Bay and Melville Sound is minimal.

Freshwater enters Roberts Bay from Little Roberts Outflow, Glenn Outflow, and smaller tributaries (Figure 10.2-2), with Little Roberts Outflow being the dominant source. The Koignuk River and the Angimajuq River supply the vast majority of freshwater into Hope Bay and Ida Bay, respectively. These inputs contribute to vertical stratification found in the inlets by forming a two-layer system with less dense water overlaying denser bottom water, which can reduce vertical mixing due to wind stress.

Roberts Bay and the surrounding embayments are generally well oxygenated, low in metals and nutrients, and have very low phytoplankton biomass levels. A total of 25 fish species have been found in Roberts Bay to date (see Table 10.2-11).

This section provides a summary of the methods and results from the marine fish habitat, inclusive of biological resources, and fish community sampling carried out in Roberts Bay and the surrounding region for the proposed Project.

10.2.2 Proximity to Designated Environmental Areas

There are currently no existing or proposed parks or conservation areas near the proposed Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 50 km east of Roberts Bay by air and over 300 km by water (as Melville Sound is isolated from the Queen Maud Gulf by the Kent Peninsula). The Draft Nunavut Land Use Plan (Nunavut Planning Commission 2016) has designated northern Bathurst Inlet, Melville Sound, and Elu Inlet as a key bird habitat site, and thus the marine LSA and RSA are contained within this area. The land use plan also designated the Project area as a High Mineral Potential area. The proposed Hiukitak River Cultural Area is on the eastern shore of northern Bathurst Inlet and is outside of the marine RSA, approximately 120 km northeast of Roberts Bay (by water).

10.2.3 Regulatory Framework

Several federal regulations guide development where it pertains to fish and fish habitat protection. These include the:

- Canada *Fisheries Act* (1985c);
- Metal Mining Effluent Regulations (SOR/2002-222); and
- Canada *Species at Risk Act* (SARA; 2002a)

The following sections describe these acts, regulations, and guidelines and how they apply to the protection of fish and fish habitat. Other federal and territorial acts and regulations relevant to Marine Water Quality and Marine Sediment Quality such as the *Arctic Waters Pollution Prevention Act (1985a), Canada Water Act* (1985b), and *Nunavut Waters and Nunavut Surface Rights Tribunal Act* (2002b) are discussed in Volume 5, Chapters 8 and 9.

10.2.3.1 Canada Fisheries Act

Fish and fish habitat are protected under the *Fisheries Act* (1985c), as well as other federal regulatory acts and principles. In 2012, the *Fisheries Act* was amended to establish (into legislation) the federal government's direction to focus efforts on protecting the productivity of commercial, recreational, and Aboriginal (CRA) fisheries; to institute enhanced compliance and protection tools that are more easily enforceable; to provide clarity, certainty, and consistency of regulatory requirements; and to enable enhanced partnerships with stakeholders.

The *Fisheries Act* includes a prohibition against causing "serious harm to fish" that are part of, or support a, CRA fishery (Section 35), provisions for flow and passage (Sections 20 and 21), and a framework for regulatory decision-making (Sections 6 and 6.1). The fisheries protection provisions of the *Fisheries Act* aim to provide for the sustainability and ongoing productivity of CRA fisheries (DFO 2013c).

The four factors in Section 6 and 6.1 to be taken into account by the Minister of DFO in decision-making (e.g., issuing authorizations) or making regulations are:

- the contribution of the relevant fish to the ongoing productivity of commercial, recreational, or Aboriginal fisheries;
- fisheries management objectives;
- whether there are measures and standards to avoid, mitigate, or offset serious harm to fish that are part of a commercial, recreational, or Aboriginal fishery; and
- public interest.

For the purposes of the *Fisheries Act*, "serious harm to fish" includes the death of fish or any permanent alteration to, or destruction (PAD) of fish habitat. The *Fisheries Act* defines fish habitat as "spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas, on which fish depend directly or indirectly in order to carry out their life processes." The term "fish" includes parts of fish; shellfish, crustaceans, marine animals, and any parts of shellfish, crustaceans, or marine animals; and the eggs, sperm, larvae, spat, and juvenile stages of fish, shellfish, crustaceans, and marine animals. An alteration of fish habitat is considered a permanent alteration if it is "of a spatial scale, duration or intensity that limits or diminishes the ability of fish to use such habitats… in order to carry out one or more of their life processes". An alteration of fish habitat is considered the destruction of fish habitat if it is "of a spatial scale, duration, or intensity that fish can no longer rely upon such habitats…in order to carry out one or more of their life processes".

The Marine Mammal Regulations (SOR/93-56) apply to the management and control of fishing for marine mammals and related activities in Canada or Canadian fisheries waters. Prohibitions under the Regulation include no disturbance of a marine mammal except when fishing under the authority of the Regulations. Going forward, for the purposes of this assessment, marine mammals will be addressed in the Marine Wildlife Chapter 11 in Volume 5.

The *Fisheries Protection Policy Statement* (DFO 2013c) was issued on November 1, 2013 and replaced the earlier *Policy for the Management of Fish Habitat* (DFO 1986). Although the new policy statement does not include the "no net loss" principle, as outlined in the earlier policy, application of this "no net loss" principle has been used to provide useful guidance when considering "serious harm to fish". Additional information is also available through scientific guidance documents developed by DFO (Koops et al. 2013; Randall et al. 2013). DFO's *Fisheries Protection Program* (FPP; DFO 2016a)) is responsible for the administration of the fisheries protection provisions of the *Fisheries Act*. Any project or activity that causes serious harm to fish that are part of, or support, a CRA fishery requires an authorization from DFO. Regulations have been developed to guide the application for this authorization under Paragraph 35(2)(b) of the *Fisheries Act* Regulations (DFO 2013a). DFO has issued additional guidance to support proponents in their approach to offsetting in *The Fisheries Productivity Policy – A Proponent's Guide to Offsetting* (DFO 2013b). As indicated above, any issues associated with marine mammals will be addressed in the Marine Wildlife Chapter 11 in Volume 5.

10.2.3.2 Metal Mining Effluent Regulations

In 1996, Environment Canada undertook an assessment of the aquatic effects of mining in Canada. This assessment provided recommendations regarding the review and amendment of the Metal Mining Liquid Effluent Regulations, currently titled the Metal Mining Effluent Regulations (MMER; SOR/2002-222), and the design of a national Environmental Effects Monitoring (EEM) program for metal mining. The MMER, under the *Fisheries Act*, instruct metal mines to conduct EEM as a condition governing the authority to deposit effluent (MMER, Part 2, section 7).

The MMER (SOR/2002-222) permit the deposition of mine effluent into sea water containing fish if the effluent pH is within a defined range, the concentrations of the MMER deleterious substances in the effluent do not exceed authorized limits, and the effluent is demonstrated to be non-acutely lethal to a marine test species such as echinoids (sea urchins and sand dollars) (Environment Canada 1992). These discharge limits were established as minimum national standards based on best available technology economically achievable at the time that the MMER were promulgated. To assess the adequacy of the effluent regulations for protecting the aquatic environment, the MMER include EEM requirements to evaluate the potential effects of effluents on fish, fish habitat, and the use of fisheries resources.

Regulations Amending the MMER were published in the Canada Gazette, Part II, in October 2006 (Canada Gazette 2006). The purpose of these amendments was to clarify the regulatory requirements by addressing matters related to the interpretation and clarity of the regulatory text that had emerged from the implementation of the Regulations. Additional amendments to the MMER were published in the Canada Gazette, Part II, in March 2012 (Canada Gazette 2012). The following changes were made in 2012 to expand EEM provisions of the MMER:

- modifications to the definition of an "effect on fish tissue" in order to be consistent with the Health Canada fish consumption guidelines and to clarify that the concentration of total mercury in tissue of fish from the exposure area must be statistically different from and higher than its concentration in fish tissue from the reference area;
- addition of selenium and electrical conductivity to the list of parameters required for effluent characterization and water quality monitoring;
- exemption for mines, other than uranium mines, from monitoring radium 226 as part of the water quality monitoring, if 10 consecutive test results showed that radium 226 levels are less than 10% of the authorized monthly mean concentration (subsection 13(2) of the Regulations; SOR/2002-222);
- change to the time frame for the submission of interpretative reports for mines with effects on the fish population, fish tissue, and benthic invertebrate community from 24 to 36 months;
- change to the time frame for the submission of interpretative reports for magnitude and geographic extent of effects, and for investigation of cause of effects, from 24 to 36 months; and
- minor changes to the wording for consistency within Schedule 5.

10.2.3.3 Canada Species at Risk Act

The federal *Species at Risk Act* (SARA; 2002c) is designed to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses and identifies species at risk. COSEWIC is designated under SARA to assess species according to their level of conservation concern: *extinct*, *extirpated*, *endangered*, *threatened*, *special concern*, *not at risk* or *data deficient*. Only those species listed in Schedule 1 of the *Act* qualify for legal protection and recovery under SARA. The Act prohibits the killing, harming, harassing, capturing or taking of an individual of a wildlife species that is listed in Schedule 1 as *extirpated*, *endangered* or *threatened* by SARA (section 32(1)). SARA also protects the residence of species listed as *extirpated*, *endangered* or *threatened* from being damaged and destroyed as specified in Section 33. No SARA-listed species were captured in marine habitats in baseline studies; however a single Bering Wolffish individual was captured in 2017. COSEWIC assessed the Bering Wolffish as "data deficient" in 2002 and this species is listed under SARA Schedule 3, Special Concern, and thus does not qualify for legal protection and recovery under SARA.

10.2.4 Data Sources

This section provides a brief chronological history of surveys of marine fish habitat and fish communities in the LSA and RSA. Marine fish habitat comprises two components: (1) biological resources such as phytoplankton, zooplankton and benthic invertebrates; and (2) physical fish habitat and fish community.

Although environmental studies of the Hope Bay Belt began in 1993 with surveys of the freshwater aquatic environment of the Boston area (Rescan 1993), sampling of the marine environment did not begin until 1997. Sampling of benthic invertebrates was conducted in Roberts Bay for BHP Minerals Canada Ltd. in 1997 and for BHP Diamonds Inc. in 1998. No studies of physical fish habitat or marine fish were conducted during the 1990s.

Miramar Hope Bay Ltd./Hope Bay Joint Venture (Miramar) acquired the property in 1999, and initiated studies in Roberts Bay of physical marine habitat (in 2000, 2003, and 2004), biological resources (phytoplankton biomass in 2006 and 2007, phytoplankton taxonomy in 2007, and zooplankton taxonomy in 2007), and marine fish communities (2002 to 2007).

Miramar also took the Doris property through the environmental permitting process in Nunavut, and was issued a Project Certificate by the Nunavut Impact Review Board (NIRB), a Type A water licence by the Nunavut Water Board (NWB), and a Schedule 2 amendment to the Metal Mining Effluent Regulations (MMER) for Tailings Impoundment Area (TIA). Other regulatory approvals were also obtained including a Fisheries Authorization and Fish Habitat Compensation Agreement for habitat lost by construction of the Roberts Bay Jetty, a Navigable Waters Authorization, a Water Compensation Agreement with the Kitikmeot Inuit Association (KIA), and an Inuit Impacts and Benefits Agreement (IIBA) with the KIA.

Newmont Mining Corporation acquired the property in March 2008, and formed Hope Bay Mining Ltd. (HBML) to continue exploration activities, and evaluate various options for long-term development of the belt. That work included preparing a review of baseline studies and a data gap analysis (Rescan 2009a). HBML continued sampling of Roberts Bay for marine habitat (2009 and 2010), biological resources (phytoplankton biomass from 2009 to 2012, phytoplankton taxonomy in 2009 and 2010, zooplankton taxonomy in 2009, and benthic invertebrates form 2009 to 2011), and marine fish communities (2007, 2009, and 2010).

In 2012, TMAC acquired the property and continued freshwater aquatic studies including baseline studies, annual compliance reports, and reports of the Aquatic Effects Monitoring Program (AEMP) of the Doris Project.

In summary, surveys of the marine aquatic environment of Roberts Bay began in 1997 and have continued to 2017 under three proponents and under both baseline sampling and compliance monitoring programs.

10.2.4.1 Marine Fish Habitat - Marine Biological Resources

Biological resources data were compiled from site-specific surveys in the LSA and RSA conducted from 1997 to 2017. The primary sources of biological resource information used in the EIS were collected between 2009 and 2017 in Roberts Bay and Ida Bay, including baseline studies (Rescan 2010a; 2011e ; ERM 2017b) and Aquatic Effects Monitoring Program (AEMP) sampling for the Doris North Project (Rescan 2011c, 2011b, 2011f, 2012a, 2013b; ERM Rescan 2014; ERM 2015, 2016, 2017a). Data collected historically (1997 to 2007) in Roberts Bay and Hope Bay are included where applicable, however, due to the inter-annual variability in the field and laboratory methods some data were not used for comparisons (e.g., phytoplankton density). All reports can be found in appendices as indicated below, except the Doris North Project Aquatic Effects Monitoring Program reports, which are available on the Nunavut Impact Review Board (NIRB) FTP (http://ftp.nirb.ca) and Nunavut Water Board FTP (ftp://ftp.nwb-oen.ca) sites.

- Hope Bay Belt Project - 1997 Environmental Data Report (Rescan 1998);
- Hope Bay Belt Project - 1998 Environmental Data Report (Rescan 1999);
- Boston and Madrid Project Areas: 2006 - 2007 Aquatic Studies (Golder Associates Ltd. 2008);
- 2009 Marine Baseline Report, Hope Bay Belt Project (Rescan 2010a);
- Hope Bay Belt Project: 2010 Marine Baseline Report (Rescan 2011e);
- Hope Bay Belt Project: 2010 Regional Marine Baseline Report (Rescan 2011f);
- Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report (Rescan 2011b);
- Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program (AEMP) Marine Expansion Base Report (Rescan 2011c);
- Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report (Rescan 2012a);
- Doris North Gold Mine Project: 2012 Aquatic Effects Monitoring Program Report (Rescan 2013b);
- Doris North Project: 2013 Aquatic Effects Monitoring Program (ERM Rescan 2014);
- Doris North Project: 2014 Aquatic Effects Monitoring Program (ERM 2015);
- Doris North Project: 2015 Aquatic Effects Monitoring Program Report (ERM 2016);
- Doris Project: 2016 Aquatic Effects Monitoring Program Report (ERM 2017a); and
- Doris Project: 2016 Roberts Bay Marine Baseline Report (ERM 2017b).

10.2.4.2 Marine Fish Habitat – Physical Characteristics and Fish Community

Baseline surveys of marine physical habitat and fish community in Roberts Bay were conducted in 2000, 2003, 2004, 2009, 2010 and 2017 as part of studies of marine fish communities (Rescan 2001; RL&L/Golder 2003; Golder 2005; Rescan 2010b, 2011a; ERM 2017c). Eleven years of marine fish community and fish habitat information (2000 to 2007, 2009, 2010, and 2017) is available for Roberts Bay, and 2 years of marine fish community information (2009 and 2010) is available for Ida Bay.

Most of the sampling effort from 2000 to 2007 focused on collecting fish community and habitat information from the mouth of Little Roberts Outflow and from the existing jetty location. In 2009 and 2010, sampling effort in Roberts Bay focused on potential marine infrastructure sites (two sites in 2009 and five sites in 2010), and the jetty and compensation shoals for the Doris North Fisheries Authorization Monitoring Program. The proposed cargo dock infrastructure is positioned adjacent and between two of the five sites sampled in 2010. In 2017, additional information on fish and fish habitat was thus collected specifically at the proposed cargo dock location, and areas sampled for Arctic Char as part of the Human Health Risk Assessment (Volume 6 Chapter 5; (ERM 2017c)). Full details of the baseline and compensation programs used to collect information are described in reports listed below.

Reports publically available on the Nunavut Impact Review Board (NIRB) FTP site (http://ftp.nirb.ca) and/or Nunavut Water Board (NWB) FTP site (ftp://ftp.nwb-oen.ca) are the following:

- Doris North Project Aquatic Studies 2004 (Golder 2005; Appendix V5-4G);
- Doris North Project Aquatic Studies 2006 (Golder 2007a; Appendix V5-4I);
- Doris North Project "No Net Loss" Plan – Revision 6 Final Report (Golder 2007b; Appendix V5-6B);
- Doris North Project Aquatic Studies 2007 (Golder 2008b; Appendix V5-4J);
- Doris North Gold Mine Project: 2010 Roberts Bay Jetty Fisheries Authorization Monitoring Report (Rescan 2010c; Appendix V5-10A);
- Hope Bay Belt Project: 2000 Supplemental Environmental Baseline Data Report (Rescan 2001; V5-3C);
- Doris North Project Aquatic Studies 2002 (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003a; Appendix V5-5A);
- Doris North Project Aquatic Studies 2003 (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003b; Appendix V5-3E);
- Doris North Project Aquatic Studies 2005 (Golder 2006; V5-4H);
- Doris North Gold Mine Project: 2008 Roberts Bay Authorization Monitoring Report (Golder 2008a); Appendix V5-10B);
- Doris North Gold Mine Project: 2009 Roberts Bay Jetty Fisheries Authorization Monitoring Report (Rescan 2009b; Appendix V5-10C);
- 2009 Marine Fish and Fish Habitat Baseline Report, Hope Bay Belt Project (Rescan 2010b; Appendix V5-10D); and
- 2010 Marine Fish and Fish Habitat Baseline Report, Hope Bay Belt Project (Rescan 2011a; Appendix V5-10E).

One new report not previously available on NIRB and/or NWT FTP sites includes the following:

- Hope Bay Project: 2017 Marine Fish and Fish Habitat Baseline Report (ERM 2017c; Appendix V5-10F).

Supplementary information for the RSA was obtained from the Back River Draft EIS (Rescan 2013a), which sampled the marine fish community in southern Bathurst Inlet, and DFO's *Annotated List of the Arctic Marine Fishes of Canada* (DFO 2004).

10.2.5 Methods

10.2.5.1 Marine Fish Habitat – Biological Resources

Marine biological resource (phytoplankton, zooplankton, and benthic invertebrates) information has been collected in Roberts Bay (LSA), Ida Bay (RSA), and Hope Bay (RSA) since 1997, and has included baseline surveys (Rescan 1998, 1999; Golder Associates Ltd. 2008; Rescan 2010a, 2011e, 2011f, 2012b; ERM 2017b) and AEMP sampling (Rescan 2011c, 2011b, 2011f, 2012a, 2013b; ERM Rescan 2014; ERM 2015, 2016, 2017a) The most intensive sampling has occurred in Roberts Bay where Project activities have been focussed, with sampling being conducted along the perimeter of the bay as well as within the deep pelagic waters. The biological components that have been surveyed and the methods with which they have been collected are described below.

<u>Phytoplankton</u>

Phytoplankton is a group of free-floating photosynthetic microorganisms that use inorganic nutrients and sunlight to produce organic matter. They play an important ecological role in many aquatic systems as primary producers and food for higher trophic levels. In the marine environment, phytoplankton is the main source of food for zooplankton, which is consumed directly by planktivorous fish. Zooplankton is also consumed by certain pelagic and benthic invertebrates, which constitute important food resources for insectivorous and omnivorous species of fish.

Baseline phytoplankton samples were collected for biomass (as indexed by the concentration of chlorophyll *a*) during the under-ice (April) and open-water (July, August, September/October) seasons and for taxonomy (community composition) during the open-water season. Baseline samples were collected locally from 12 different sites in Roberts Bay from 2006 to 2011, and at the near-shore sites RBW and RBE from 2010 to 2016 as part of the Doris AEMP program (biomass only; Table 10.2-1 and Figure 10.2-3). Regionally, samples were collected from several sites in Ida Bay between 2009 and 2016 and at one site in Hope Bay during the summer of 2007 (Table 10.2-2).

Phytoplankton biomass (as chlorophyll *a*) and taxonomy samples were collected in triplicate from 1 m depth using Niskin (ice-covered sampling) or GO-FLO sampling bottles (open-water sampling). In 2006 and 2007, single samples were collected from 3-m depth using a Kemmerer bottle sampler and depth-integrated water sampler, respectively. Biomass samples were transferred into 1 L plastic bottles and stored in coolers (i.e., cool, dark environment). The biomass samples were filtered onto 0.45 μm filters, which were then wrapped in aluminum foil, and stored frozen. Chlorophyll samples were hand carried to Vancouver (BC) to ensure they remained frozen, and then sent to ALS Environmental (Burnaby, BC) for analyses. Taxonomy samples were preserved with Lugol's iodine solution and were sent to a qualified taxonomist for enumeration and identification.

Phytoplankton communities were described using abundance (cells/L), richness (number of taxa per sample), and diversity (Simpson's Diversity Index). The Simpson's Diversity Index is considered a dominance index because it weights towards the most abundant species (represents the probability that two individuals selected at random from the population are different species or genera) and is defined as:

$$D = 1 - \Sigma(p_i)^2$$

where p_i is the proportion of the i^{th} taxa at a sampling station and Σ indicates that the $(p_i)^2$ is summed over all taxa.

Figure 10.2-3
Marine Phytoplankton Sampling Sites, 2006 to 2016

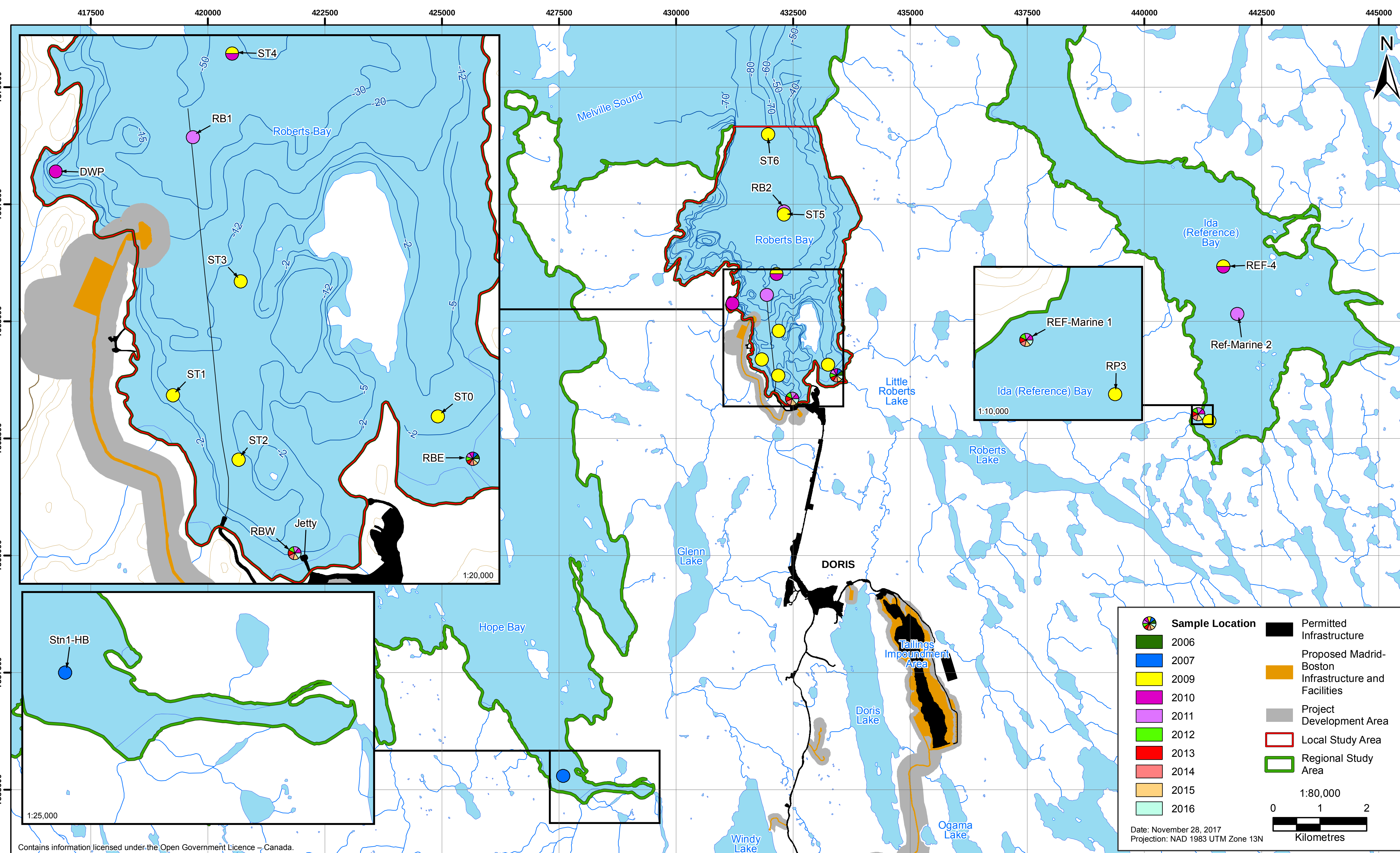


Table 10.2-1. Marine Phytoplankton Biomass (as Chlorophyll *a*) Sampling Sites, 2006 to 2016

	2006	2007	2009	2010	2011	2012	2013	2014	2015	2016
Roberts Bay	**Sep**	**Jul, Aug, Sep**	**Aug**	**Apr, Jul, Aug, Sep/Oct**	**Apr, Jul, Aug, Sep**	**Apr, Jul, Aug, Sep**	**Apr, Jul, Aug, Sep**	**Apr, Jul, Aug, Sep**	**Apr, Jul, Aug, Sep**	**Apr, Jul, Aug, Sep**
RBW	-	-	-	X	X	X	X	X	X	X
RBE	X[a]	X[a]	-	X	X	X	X	X	X	X
ST0	-	-	X	-	-	-	-	-	-	-
ST1	-	-	X	-	-	-	-	-	-	-
ST2	-	-	X	-	-	-	-	-	-	-
ST3	-	-	X	-	-	-	-	-	-	-
ST4	-	-	X	X	-	-	-	-	-	-
ST5	-	-	X	-	-	-	-	-	-	-
ST6	-	-	X	-	-	-	-	-	-	-
DWP	-	-	-	X	-	-	-	-	-	-
RB1	-	-	-	-	X	-	-	-	-	-
RB2	-	-	-	-	X	-	-	-	-	-
Ida Bay										
REF-Marine 1	-	-	-	X[b]	X	X	X	X	X	X
REF-Marine 2	-	-	-	-	X	-	-	-	-	-
RP3	-	-	X	-	-	-	-	-	-	-
REF4	-	-	X	X	-	-	-	-	-	-
Hope Bay										
Stn1-HB	-	X	-	-	-	-	-	-	-	-

Notes:
Dashes indicate no samples were collected.
Three replicates collected at each sampling site unless otherwise indicated.
[a] *Single replicate collected at each site.*
[b] *July and August sampling only.*

Table 10.2-2. Marine Phytoplankton Taxonomy Sampling Sites, 2007 to 2010

	2007	2009	2010
Roberts Bay	**Jul, Aug, Sep**	**Aug**	**Aug, Sep**
ST0	-	X	-
ST1	-	X	-
ST2	-	X	-
ST3	-	X	-
ST4	-	X	X[b]
ST5	-	X	-
ST6	-	X	-
Ida Bay			
RP3	-	X	-
REF4	-	X	X
Hope Bay			
Stn1-HB	X[a]	-	-

Notes:
Dashes indicate no samples were collected.
Three replicates collected at each sampling site unless otherwise indicated.
[a] *Single replicate collected at each site.*
[b] *August sampling only.*

Zooplankton

Marine zooplankton communities are key sources of food for planktivorous fish species, and they are an important trophic linkage between primary producers and higher trophic levels in marine food webs. Baseline zooplankton samples were collected for abundance and taxonomy at six sites in Roberts Bay in August 2009, at two sites in Ida Bay in August 2009, and one site in Hope Bay in July, August, and September 2007 (Table 10.2-3; Figure 10.2-4).

In 2009, zooplankton samples were collected in triplicate at each site using a Birge-style zooplankton net with a mesh size of 202 µm fitted with a flow meter. Vertical tows were conducted at deep sites (>20 m; ST4-ST6 and REF4), oblique tows at shallower depths (5-20 m; ST1-ST3 and RP3), and horizontal tows at the shallowest site (3 m; ST0). Vertical tows were conducted by lowering the net to 1 m above the sediment and brought to the surface at a speed of 0.5 m/s. Oblique and horizontal tows were conducted by slowly dragging the net behind a moving aluminum boat. Flow meter readings were taken before and after net deployment to determine the volume of water that passed through the net. Similar volumes were sampled for each replicate haul so that species-volume relationships were maintained and diversity relationships were comparable. In 2007, a single zooplankton sample was collected in July, August, and September using a Wisconsin net with a mesh size of 153 µm. Samples were collected by performing a vertical tow from 1m above the sediment to the water surface. A flow meter was not used for these tows.

Zooplankton samples were preserved with 10% buffered formalin and sent to a qualified taxonomist for enumeration and identification. In 2009, zooplankton communities were described using abundance (organisms/m^3), richness (number of genera per sample) and diversity (Simpson's Diversity Index at a genera level). In 2007, zooplankton communities were described using biomass (µg/m^3).

Figure 10.2-4
Marine Zooplankton Sampling Sites, 2007 and 2009

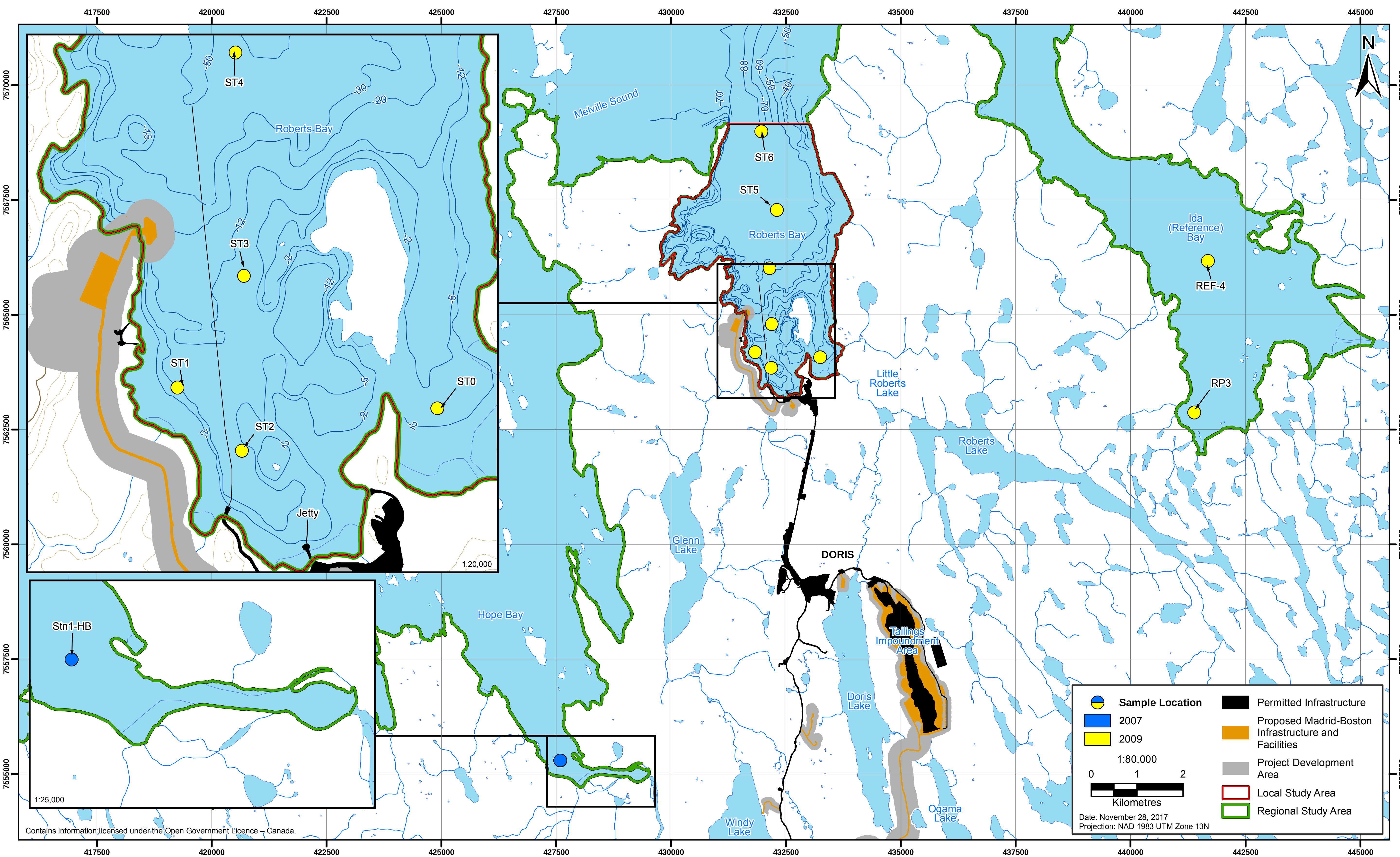


Table 10.2-3. Marine Zooplankton Taxonomy Sampling Sites, 2007 and 2009

Roberts Bay	2007 Jul, Aug, Sep	2009 Aug
ST0	-	X
ST1	-	X
ST2	-	X
ST3	-	X
ST4	-	X
ST5	-	X
ST6	-	X
Ida (Reference) Bay		
RP3	-	X
REF4	-	X
Hope Bay		
Stn1-HB	Xa	-

Notes:
Dashes indicate no samples were collected.
Three replicates collected at each sampling site unless otherwise indicated.
[a] *Single replicate collected at each site.*

Benthic Invertebrates

Marine benthic invertebrates (also known as benthos) are both an important source of food for benthic-feeding fishes and are an important linkage for energy transfer between lower (e.g., primary producers) and higher trophic levels of marine food webs, including those ultimately occupied by piscivorous fishes, birds, and mammals (Hobson and Welch 1992; DFO 2008; McMeans et al. 2013). In the shallow waters of coastal environments (<40 m depth), like the nearshore sites of Roberts Bay, benthic organisms can be responsible for 80% of the total ecosystem primary production (Rysgaard and Nielsen 2006).

Baseline benthos samples were collected from 34 different sites in Roberts Bay from 1997 to 2016 (Table 10.2-4; Figure 10.2-5). In the RSA, benthic invertebrates were collected at five sites in Ida Bay from 2009 to 2016, and at three sites in Hope Bay in 1998 (Figure 10.2-5). All benthic invertebrate samples were collected in August, except in 1998 when samples were collected in July.

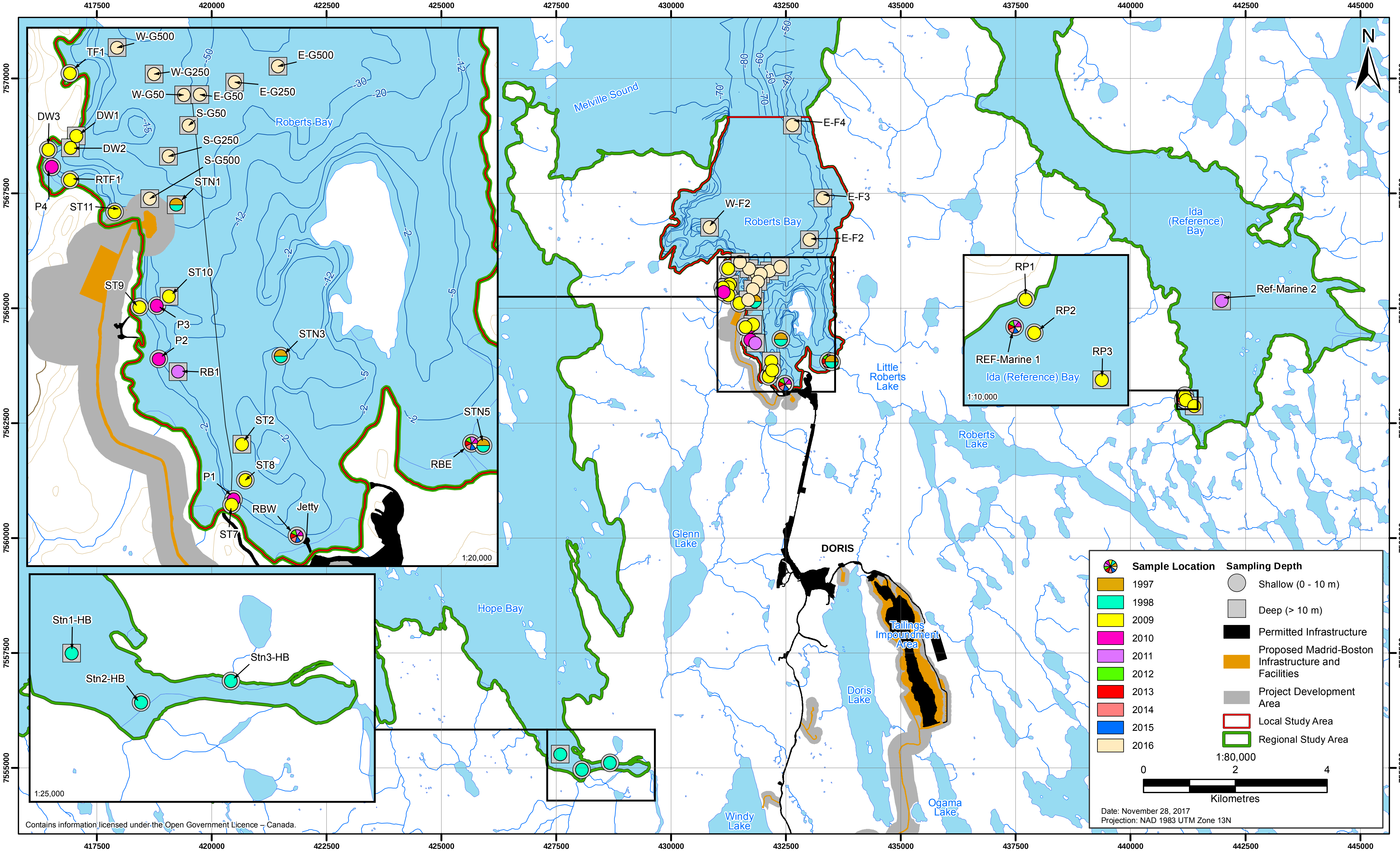
Table 10.2-4. Marine Benthic Invertebrate Sampling Sites, 1997 to 2016

Roberts Bay	Depth (m)	1997 Aug	1998 Jul	2009 Aug	2010 Aug	2011 Aug	2012 to 2015 Aug	2016 Aug
RBW	<5	-	-	-	X[a]	X[a]	X[a]	X[a]
RBE	<5	-	-	-	X[a]	X[a]	X[a]	X[a]
STN1	15.5-19	X	X	-	-	-	-	-
STN3	9.5-10.4	X	X	-	-	-	-	-
STN5	0.75-1.2	X	X	-	-	-	-	-
ST2	7	-	-	X	-	-	-	-
ST7	2	-	-	X	-	-	-	-
ST8	8	-	-	X	-	-	-	-
ST9	2	-	-	X	-	-	-	-

Roberts Bay	Depth (m)	1997 Aug	1998 Jul	2009 Aug	2010 Aug	2011 Aug	2012 to 2015 Aug	2016 Aug
ST10	13	-	-	X	-	-	-	-
ST11	8	-	-	X	-	-	-	-
DW1	13	-	-	X	-	-	-	-
DW2	13	-	-	X	-	-	-	-
DW3	1	-	-	X	-	-	-	-
RTF1	3	-	-	X	-	-	-	-
TF1	2	-	-	X	-	-	-	-
P1	5.5	-	-	-	X	-	-	-
P2	3	-	-	-	X	-	-	-
P3	3.5	-	-	-	X	-	-	-
P4	5	-	-	-	X	-	-	-
RB1	42	-	-	-	-	X[a]	-	-
W-G50	53-68	-	-	-	-	-	-	X[a]
E-G50	49-50	-	-	-	-	-	-	X[a]
S-G50	54	-	-	-	-	-	-	X[a]
W-G250	49-52	-	-	-	-	-	-	X[a]
E-G250	45-51	-	-	-	-	-	-	X[a]
S-G250	39-40	-	-	-	-	-	-	X[a]
W-G500	39-44	-	-	-	-	-	-	X[a]
E-G500	51-53	-	-	-	-	-	-	X[a]
S-G500	31	-	-	-	-	-	-	X[a]
W-F2	36-38	-	-	-	-	-	-	X[a]
E-F2	41-44	-	-	-	-	-	-	X[a]
E-F3	44-46	-	-	-	-	-	-	X[a]
E-F4	39-45	-	-	-	-	-	-	X[a]
Ida (Reference) Bay								
REF-Marine 1	<5	-	-	-	X[a]	X[a]	X[a]	X[a]
REF-Marine 2	40	-	-	-	-	X[a]	-	-
RP1	5	-	-	X	-	-	-	
RP2	9	-	-	X	-	-	-	-
RP3	14	-	-	X	-	-	-	-
Hope Bay								
Stn1-HB	3.7	-	X	-	-	-	-	-
Stn2-HB	3.6	-	X	-	-	-	-	-
Stn3-HB	8	-	X	-	-	-	-	-

Notes:
Dashes indicate no samples were collected.
[a] *Each replicate was a composite of three subsamples.*

Figure 10.2-5
Marine Benthic Invertebrate Sampling Sites, 1997 to 2016



Benthos samples were collected in triplicate with an Ekman sampler in 1997 and with a Ponar dredge sampler in 1998, 2009, and 2010 (P1-P4). From 2010 to 2016, five composite (three subsamples each) benthos samples were collected using a Petite Ponar dredge sampler at RBW, RBE, and REF-Marine 1 sites as part of the Doris AEMP program. Replicate samples were collected approximately 5 to 50 m apart. Additional benthos samples were collected at 13 sites in Roberts Bay in 2016; one composite sample (consisting of three subsamples) was collected at each site using a Petite Ponar sampler. The sampler was carefully set open, lowered gradually onto the sediment floor using a metered cable, and triggered closed. Once recovered, either 1 L of each sample (2009 and 2010 only) or the entire sample was transferred into a 500 µm sieve bucket and rinsed with site water until free of sediment particles smaller than 500 µm. The material retained within the sieve was then transferred to a labelled plastic jar and filled with 10% buffered formalin. All benthos samples were sent to an analytical laboratory for enumeration and identification. Benthos counts were normalized to density as organisms/m^2 based on the total surface area sampled. Benthic invertebrate communities were described using density (organisms/m^2), richness (number of families or genus per sample), and diversity (Simpson's Diversity Index at a family or genus level).

Quality Assurance/Quality Control (QA/QC)

Chain of custody forms were used for all biological resources samples. Replicates were usually collected to account for environmental heterogeneity: three samples were collected for chlorophyll *a* (phytoplankton biomass), phytoplankton taxonomic analysis, zooplankton, and benthos (1997, 2009, and 2010), and five composite samples were collected for all AEMP benthos (2010 and 2016). Additional QA/QC measures were used by the benthic invertebrate taxonomists to ensure consistent and accurate sorting of benthos samples. As part of the AEMP QA/QC program, re-sorting of benthic sample residues was conducted on a randomly selected 10% of the samples of benthos to determine the level of sorting efficiency. The criterion for an acceptable sorting was that more than 90% of the cumulative number of organisms found in the initial + QA/QC sorts were recovered during the initial sort, as required by Environment Canada for invertebrate community surveys (Environment Canada 2002). This was calculated by the following equation:

$$\%\, sorting\ efficiency = \left(1 - \frac{\#\ in\ QA/QC\ re\text{-}sort}{\#\ sorted\ originally + \#\ in\ QA/QC\ re\text{-}sort}\right) \times 100$$

Any sample not meeting the 90% removal criterion was re-sorted a third time. The 90% minimum efficiency was attained for all samples of benthos.

10.2.5.2 Marine Fish Habitat – Physical Characteristics

Since 2000, marine fish habitat in Roberts Bay has been assessed using a suite of methods. Table 10.2-5 summarizes fish habitat sampling methods by year. Methods of fish habitat assessment were described in detail in Section 6.2.5.1 (Fish Habitat) of this EIS. Marine fish habitat outside of Roberts Bay has not been assessed, although observations were made of shoreline habitat in Ida Bay while fishing at that site.

Marine fish habitat is characterized as either shoreline, intertidal or subtidal. The shoreline is defined as habitats above the high water elevation. The intertidal zone is defined as all habitats between the high water elevation and 1 m below the low tide elevation. The subtidal zone is defined as all habitats below low tide elevation.

In 2000, aerial surveys of the shoreline and the intertidal zone of Roberts Bay were conducted by helicopter. In 2003, a bathymetric map of Roberts Bay was first prepared. In 2004, 2009, 2010 and 2017, visual surveys of the intertidal zone were conducted by walking and/or boating along the shoreline. Description of the substrate in the intertidal zone was accomplished by first dividing it into homogenous habitat units. For example, in 2009, habitat surveys of three potential dock sites were conducted by walking along the shoreline and delineating habitat units based on the dominant type of littoral zone substrate. Substrate types were divided into the following size classes: bedrock (> 4,000 mm), boulder (256 to 4,000 mm), cobble (64 to 256 mm), gravel (2 to 64 mm), fines (0 to 2 mm). Within each habitat unit, substrate composition was recorded as a percent coverage (e.g., 70% cobble, 20% gravel, and 10% fines) and the length of each unit was measured. Ground and aerial photographs were taken to illustrate various types of habitat units. In the office, a combination of field notes and photographs were used to create habitat maps.

Table 10.2-5. Summary of Marine Fish Habitat Surveys Conducted in Roberts Bay, 2000 to 2017

Year	Sampled Environment			Survey Type				
	Shoreline	Intertidal	Subtidal	Bathymetry	Hydroacoustic	Visual	Aerial	Underwater Video
2000	X	X	-	-	-	-	X	-
2003	-	X	X	X	-	-	-	-
2004	-	X	-	-	-	X	-	-
2009	-	X	X	-	-	X	-	-
2010	-	X	X	-	X	X	-	X
2017	-	X	X	X	X	X	-	-

Note: X = survey completed, - = survey not done

Subtidal zone habitat was characterized using observations collected through visual survey, hydroacoustics and/or underwater video sampling. In 2009, the upper subtidal was visually surveyed. In 2010, the subtidal was surveyed using hydroacoustic techniques ground-proofed by video cameras. In 2017, hydroacoustic techniques were also used and ground-proofed by Ekman grabs of the bottom sediment. Hydroacoustic surveys characterized dominant substrates based on bottom echo types along the surveyed transect lines. Underwater videos and/or Ekman grabs were used to verify the hydroacoustic substrate classifications. Mapping software was then used to interpolate substrate classifications and depth into maps.

10.2.5.3 Marine Fish Community

Since 2002, the marine fish community in Roberts Bay has been assessed using a suite of gear chosen to sample a variety of habitats and species. Sampling gear included gillnets, fyke nets, angling, minnow traps, beach seines, crab traps, and long-lines. Table 10.2-6 summarizes the fish community sampling methods, general sample locations, and sampling dates for each year since 2000.

The sampling methods varied between years depending upon the survey objectives. With two exceptions (crab traps and long lines), all methods of fishing were described in detail in Section 6.2.5.2 (Freshwater Fish) of this EIS.

Crab traps were used to sample large-bodied invertebrates (e.g., crabs, isopods), but they also captured fish (Rescan 2010b, 2011a; ERM 2017c). Traps were placed overnight in the deeper waters of each site in Roberts Bay and Ida Bay. Long lines were also used to capture actively-feeding fish in Roberts Bay and Ida Bay.

From 2002 to 2007, the objective was to determine fish species composition, relative abundance, movement, and biology of the nearshore subtidal area of Roberts Bay for a proposed marine jetty off-loading facility.

Table 10.2-6. Fish Community Sampling Methods, Locations, and Dates in Roberts Bay and Ida Bay from 2002 to 2017

Sample Method	Year								
	2002 August 27 to September 2	2003 July 24 to 28 August 9 to 29	2004 August 20 to 21	2005 August 8 to 12	2006 July 10 to 12	2007 July 12 to 17	2009 August 21 to September 5	2010 July 30 to August 19 August 29 to September 24	2017 August 2 to August 9 August 17 to August 27
Sinking Gillnet	-	• Multiple panels, each panel 15.1 × 1.5 m • Variable mesh, 19 - 109 mm • Throughout Roberts Bay near Little Roberts Outflow, jetty, compensation shoals, proposed marine outfall berm	-	-	-	-	• 6 panels, totalling 91.2 × 2.4 m • Variable mesh, 25 - 89 mm • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• 6 panels, totaling 91.2 × 2.4 m • Variable mesh, 25 - 89 mm • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• 6 panels, totalling 91.2 × 2.4 m • Variable mesh, 25 - 89 mm • LSA (Roberts Bay; including potential marine infrastructure site; near Glenn and Little Roberts Outflow)
Floating Gillnet	-	-	-	-	-	-	• 6 panels 91.2 × 2.4 m • Variable mesh, 25 - 89 mm • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• 6 panels 91.2 × 2.4 m • Variable mesh, 25 - 89 mm • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• 6 panels 91.2 × 2.4 m • Variable mesh, 25 - 89 mm • LSA (Roberts Bay; including potential marine infrastructure site; and near Glenn and Little Roberts Outflow)
Beach Seine	-	• Roberts Bay at Little Roberts Outflow	• Roberts Bay at Little Roberts Outflow	• Jetty	-	-	• Marine shoreline • LSA (Roberts Bay) and RSA (Ida Bay)	• Marine shoreline • LSA (Roberts Bay) and RSA (Ida Bay)	• Marine shoreline • LSA (Roberts Bay at potential marine infrastructure site)
Minnow Trap	-	-	-	-	-	-	• LSA (Roberts Bay; Marine shoreline and rock structures [jetty and shoals]) • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• LSA (Roberts Bay; Marine shoreline and rock structures [jetty and shoals]) • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• LSA (Roberts Bay at potential marine infrastructure site)
Angling	-	-	-	• Throughout LSA (Roberts Bay)	-	-	-	-	• LSA (Roberts Bay; including potential marine infrastructure site; and near Glenn and Little Roberts Outflow)
Fyke Net	• Roberts Bay along western shoreline	• Roberts Bay at Little Roberts Outflow	• Roberts Bay at Little Roberts Outflow	• Jetty	• Jetty	• Jetty	-	• LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals)	-
Crab Trap	-	-	-	-	-	-	• Marine fish and benthos • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• Marine fish and benthos • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• Marine fish and benthos • LSA (Roberts Bay at potential marine infrastructure site)
Visual Observation	-	-	-	-	-	-	• Snorkel surveys • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	-	-
Long Line	-	-	-	-	-	-	• Floating/sinking combination line • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• Suspended line, hooks at 2.5 m intervals • LSA (Roberts Bay; including potential marine infrastructure sites; jetty and compensation shoals) • RSA (Ida Bay; including reference site and shoals)	• Suspended line, hooks at 2.5 m intervals • LSA (Roberts Bay at potential marine infrastructure site)

Note: Dash indicates not sampled

The most intensive marine fish community programs in Roberts Bay and Ida Bay were conducted in 2009 and 2010 (Rescan 2009b, 2010b, 2011a).The 2009 fish community survey objectives were to:

- collect baseline nearshore intertidal and subtidal fish community, macrobenthos community (i.e., large-bodied benthos), and fish habitat data at potential marine infrastructure sites in Roberts Bay;
- collect baseline nearshore intertidal and subtidal fish community and macrobenthos community data in Ida Bay as a reference location; and
- determine baseline nearshore intertidal and subtidal fish community and macrobenthos community at the four shoals in Roberts Bay (artificial shoals) and Ida Bay (natural shoals).

The 2010 fish community survey objectives were to:

- collect baseline nearshore intertidal and subtidal fish community, macrobenthos community and fish habitat at five potential marine infrastructure sites in Roberts Bay;
- collect baseline nearshore intertidal and subtidal fish community and macrobenthos community data in Ida Bay; and
- determine baseline nearshore intertidal and subtidal fish community and macrobenthos community at the four shoals in Roberts Bay and Ida Bay.

Additional fish community sampling effort was conducted in 2017 with the following objectives (ERM 2017c):

- collect baseline nearshore intertidal and subtidal fish community, macrobenthos community (i.e., large-bodied benthos), and fish habitat data at the proposed cargo dock location site in Roberts Bay that was not assessed previously as part of the EIS; and
- collect Arctic Char muscle samples throughout Roberts Bay as part of the Human Health Environmental Risk Assessment.

Figures 10.2-6 to 10.2-10 show the locations of sampling gears installed in the LSA and RSA from 2002 to 2007 and in 2009, 2010 and 2017. In 2009, a total of 38 floating gillnet sets, 48 sinking gillnet sets, 25 long line sets, 193 minnow trap sets, 84 crab trap sets, and 31 beach seines were conducted (Rescan 2010b, 2010c). In 2010, 56 floating gillnet sets, 59 sinking gillnet sets, 35 fyke net sets, 54 long line sets, 364 minnow trap sets, 177 crab trap sets, and 37 beach seines were conducted (Rescan 2010c, 2011a). Fish community sampling was conducted from the jetty west and northward along the shoreline of Roberts Bay. In 2017, a total of 5 floating gillnet sets, 23 sinking gillnet sets, 6 long line sets, 30 minnow trap sets, 15 crab trap sets, 6 beach seines hauls and 6 angling periods were conducted (ERM 2017c). Fish community sampling was mainly conducted near the proposed cargo dock location on the west shoreline of Roberts Bay with some more gillnets set and angling on the east side of Roberts Bay.

Significant fish community sampling effort was conducted along the western shoreline of Ida Bay in 2009 and 2010. In 2009, a total of 17 floating gillnet sets, 21 sinking gillnet sets, 16 long line sets, 116 minnow trap sets, 11 beach seines, and 42 crab trap sets were conducted (Rescan 2010b). In 2010, a total of 11 floating gillnets sets, 11 sinking gillnet sets, 10 long line sets, 167 minnow trap sets, 11 beach seines, and 57 crab trap sets were conducted (Rescan 2011a).

For all fish sampling conducted from 2002 to 2017, the following data were collected:

- UTM coordinates and depth of each location at which fishing gear was deployed.

- Date of deployment and times that each gear was installed and retrieved.
- Catch (both total and for each species) for each location, gear type, date, and retrieval time.
- Catch per unit effort (CPUE; e.g. number of fish caught per hour fishing of a fyke net) for each location, gear type, date, and retrieval time.
- Fate of each fish captured (released live, escaped during handling, or died during capture and handling).
- Biological data for each fish captured. At a minimum, data on species, length, and weight were collected. Fish with clipped fins indicating previous sampling for ageing purpose or fish carrying dorsal tags were noted and tag numbers recorded. For most fish that were released live non-destructive samples of ageing structures (scales and fin rays) were also taken for age reading.
- Additional biological data from accidental and euthanized mortalities (i.e., fish collected for diet analysis or tissue metals). These included sex and maturity, reproductive status, gonad weight, stomach contents, and collection of otoliths for ageing.
- Large fish (>300 mm long) were tagged using tags with unique numbers and released live to learn about migratory routes from their recapture (2009 and 2010 only).

Detailed biological data are available for review in the appended marine fish reports (refer to Section 10.2.4.2 for specific details).

A total of 25 fish species from 13 families were captured in marine waters during baseline surveys from 2002 to 2017, including 5 species that could only be identified to the family level. Table 10.2-7 shows their common names and scientific names.

Results of fish tagging are also not discussed in detail in this chapter, but are available for review in the appended marine fish reports, because the number of re-captures was too low to provide more than a confirmation of basic life history. Only four fish were re-captured after 8 years of tagging and many hundreds of tagged releases, as follows:

- Of the fish tagged in Roberts Bay in 2003, only two were recaptured (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003b). The first was an Arctic char (636 mm in fork length) tagged in Roberts Bay on August 21 that was recaptured on September 1 at the mouth of the Burnside River in Bathurst Inlet, approximately 200 km away, indicating migration within the RSA. The second fish was a Lake Trout re-captured (461 mm in fork length, weight = 955 g) in Roberts Bay on 12 August 2003 that had been originally tagged on 28 August 2002 in Roberts Outflow (428 mm in fork length), confirming out-migration from the Roberts system to Roberts Bay.
- Two of the 278 fish that were tagged and released after capture in trap nets in 2010 were re-captured – a recapture rate of less than 1%. One Arctic Char that was tagged on August 21 at one trap net was recaptured at a second trap net one day later, and one Saffron Cod that was captured on September 14 at one trap net was recaptured the same day at an adjacent trap net.
- Apart from those 4 re-captures, 1 Arctic Char and 46 Greenland Cod that were caught in trap nets had clipped pelvic fins, indicating recent capture at one of the port sampling sites in Roberts Bay, and removal of a pelvic fin for age reading.

QA/QC for sampling of marine fish included the daily review of field data sheets, the use of chain of custody forms, and taxonomic and laboratory QA/QC procedures. Field notes were transcribed onto electronic spreadsheets and all transcriptions were compared with field notes to correct transcription errors.

Figure 10.2-6
Extent of Marine Fish Community Sampling within the LSA and RSA, 2002 to 2007, 2009, 2010 and 2017

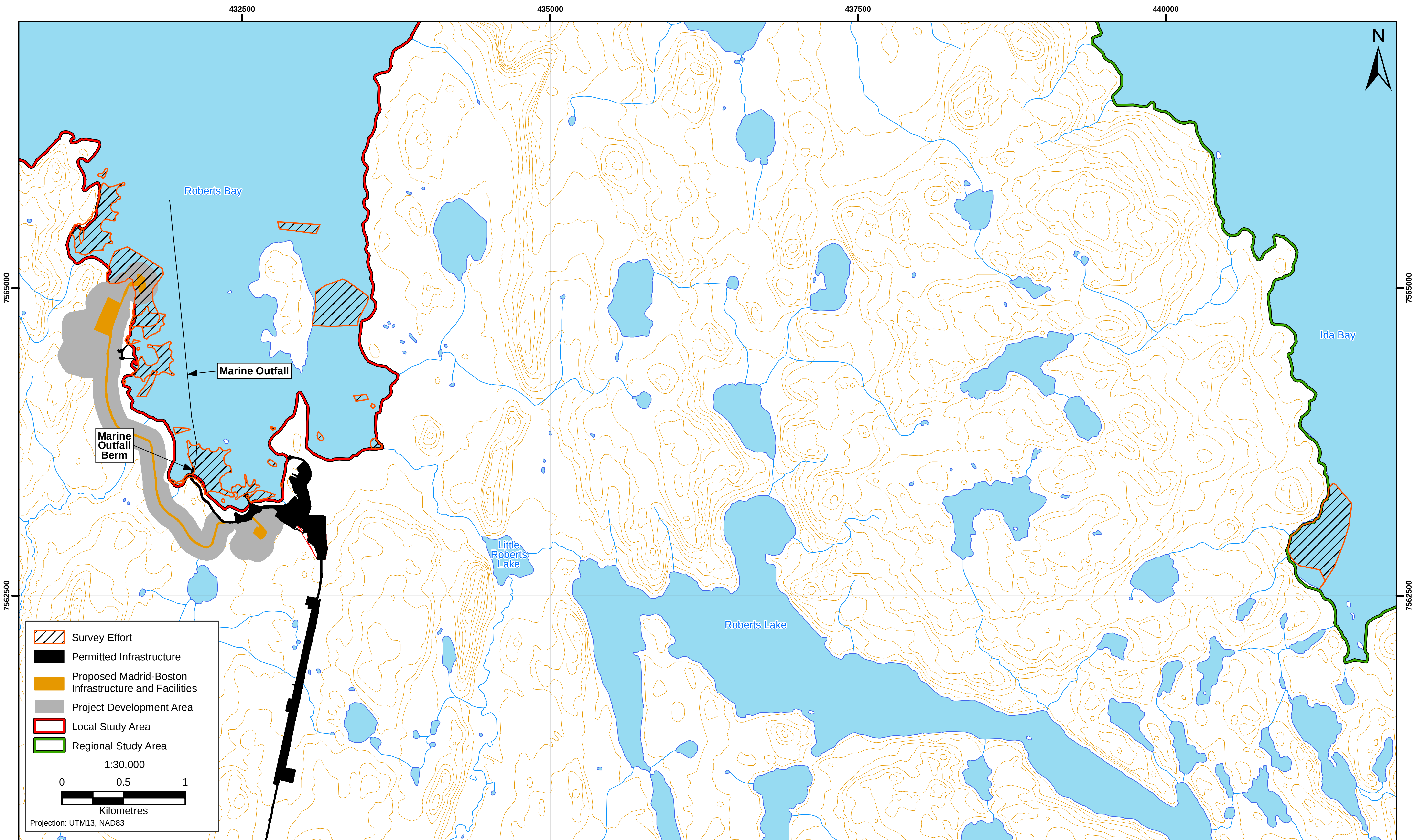


Figure 10.2-7
Marine Fish Community Gillnet, Long Line, Angling and Fyke Net Sample Locations within Roberts Bay, 2002 to 2007, 2009, 2010 and 2017

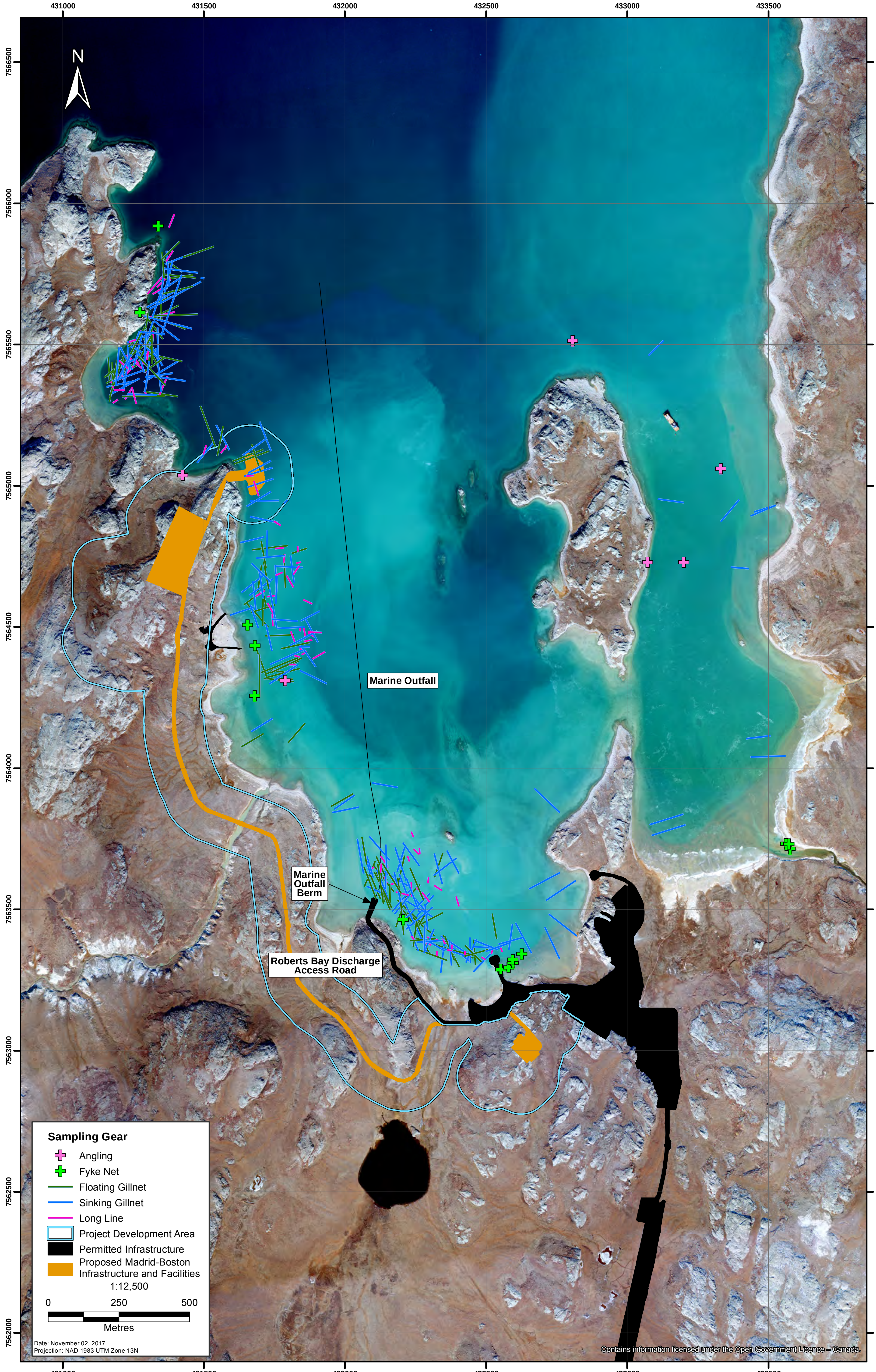


Figure 10.2-8
Marine Fish Community Beach Seine, Minnow Trap, and Crab Trap Sample Locations within Roberts Bay, 2002 to 2007, 2009, 2010 and 2017

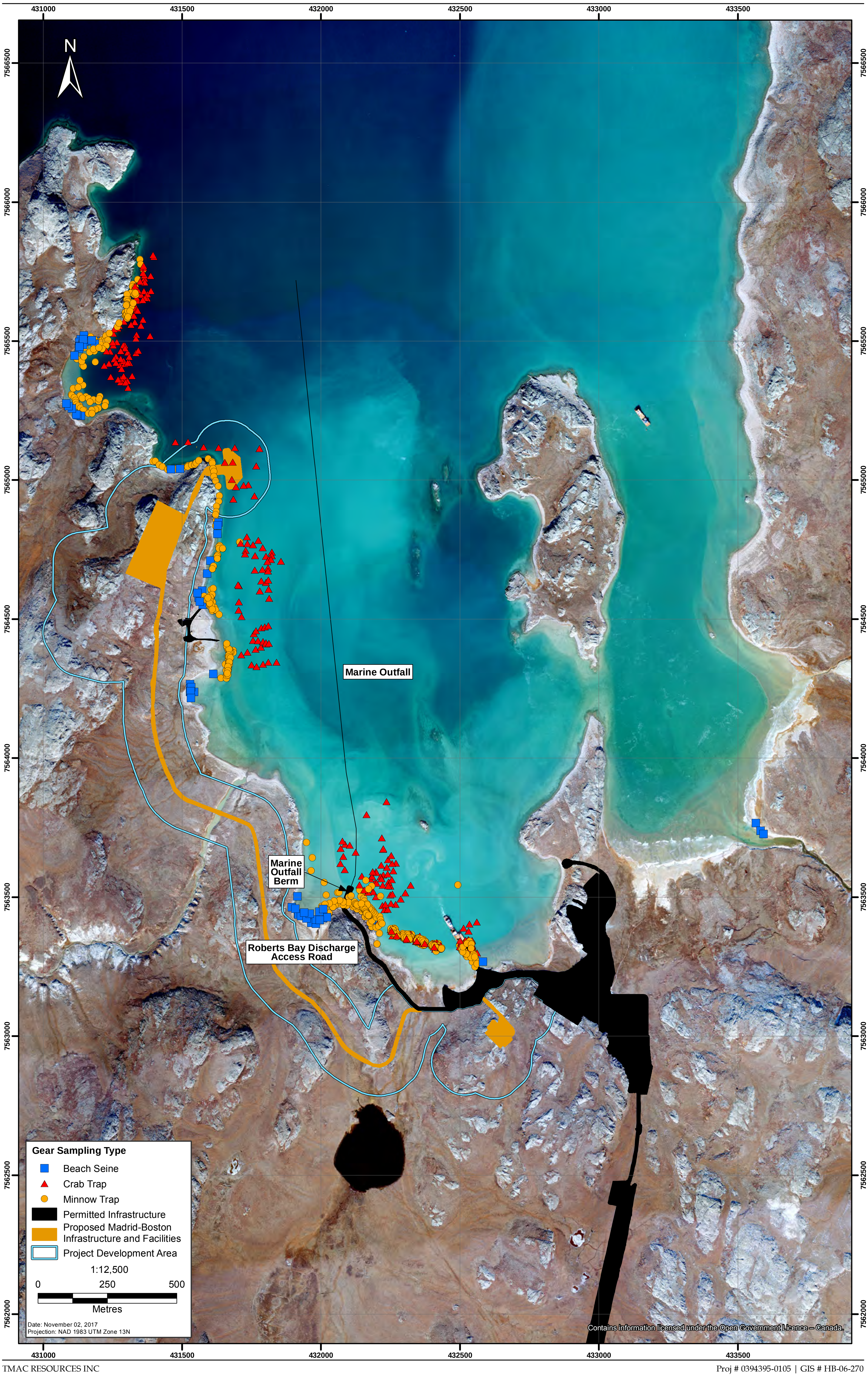


Figure 10.2-9
Marine Fish Community Gillnet and Long Line Sample Locations within Ida Bay, 2009 and 2010

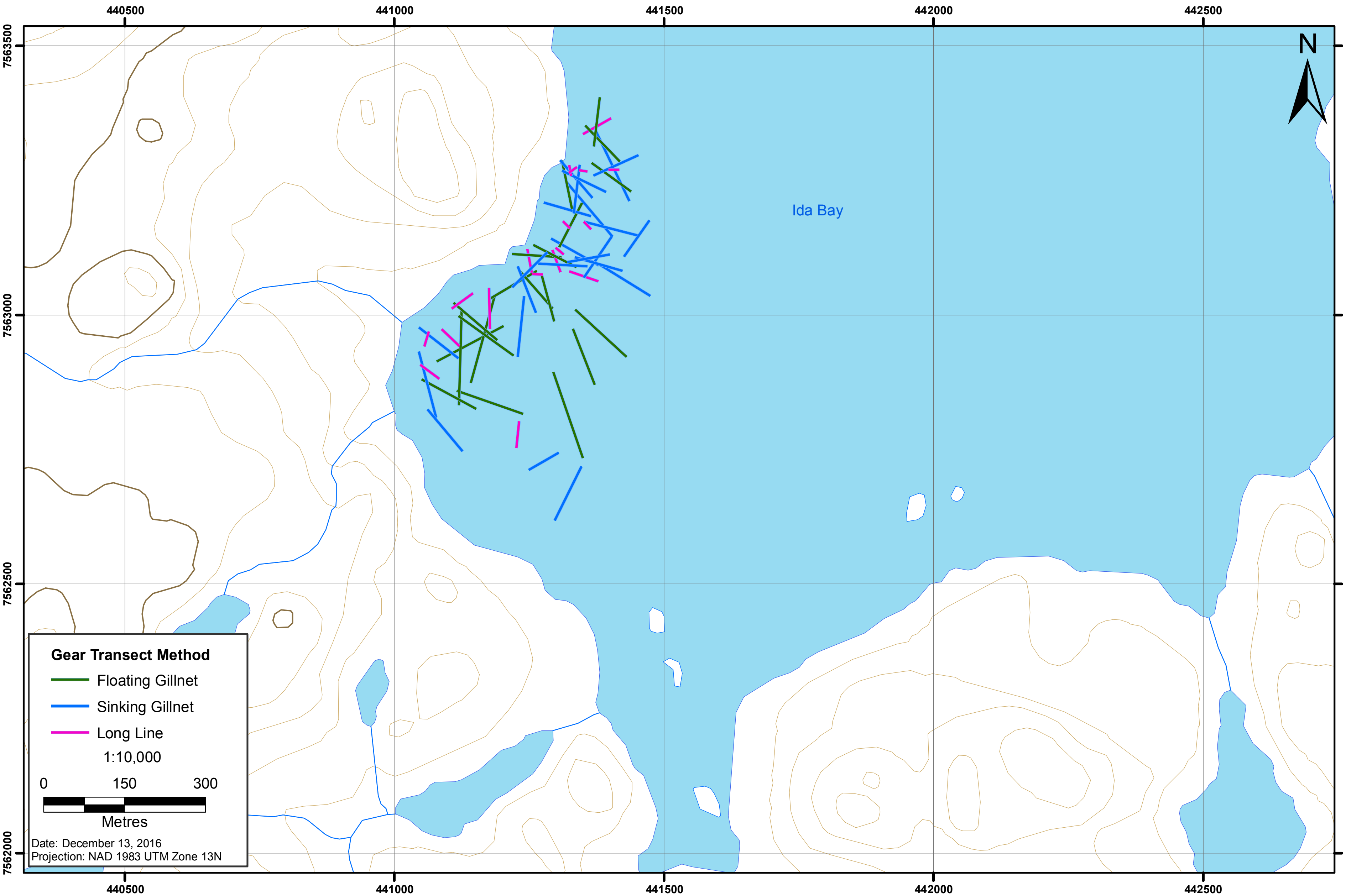


Figure 10.2-10
Marine Fish Community Beach Seine, Minnow Trap, and Crab Trap Locations within Ida Bay, 2009 and 2010

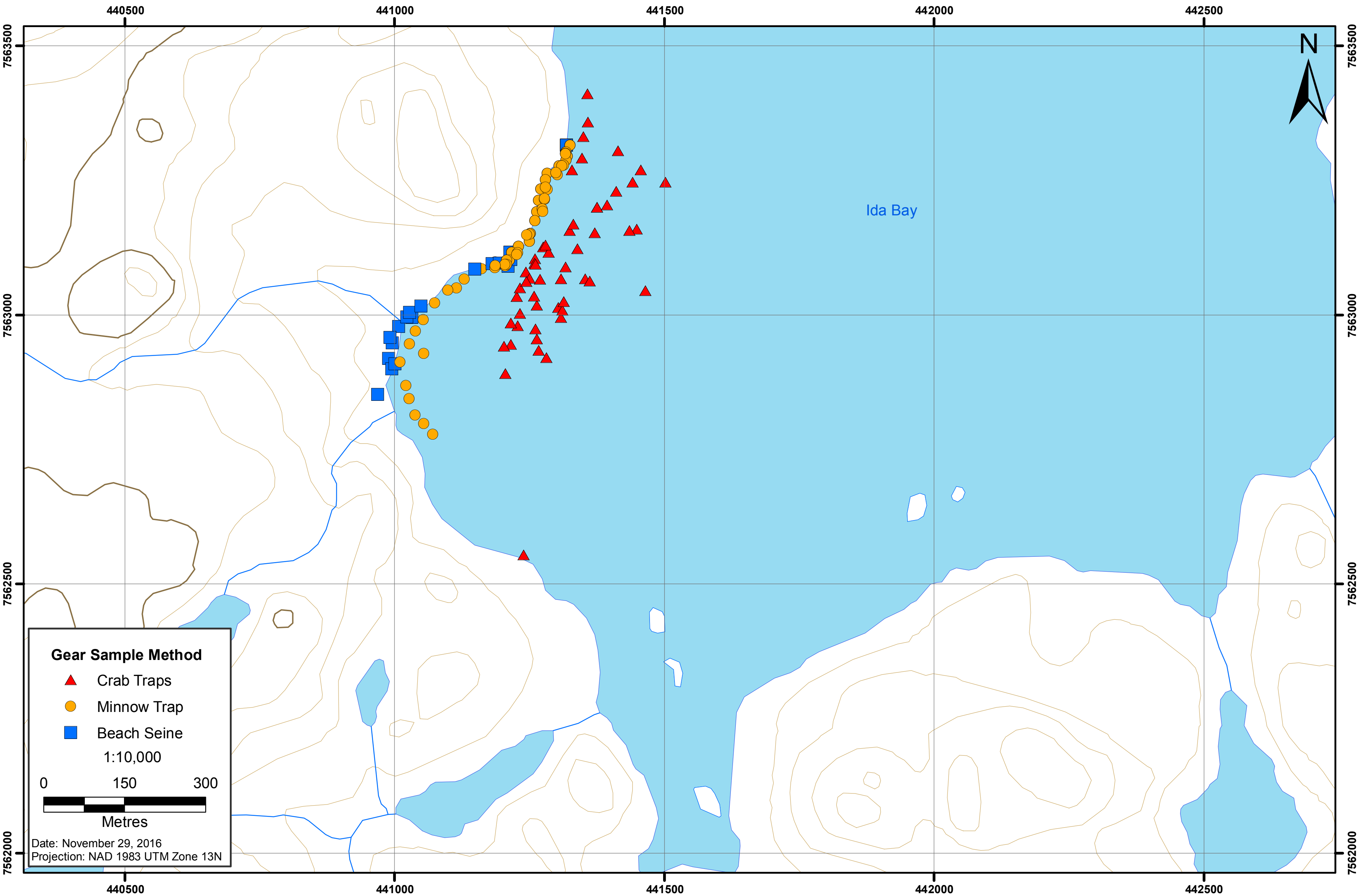


Table 10.2-7. Common and Scientific Names of Fish Species Captured During Marine Surveys, 2002 to 2017

Family	Common Name	Scientific Name
Agonidae	Poacher	Unidentified
Ammodytidae	Sand Lance	Unidentified
Anarhichadidae	Bering Wolffish	*Anarhichas orientalis*
Clupeidae	Pacific Herring	*Clupea pallasii*
Cottidae	Shorthorn Sculpin	*Myoxocephalus scorpius*
	Fourhorn Sculpin	*Triglopsis quadricornis*
	Sculpin	Unidentified
Gadidae	Greenland Cod	*Gadus ogac*
	Saffron Cod	*Eleginus gracilis*
Gasterosteidae	Ninespine Stickleback	*Pungitius pungitius*
Liparidae	Snailfish	Unidentified
Osmeridae	Capelin	*Mallotus villosus*
	Rainbow Smelt	*Osmerus mordax*
Pholidae	Banded Gunnel	*Pholis fasciata*
Pleuronectidae	Arctic Flounder	*Liopsetta glacialis*
	Longhead Dab	*Limanda proboscidea*
	Starry Flounder	*Platichthys stellatus*
	Flounder	Unidentified
Salmonidae	Arctic Char	*Salvelinus alpinus*
	Lake Trout	*Salvelinus namaycush*
	Lake Whitefish	*Coregonus clupeaformis*
	Cisco	*Coregonus artedi*
	Least Cicso	*Coregonus sardinella*
	Inconnu	*Stenodus leucicthys*
Stichaeidae	Arctic Shanny	*Stichaeus punctatus*

Some length, weight, and age data were plotted against each other (e.g., weight-length regressions and length-age plots) to identify outliers that may have resulted from transcription errors. If errors could not be corrected by re-examining field notes, then those data were excluded from analysis.

10.2.6 Characterization of Baseline Conditions

The key findings of surveys of marine fish habitat, inclusive of biological resources (i.e., phytoplankton, zooplankton, and benthic invertebrate communities), physical characteristics, and fish communities in the LSA (i.e., Roberts Bay) and RSA (i.e., Ida and Hope bays) are summarized in the following sections.

10.2.6.1 Marine Fish Habitat – Biological Resources

<u>Phytoplankton</u>

Phytoplankton biomass was generally low and seasonally variable in Roberts Bay and the adjacent two inlets (Hope and Ida bays). In Roberts Bay, under-ice (April) biomass levels averaged 0.35 µg chl *a*/L (range: 0.04 to 1.32 µg chl *a*/L), and and open-water biomass levels averaged 0.74 µg chl *a*/L (range: 0.02 to 8.24 µg chl *a*/L; Table 10.2-8). In neighbouring Ida Bay, under-ice biomass levels averaged 1.17 µg chl *a*/L (range: 0.06 to 3.68 µg chl *a*/L) and open-water biomass levels averaged 0.42 µg chl *a*/L (range: 0.03 to 1.50 µg chl *a*/L; Table 10.2-8).Biomass levels in Hope Bay were also low, averaging 0.62 µg chl *a*/L between July and September 2007. Chlorophyll *a* concentrations were most variable at the shallow RBE site in eastern Roberts Bay, with the greatest concentrations recorded in August 2010 and September 2016 (ranging from 5 to 10 µg chl *a*/L between replicates). This may be attributable to the resuspension of benthic primary producers at this shallow site.

The low biomasses present in the marine LSA and RSA waters were likely driven by low light levels during the under-ice season and nitrogen-limitation during the open-water season. Nitrogen levels were consistently below detection limits in Roberts Bay and Ida Bay during the open-water season (Section 8.2.4) due to the strong vertical stratification in the inlets that inhibited the entrainment of deep-water nutrients into the surface euphotic zone to support photosynthesis.

The phytoplankton communities that were present in Roberts Bay in 2009 and 2010 were dominated by the chrysophyte (golden algae) *Dinobryon balticum* and the large diatom *Leptocylindrus danicus*, both numerically and as contributors to phytoplankton biomass (as carbon; Table 10.2-8). The large silicoflagellate *Ebria tripartita* was also an important contributor to phytoplankton biomass, but was not present in high abundance. Cryptomonads were very abundant, but due to their small size, contributed little to total phytoplankton biomass. In Ida Bay, phytoplankton communities were dominated by small cryptomonads and *L. danicus*. The green algae *Ankistrodesmus* spp. were also numerous and the large dinoflagellate *Protoceratium reticulatum* contributed significantly to the biomass (Table 10.2-8). Cryptomonads, dinoflagellates (*Peridinium* sp.), and green algae (*Staurastrum* sp.) were also abundant (by carbon mass) in Ida Bay.

Phytoplankton community mean taxa richness and diversity was similar among sites in Roberts Bay (12 to 17 taxa/sample and 0.21 to 0.44 Simpson's Index; (Rescan 2010a, 2011e) and was similar to that observed in the adjacent Ida Bay (11 to 14 taxa/sample and 0.12 to 0.41 Simpson's Index). The overall phytoplankton diversity was low in Roberts, Ida, and Hope bays, as the marine waters were typically dominated by a few taxa.

<u>Zooplankton</u>

Zooplankton abundance in Roberts Bay ranged from 8,388 to 16,528 organisms/m^3, with a mean abundance of 12,875 organisms/m^3 (Table 10.2-9). The lowest abundance was observed in eastern Roberts Bay where the inlet receives flow from Little Roberts Creek (ST0), and the greatest in western Roberts Bay near the Glenn Creek outflow (ST1). Most of the deeper water sites (ST3-ST6) had very similar zooplankton abundances near 12,000 organisms/m^3. The Roberts Bay zooplankton communities were dominated by calanoid copepods (*Acartia longiremis* and *Centropages abdominalis)* and the cladoceran *Evadne nordmanni*. The presence of copepods and cladocerans indicate a robust pelagic food web.

Zooplankton communities in Ida Bay were similar to Roberts Bay communities in abundance and structure, ranging between 10,431 and 11,008 organisms/m^3 and comprising mainly calanoid copepods (*Acartia longiremis* and Pseudocalaniods; Table 10.2-9). Zooplankton communities in Hope Bay were analyzed using a non-comparable method to that used in Roberts and Ida bays, therefore, particular values cannot be compared. However, calanoid copepods and cladocerans were the dominant zooplankters.

Table 10.2-8. Summary of Phytoplankton in Roberts, Ida and Hope Bays, 2006 to 2016

	Min	Mean	Max	Predominant Taxa (numerically)	Predominant Taxa (by carbon biomass)
Roberts Bay (2006-2007, 2009-2016)					
Under-ice					
Biomass (µg chl *a*/L)	0.04	0.35	1.32	-	-
Open-water					
Biomass (µg chl *a*/L)	0.02	0.74	8.24	*Dinobryon balticum* (chrysophyte)	*Leptocylindrus danicus* (diatom)
Biomass (µg C/L)	6.15	12.95	50.29	unidentified Cryptomonads	*Dinobryon balticum* (chrysophyte)
Abundance (cells/L)	120,030	214,330	411,738	*Leptocylindrus danicus* (diatom)	*Ebria tripartita* (silicoflagellate)
Ida Bay (2009-2016)					
Under-ice					
Biomass (µg chl *a*/L)	0.06	1.17	3.68	-	-
Open-water					
Biomass (µg chl *a*/L)	0.03	0.42	1.50	unidentified Cryptomonads	*Leptocylindrus danicus* (diatom)
Biomass (µg C/L)	4.94	15.02	43.18	*Leptocylindrus danicus* (diatom)	unidentified Cryptomonads
Abundance (cells/L)	132,132	209,535	337,294	*Ankistrodesmus* spp. (chlorophyte)	*Protoceratium reticulatum* (dinoflagellate)
Hope Bay (2007)					
Under-ice					
Biomass (µg chl *a*/L)	-	-	-	-	-
Open-water					
Biomass (µg chl *a*/L)	0.45	0.62	0.90	-	Cryptomonads
Biomass (µg C/L)	na	na	na	-	*Peridinium sp.* (dinoflagellate)
Abundance (cells/L)	na	na	na	-	*Staustrum sp.* (green algae)

Notes:
Values represent all available data from 1997 to 2016.
Dashes indicate no samples were collected.
Units: µg chl a/L = micrograms chlorophyll a per litre; µg C/L = micrograms carbon per litre; and cells/L= cells per litre.
Predominant taxa are the three most abundant groups in the pooled total of all samples.
na = not applicable as sampling and identification methods not comparable.

Table 10.2-9. Summary of Zooplankton in Roberts, Ida and Hope Bays, 2007 and 2009

	Min	Mean	Max	Predominant Taxa (numerically)
Roberts Bay (2009)				
Abundance (organisms/m^3)	8,388	12,875	16,529	*Acartia longiremis* (calanoid copepod)
				Evadne nordmanni (cladoceran)
				Centropages abdominalis (calanoid copepod)
Ida Bay (2009)				
Abundance (organisms/m^3)	10,431	na	11,008	*Acartia longiremis* (calanoid copepod)
				Pseudocalanidae spp. (calanoid copepod)
				Pseudocalanus minutus (calanoid copepod)
Hope Bay (2007)				
Abundance (organisms/m^3)	na	na	na	*Limnocalanus macrurus* (calanoid copepod)
				Bosmina longirostris (cladoceran)
				Epischura lacustris(calanoid copepod)

Notes:
Values represent all available data from 1997 to 2016.
Predominant taxa are the three most abundant groups in the pooled total of all samples.
na = not applicable as sampling and identification methods not comparable.

Zooplankton taxa richness was lower in the near-shore sites of Roberts Bay (~17 taxa) than in the offshore sites of Roberts Bay and Ida Bay (~24 taxa; Rescan 2010a). The Simpson's Diversity Index was similar (range: 0.57 to 0.73) among all sites in Roberts and Ida bays, and indicated moderately diverse zooplankton communities.

Benthic Invertebrates

Benthos sampling in Roberts Bay was conducted in a variety of substrate habitats (Marine Sediment Quality, Chapter 9 of Volume 5). Benthic invertebrate density varied widely across these habitats, ranging from 23 to 41,211 organisms/m^2, with a mean density of 10,269 organisms/m^2 (Table 10.2-10). Density was lowest at the shallow, near-shore sites in eastern Roberts Bay (RBE; mean: 872 organisms/m^2) and western Roberts Bay (ST9; mean: 288 organisms/m^2) that were dominated by sand and heavily influenced by freshwater inputs. Nematodes were occasionally the most numerous benthic organism observed, although these were excluded from some total density estimates because they were not accurately quantified (i.e., they belong to the meiobenthos size category and would be expected to pass through the sieve used to collect macrobenthos). In general, the most numerous benthic macroinvertebrates in Roberts Bay samples were various species of free-swimming polychaetes (*Nephtys* spp. and *Bipalponephtys neotena*) and sedentary polychaetes (*Mediomastus* spp., *Pectinaria granulata* and *Leitoscoloplos* spp.), as well as the clam *Macoma balthica* (Table 10.2-10).

Benthic invertebrate density was less variable in Ida and Hope bays than in Roberts Bay, likely due to the fewer number of sites and substrate types sampled in these areas (Table 10.2-10). Benthic invertebrate density in Ida Bay ranged from 1,520 to 13,661 organisms/m^2, with a mean density of 7,392 organisms/m^2. The benthic invertebrate community in Ida Baywas dominated by the free-swimming polychaetes *Bipalponephtys neotena, Pholoe inornata*, and *Nephtys* spp., and the amphipod *Ponotporeia femorata*. In 2010, the REF-Marine 1 site was dominated by the bivalve clam species *M. balthica*. The Hope Bay benthic invertebrate community ranged from 1,667 to 3,346 organisms/m^2 and was dominated by the sedentary polychaetes *Mediomastus* sp. and *Laonice* cf *cirrata* and the free-swimming polychaete *Nephtys cornuta*. The lower abundance seen in the Hope Bay samples could have been due to the strong freshwater influence of the Koignuk River, which would contribute to large fluctuations in salinity making the area inhospitable to most stenohaline (salt-fluctuation intolerant) organisms.

Table 10.2-10. Summary of Benthic Invertebrates in Roberts, Ida and Hope Bays, 1997 to 2016

	Min	Mean	Max	Predominant Taxa (numerically)
Roberts Bay (1997, 1998, 2009-2016)				
Density (organisms/m^2)	23	10,269	41,211	*Nephtys* spp. & *Bipalponephtys neotena* (free-swimming polychaetes)
				Mediomastus spp., *Pectinaria granulata* & *Leitoscoloplos* spp. (sedentary polychaetes)
				Macoma balthica (bivalve)
Ida Bay (2009-2016)				
Density (organisms/m^2)	1,520	7,392	13,661	*Bipalponephtys neotena*, *Pholoe inornata*, and *Nephtys* spp. (free-swimming polychaetes)
				Ponotporeia femorata (amphipod)
Hope Bay (1998)				
Density (organisms/m^2)	1,667	2,503	3,346	*Mediomastus* sp. & Laonice cf cirrata (sedendary polychaete)
				Nephtys cornuta (free-swimming polychaete)

Notes:
Values represent all available data from 1997 to 2016.
Predominant taxa are the three most abundant groups in the pooled total of all samples.

Substantial spatial and temporal variation in benthos diversity was observed in Roberts Bay during the baseline programs (taxa richness ranged from 1 to 22 taxa/sample and Simpson's diversity index from 0 to 0.82 (Rescan 2010a, 2011e), as well as the AEMP program (taxa richness ranged from 1 to 27 families/sample and Simpson's diversity index from 0.13 to 0.84 (Rescan 2013b; ERM Rescan 2014; ERM 2017a). Richness and diversity were lowest at very shallow, near-shore sites with sandy substrates (e.g., ST9, TF1, DW3, and RBE).

Similar to Roberts Bay, benthic invertebrate richness and diversity were spatially and temporally variable in Ida Bay. During the baseline programs, taxa richness ranged from 4 to 18 taxa/sample and Simpson's diversity index from 0.37 to 0.84 (Rescan 2010a, 2011e); during the AEMP program, family richness ranged from 5 to 29 families/sample and Simpson's diversity index from 0.39 to 0.89 (Rescan 2011b; ERM Rescan 2014; ERM 2016).Within Ida Bay, richness and diversity values were lowest at the shallow RP1 site.

10.2.6.2 Marine Fish Habitat – Physical Characteristics

Roberts Bay is dominated by cliffs up to 50 m in height at the northern and western areas of the bay. The eastern and southern areas of Roberts Bay are more gradually sloped and contain numerous lake drainages. While the cliff areas are generally devoid of terrestrial vegetation, the gently sloped valleys have lush growths of reeds, grasses, and other low growing tundra vegetation.

The marine shoreline environment of Roberts Bay is subject to a very small tidal range, likely on the order of 30 cm or less, as reported by the Canadian Hydrographic Service. Other physical forces such as waves, storms, and ice scouring likely influence the physical habitat of shoreline organisms in Roberts Bay more than tides.

Shoreline and intertidal zones of Roberts Bay were assessed along the southern and western shores of Roberts Bay in 2000 (Figure 4.4-2; Rescan 2001), 2009 (Rescan 2010b), 2010 (Rescan 2011a) and 2017 (ERM 2017c). The shoreline substrates consist mainly of bedrock in the northwest and south portions of Roberts Bay; however, gravel and sand are present in bays and at stream outlets (Figure 10.2-11). The eastern portion of the bay is dominated by boulder, gravel, and sand substrates. None of the areas surveyed were vegetated. Habitat quality was rated fair to good in the northern areas and good to excellent in the southern region on the basis of cover provided for fish and invertebrates and potential for supporting communities of invertebrates, a food source for marine fish.

In 2010, additional detailed intertidal and subtidal substrate surveys were completed to the north and the south of the proposed cargo dock site, while in 2017 the proposed dock site was characterized per se, giving a complete picture (Rescan 2011a; ERM 2017c)(Figure 10.2-12). Water depths reached up to 20-25 m towards the seaward end of the dock. While nearshore areas were typically dominated by bedrock, cobble or sand and gravel substrates, subtidal substrates consisted primarily of mud, along with small patches of cobble and/or gravel, as confirmed through hydroacoustic and Ekman grabs (ERM 2017c)(Figure 10.2-12). No unique features such as stream outlets or uncommon substrates were observed during any of the historical baseline surveys at the site of the cargo dock.

Outside of Roberts Bay, and into and beyond the RSA, sealift and fuel resupply activities occurs along existing routes via the Northwest Passage. Habitat along the commercial sealift lane consists of offshore, deep-water habitats, typical of Arctic marine ecosystems. Because of the use of deeper habitat requirements for safe navigation, sensitive nearshore and shallow habitats, preferred by many spawning marine fish species are not present along the route. Marine waters in these areas are typically ice-covered from late October to June, most of that time with land-fast ice that is approximately 1.5 m thick.

10.2.6.3 Marine Fish Community

Species Richness

A total of 25 species of fish were captured in Roberts Bay from 2002 to 2017 (Table 10.2-11). That is half the number of fish species (57) known to be present within the Queen Maude Gulf marine ecozone (Coad and Reist 2004). Nineteen of those 25 species were identified to the species level and 5 were identified to the family level. Only 14 of those 25 species were found in Ida Bay.

Three additional fish species are known to be present in Bathurst Inlet, based upon recent (Rescan 2013a) and historical sampling (Stewart et al. 1993), but were not captured in Roberts Bay: Round Whitefish (*Prosopium cylindraceum*), Sockeye Salmon (*Oncorhynchus nerka*), and Slender Eel Blenny (*Lumpenus fabricii*). Sockeye Salmon was reported as being present in southern Bathurst Inlet; a single individual was observed in 1965 (Stewart et al. 1993). That observation was likely the result of a group of individuals straying outside the normal geographic range (as opposed to a resident population).

Fish Species of Conservation Concern

A single Bering Wolffish (*Anarhichas orientalis*) individual measuring 470 mm was captured in 2017 using gillnets, on the east side of Robert Bay approximately 2 km from the proposed cargo dock location, north of Roberts Outflow in 4 to 7-m-deep water. This species, previously only confirmed in Bathurst Inlet, was assessed by COSEWIC as “data deficient” in 2002 (COSEWIC 2002). Although listed Schedule 3 (Special Concern) of the *Species at Risk Act* (2002), its status does not quality for legal protection and recovery under SARA.

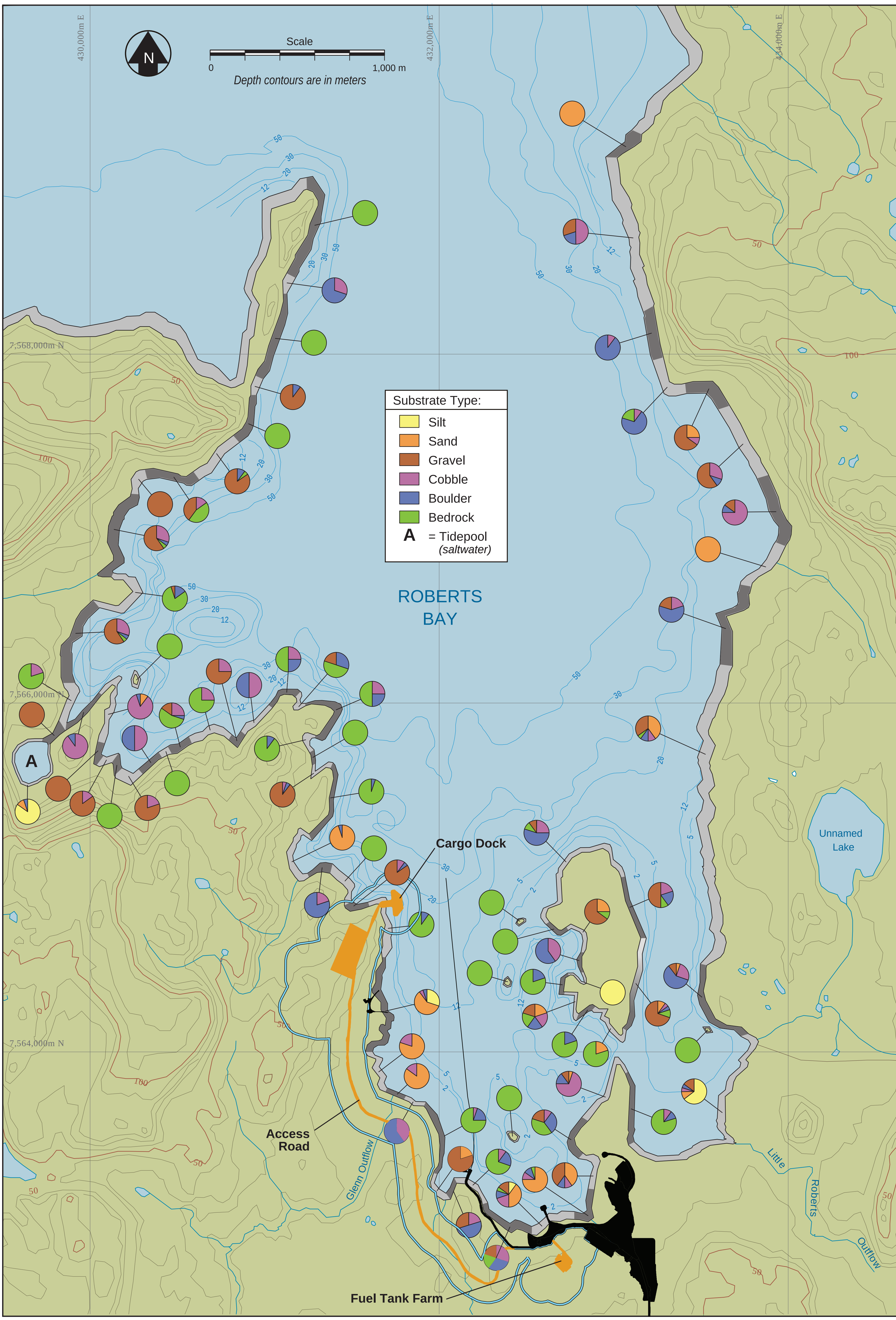

Scale
0
1,000 m
Depth contours are in meters
N
430,000m E
432,000m E
434,000m E
7,568,000m N
7,566,000m N
7,564,000m N
Substrate Type:
Silt
Sand
Gravel
Cobble
Boulder
Bedrock
A = Tidepool (saltwater)
ROBERTS BAY
A
Cargo Dock
Access Road
Fuel Tank Farm
Glenn Outflow
Unnamed Lake
Little Roberts Outflow

Figure 10.2-12

Intertidal and Subtidal Zone Substrate Composition in the Vicinity of the Marine Cargo Dock in Roberts Bay

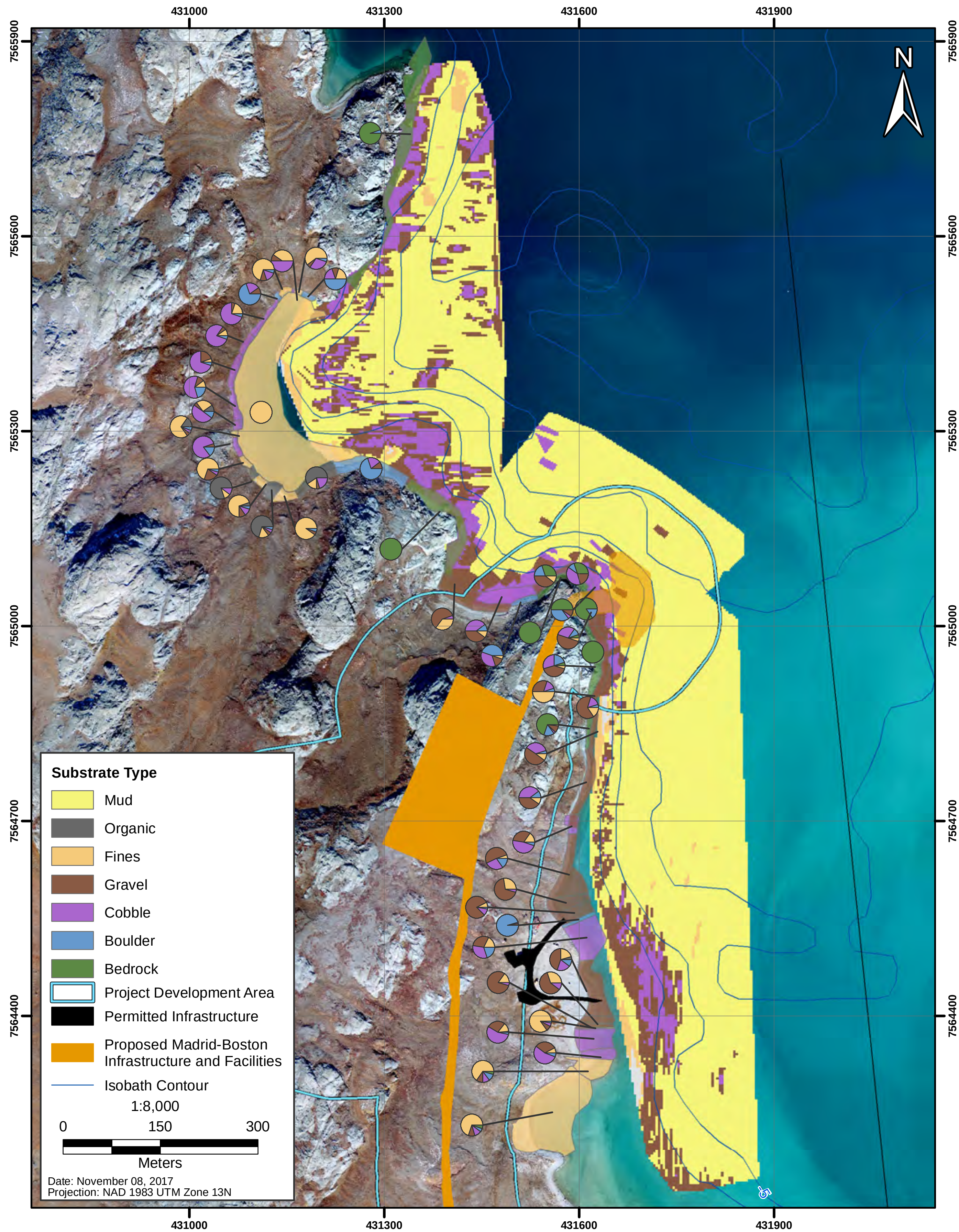


Table 10.2-11. Numbers of Fish Captured in Roberts Bay and Ida Bay, 2002 to 2017

	Roberts Bay											Ida Bay			
Species	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2009**	**2010**	**2017**	**Total**	**Percent**	**2009**	**2010**	**Total**	**Percent**
Saffron Cod	117	1,715	2	2,301	0	34	154	550	25	4,898	50.55	0	8	8	2.3
Capelin	0	2,627	0	0	32	0	9	1	0	2,669	27.54	0	0	0	0.0
Arctic Flounder	0	112	0	119	34	145	11	46	0	467	4.82	2	14	16	4.5
Pacific Herring	0	6	0	5	0	54	164	83	34	346	3.57	26	13	39	11.0
Fourhorn Sculpin	1	22	0	1	2	16	0	226	34	302	3.12	0	116	116	32.9
Arctic Char	1	25	0	8	11	6	58	242	17	368	3.80	20	7	27	7.6
Sculpin spp.	0	0	0	0	0	0	164	0	0	164	1.69	122	0	122	34.6
Greenland Cod	16	3	0	0	3	0	44	205	8	279	2.88	2	1	3	0.8
Lake Trout	0	14	0	3	24	7	3	2	0	53	0.55	0	1	1	0.3
Longhead Dab	0	1	0	0	0	0	5	18	6	30	0.31	0	0	0	0.0
Starry Flounder	0	0	0	3	0	0	9	15	3	30	0.31	6	2	8	2.3
Arctic Shanny	0	0	0	0	0	0	5	14	0	19	0.20	0	1	1	0.3
Shorthorn Sculpin	0	0	0	0	0	0	0	13	4	17	0.18	0	10	10	2.8
Ninespine Stickleback	0	0	0	0	0	0	4	6	0	10	0.10	3	6	9	2.5
Flounder spp.	0	0	0	0	0	0	8	0	0	8	0.08	0	0	0	0.0
Cisco	0	7	0	0	0	0	0	0	0	7	0.07	0	0	0	0.0
Banded Gunnel	1	0	0	0	0	0	0	11	0	12	0.12	0	0	0	0.0
Lake Whitefish	0	0	0	2	0	0	0	1	1	4	0.04	0	0	0	0.0
Least Cisco	0	2	0	0	0	0	0	0	0	2	0.02	0	0	0	0.0
Bering Wolffish	0	0	0	0	0	0	0	0	1	1	0.01	0	0	0	0.0
Poacher spp.	0	0	0	0	0	0	0	1	0	1	0.01	0	1	1	0.3
Rainbow Smelt	0	0	1	0	0	0	0	0	0	1	0.01	0	0	0	0.0
Sandlance spp.	0	0	0	0	0	0	0	1	0	1	0.01	0	0	0	0.0
Snailfish spp.	0	0	0	0	0	0	0	1	0	1	0.01	0	0	0	0.0
Total	**136**	**4,534**	**3**	**2,442**	**106**	**262**	**638**	**1,436**	**133**	**9,690**	**100.00**	**181**	**180**	**353**	**100.0**

Source by year: 2002 (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003a); 2003 (RL&L/Golder 2003); 2004 (Golder 2005); 2005 (Golder 2006); 2006 (Golder 2007a); 2007 (Golder 2008b); 2009 (Rescan 2009b, 2010b); 2010 (Rescan 2010c, 2011a)

Found from Hokkaido throughout the Sea of Okhotsk to Alaska, three collected specimens from Bathurst Inlet (collected in 1964, 1965, and 1969) were until now the only three confirmed Bering Wolffish specimens from the Canadian Arctic (Houston and McAllister 1990; COSEWIC 2002). The collection of only four specimens now suggests this species is rare, as surveys in Bathurst Inlet have been conducted extensively by DFO, the Canadian Museum of Nature, and consultants for mining companies. One fishing guide/outfitter in Bathurst inlet claims to catch wolffish on a regular basis, but does not distinguish between *A. orientalis* and *A. denticulatus* (Northern wolfish) (COSEWIC 2002).

Number of Fish

A total of 9,690 fish were captured in Roberts Bay from 2002 to 2017. Saffron Cod made up 50.55% of the total number, followed by Capelin (27.54%), Arctic Flounder (4.82%), Arctic Char (3.80%), Pacific Herring (3.57%), Fourhorn Sculpin (3.12%), unidentified Sculpins (1.69%), and Greenland Cod (2.88%). The remaining 15 species each made up between 0.01% and 0.55%.

A total of 353 fish were captured in Ida Bay in 2009 and 2010. Unidentified Sculpin made up 34.6% of the total, followed by Fourhorn Sculpin (32.9%), Pacific Herring (11.0%), Arctic Char (7.6%), Arctic Flounder (4.5%), Shorthorn Sculpin (2.8%), and Ninespine Stickleback (2.5%). The remaining six species made up between 0.3% (unidentified Poacher and Lake Trout) and 2.3% (Starry Flounder and Saffron Cod). Ten of the species found in Roberts Bay were not found in Ida Bay.

The two most common species had the most variable catches. Saffron Cod was caught in 8 of the 9 sampling years, but 82% of its numbers were caught in only two of those years: 35% in 2003 and 47% in 2005. Capelin also had highly variable catches; 98.4% of its numbers were caught in 2003. This suggests that both species are migratory and may use habitat in Roberts Bay for only part of the year. Since Capelin has not been observed spawning on beaches in Roberts Bay, they were probably passing through Roberts Bay in 2003 on the way to beach spawning sites elsewhere in Melville Sound.

Several other species have less variable catches than those two species, suggesting that they may be less migratory than Saffron Cod and Capelin and may reside for longer time periods in Roberts Bay. Arctic Char, for example was caught in eight of the nine sampling years and its catch ranged from 1 to 58 in each of those seven years. It is reasonable to assume that many of those Arctic Char may have reared and overwintered in lakes whose outlet streams flow into Roberts Bay. Another example is Arctic Flounder, which was caught in seven of the nine years and had numbers ranging from 11 to 145 in each of those seven years.

Differences in species composition in Roberts Bay were observed between early (late July/early August) and late (late August/early September) sampling periods in 2009 and 2010. This was due to differences in fishing effort among areas and to habitat preferences of the fish. For example, in 2009, Pacific Herring dominated catches during the early sampling period, whereas Saffron Cod were most prevalent later in the summer. Moreover, although Arctic Char only comprised 1% of captures during early sampling in 2010, later in the summer captures constituted 21% of the catch. Sampling in 2009 caught more pelagic and bentho-pelagic species because more sampling effort was expended with gillnets in offshore subtidal zone than in previous years (Rescan 2010b).

Differences in dominant fish community composition were also observed among sampling areas, which are likely a reflection of site-specific habitat conditions (i.e., depth, substrate). For example, certain sampling areas in the northwest area of Roberts Bay had a greater community composition of Arctic Char than other areas (Rescan 2010b, 2011a).

Life Histories, Habitat Preferences, and Distribution of Fish Species

Anadromous Species

Seven of the 25 fish species found in Roberts Bay are anadromous: Arctic Char, Lake Trout, Cisco, Lake Whitefish, Least Cisco, Inconnu and Rainbow Smelt (Table 10.2-12). All except Rainbow Smelt depend on habitat in lakes for spawning, incubation, rearing and overwintering and use the sea, specifically Roberts Bay and other nearby inlets in Melville Sound, for feeding during the open-water season (Scott and Crossman 1973). They are fall-spawners whose eggs incubate in gravels or boulder/rubble substrate over winter. The eggs hatch in spring and the fry emerge from the incubation gravels several days later. Juveniles rear in lakes and outlet streams for several years before first out-migrating to the sea. They return to their natal lakes in the autumn to overwinter.

One Rainbow Smelt was captured in Roberts Bay in 2004. Rainbow Smelt occur in rivers, coastal areas and ponds. They spawn in spring in streams, often ephemeral streams ones that go dry in the summer. Eggs hatch in 1–4 weeks, depending on water temperature, and the fry rear briefly in their natal streams before out-migrating to marine habitat. They spend the summers along the coast, normally in shallow water. They overwinter under the ice in estuaries.

An eighth species, Ninespine Stickleback, is known to have an anadromous life history variant. It was captured in Roberts and Ida bays in 2009 and 2010. Throughout their range in the northern temperate zone they have three life-history types: freshwater, brackish, and anadromous (Arai and Goto 2005). This species spawns in spring in shallow, nearshore areas of lakes, ponds, streams, and estuaries. The fry rear in that same habitat. The anadromous variant out-migrates during the open-water season and forages in inshore areas of estuaries and marine bays. They return to lakes or to deep pools in rivers and estuaries to overwinter.

Arctic Char: Marine Fish VEC

The anadromous life stage of Arctic Char is one of the two VECs for marine fish (the other is Saffron Cod). Arctic Char are present in northern coastal regions in rivers, lakes, estuaries, and marine environments. They exhibit both anadromous and lake resident (i.e., lacustrine) life histories. Arctic Char are the most economically important fish to the Inuit population of Nunavut. In the Melville Sound area, commercial fisheries operate during upstream runs in Elu Inlet and the Kolgayok River (DFO 2004). TK shows that they are also a prized food fish (Sections 10.1.1 and 6.1.1.1) and are expected to be found throughout the RSA where access to freshwater habitats for overwintering and spawning are accessible from ocean habitat.

In the central Canadian Arctic, spawning of Arctic Char takes place in lakes, because most rivers freeze completely in winter (Johnson 1980; Tables 10.2-12, 6.2-22, and 6.2-23). Spawning occurs in those lakes in the fall, usually September or October, over gravel or cobble shoals and shorelines of lakes. Males arrive first on the spawning grounds and establish and defend territories. Females arrive later and are courted by males. Depending on substrate size, a female may either dig a nest or redd, in which the eggs are deposited, or broadcast eggs in water 3 to 6 m deep. Eggs incubate under ice for about six months.

In most systems, char are ready to take their first migration to sea at age 4 to 5 years and at a length of 150 to 250 mm (Johnson 1980). Smolts out-migrate to the sea in spring and early summer and feed throughout summer (A. D. Spares, M.J.W. Stokesbury, R.K. O'Dor and T.A. Dick. 2012; A. D. Spares et al. 2012; J.-S. Moore, L.N. Harris, S.T. Harris, L. Bernatchez, R.F. Tallman and A.T. Fisk. 2016; J.-S. Moore et al. 2016). Young Arctic Char do not venture much past the brackish water of river estuaries, but as they grow, they develop a tolerance to higher salinity sea water. They feed in nearshore areas along the coast for the duration of the summer. More abundant food resources in marine waters allow anadromous Arctic Char to grow faster and larger than the freshwater, resident form. In the autumn, all Arctic Char return to freshwater to overwinter to escape freezing in the sea to spawn and/or overwinter in lakes (Johnson 1980).

Table 10.2-12. Life History Characteristics of Fish Species Captured during Marine Fish Community Surveys in Roberts Bay, 2002 to 2017

Species	Scientific Name	Primary Habitat-Depth Range	Spawning		Fry Emergence Timing	Habitat Preference		
			Timing	Habitat Preference		Juvenile Rearing	Adult Rearing	Overwintering
Arctic Char (anadromous)	*Salvelinus alpinus*	Marine-Benthopelagic/ Freshwater	Sept - Oct[1]	Freshwater lakes[1]	April - July[2]	Freshwater lakes and rivers[1]	Marine, nearshore coastal areas, benthopelagic[1]	Freshwater lakes[1]
Lake Trout (anadromous)	*Salvelinus namaycush*	Marine-Benthopelagic/ Freshwater	Oct - Nov[2]	Freshwater lakes	March - April[2]	Freshwater	Freshwater, brackish, benthopelagic	Freshwater
Cisco (anadromous)	*Coregonus artedi*	Marine-Benthopelagic/ Freshwater	Sept - Oct[4]	Freshwater rivers[3]	May - June[4]	Marine, nearshore, shallow brackish[3]	Marine, nearshore, offshore, near surface	Marine, nearshore brackish water, freshwater rivers[3,4]
Least Cisco (anadromous)	*Coregonus sardinella*	Marine-Benthopelagic/ Freshwater	Sept - Nov[5]	Freshwater, deep pools of rivers and lakes over sand and gravel substrates[2]	Spring[2]	Marine, nearshore, estuaries, move downstream to sea upon hatching[2]	Freshwater (upriver migration in spring and summer), marine, nearshore, estuaries (downstream migration following spawning)[2]	Estuaries, brackish water[12]
Lake Whitefish (anadromous)	*Coregonus clupeaformis*	Marine-Benthopelagic/ Freshwater	Nov - Dec[2]	Freshwater rivers and lakes	April - May[2]	Freshwater or brackish[5]	Freshwater, brackish, benthopelagic[5]	-
Inconnu (anadromous)	Stenodus leucichtys	Marine-Benthopelagic/ Freshwater	Late Summer - Fall	Freshwater rivers	Spring	Freswater or brackish	Freshwater, brackish, benthopelagic	Marine or brackish5
Rainbow Smelt (anadromous)	*Osmerus mordax*	Marine-Benthopelagic/ Freshwater	Spring	Freshwater streams	7-30 days after spawning	Streams, and marine, nearshore, shallow, brackish	Marine, nearshore coastal areas, benthopelagic	Estuaries, brackish water
Saffron Cod	*Eleginus gracilis*	Marine-Demersal	Feb - Mar	Marine, nearshore, under ice, clean sand or pebble substrate	April - June	Marine or brackish, nearshore, shallow (< 25 m)	Marine or brackish, nearshore occasionally offshore, demersal	Marine or brackish
Greenland Cod	*Gadus ogac*	Marine-Demersal	Mar - Apr[8]	-	Apr - May	Marine or brackish, demersal[8]	Marine and brackish, marine nearshore, demersal[7]	Marine, nearshore, estuaries[8]
Fourhorn Sculpin	*Triglopsis quadricornis*	Marine-Demersal	Mid-winter	Marine, benthic, nearshore, gravel substrate	3 months after spawning	Marine or brackish, very shallow, nearshore	Freshwater, brackish, marine nearshore, demersal	Marine, nearshore, lakes
Shorthorn Sculpin	*Myoxocephalus scorpius*	Marine-Dermersal	Nov - Dec[9]	Marine, nearshore, rocky bottom[9]	Mid-March to mid-April[9]	Marine or brackish, mid-water benthic[9]	Marine or brackish, nearshore, demersal[5]	Marine or brackish[5]
Ninespine Stickleback	*Pungitius pungitius*	Marine-Benthopelagic/ Freshwater	Spring[5]	Freshwater, nearshore areas in lakes, ponds, streams[5]	15 days after spawning	Freshwater or brackish, shallow, sheltered	Brackish, shallow, sheltered	Freshwater, brackish
Arctic Flounder	*Liopsetta glacialis*	Marine-Demersal	Jan - June	Marine, shallow coastal areas	15 days after spawning	Marine, nearshore, shallow brackish	Marine, nearshore, offshore, demersal	Marine, nearshore, offshore, benthic[5]
Starry Flounder	*Platichthys stellatus*	Marine-Demersal	Spring	Marine, shallow nearshore	5 days after spawning	Estuaries, rivers, shallow marine nearshore	Brackish or marine, demersal, shallow to mid-water, sand and mud substrate, low salinity	Marine, deep water up to 300 m
Capelin	*Mallotus villosus*	Marine-Pelagic	Mid July - late Aug	Marine, sand and gravel beaches with strong wave action	15 days after spawning	Midwater in estuaries and offshore marine areas	Marine, offshore	Marine, offshore
Pacific Herring	*Clupea pallasii*	Marine-Pelagic	June-Sept	Protected nearshore brackish areas, clean substrate or algae	July	Marine or brackish, nearshore	Marine, offshore, pelagic	Marine, offshore
Arctic Shanny	*Stichaeus punctatus*	Marine-Demersal	Feb - Mar[10]	Marine, subtidal, boulder and cobble substrates[10]	July - August[10]	Marine, subtidal, gravel and cobble substrates[10]	Marine, subtidal, boulder and cobble substrates[10]	Marine, subtidal, boulder and cobble substrates[10]
Banded Gunnel	*Pholis fasciata*	Marine-Demersal	-	Marine, benthic, shallow subtidal[5]	May - June[11]	Marine, benthic, shallow subtidal[5]	Marine, benthic, shallow subtidal[5]	Marine, benthic, shallow subtidal[5]
Longhead dab	*Limanda proboscidea*	Marine-Demersal	June - Sept[5]	Marine, benthic, shallow[5]	July - Oct	Marine, benthic, shallow[5]	Marine, benthic, shallow[5]	Marine, benthic, shallow[5]
Poacher[a]	-	Marine-Demersal	-	-	-	-	-	-
Sand Lance[b]	*Ammodytes americanus*	Marine-Dermersal	Nov - Feb	Marine, nearshore, bottom-dwellers	Jan - April	-	-	-
Snailfish[c]	-	Marine-Demersal	-	-	-	-	-	-
Bering Wolffishd	Anarhichas orientalis	Marine-Demersal	-	Marine, shoal	-	Marine, benthic, rocky bottom	Marine, benthic, shallow rocky bottom	Marine, offshore

Notes: Dashes indicate information not available.
Demersal = bottom feeders; Pelagic = feed in open water; Benthopelagic = feed in open water and on bottom
[1](DFO 2004); [2](Scott and Crossman 1973); [3](Fechhelm et al. 1999); [4](Gallaway et al. 1983); [5](Froese and Pauly 2017); [6](Reist and Chang-Kue 1997); [7](Mikhail and Welch 1989); [8](Morin, Hudon, and Whoriskey 1991); [9](Ennis 1970); [10](Farwell, Green, and Pepper 1976); [11](Ochman and Dodson 1982); [12](Craig et al. 1984)
[a] Exact species unconfirmed, no information available on life history timing.
[b] Species unconfirmed but likely northern sand lance, Ammodytes americanus, *based on geographical position, and inshore capture.*
[c] Exact species unconfirmed, but possibly Liparis fabricii; *no information available on life history timing.*
[d] Very little is known about the Bering Wolffish habitat and habits, most of the information was derived from the latest COSEWIC (2002) status report.

Freshwater populations of Arctic Char feed on planktonic crustaceans, amphipods, molluscs, insects, and fishes, while anadromous populations are primarily piscivorous.

The Arctic Char captured in Roberts Bay from 2002 to 2017 were likely a mixture of out-migrants from rearing and overwintering lakes in the freshwater fish LSA and in-migrants from other river systems along the coast east and west of Roberts Bay. Most of the local Arctic Char are produced by the lakes of the Roberts drainage, including Little Roberts Lake, Roberts Lake and headwater lakes to Roberts Lake, and some are also produced by Glenn Lake.

Marine Species

Fifteen of the species sampled in Roberts Bay are exclusively marine in their habitat preferences and have never been captured in freshwater or estuarine habitats of the Project area. Table 10.2-13 summarizes the life histories of 15 marine species: the 12 species that were identified to the species level plus another 3 that were identified only to the family level (Sand Lance, Poacher, and Snailfish). Life history summaries were not prepared for unidentified flounder and sculpin species because life history summaries were available for several members of their families.

Three species are summer-spawners: Capelin (July-August), Pacific Herring (June-September), and Longhead Dab (June-September; Table 10.2-13). Capelin spawns in the subtidal and intertidal zones of sandy beaches, Pacific Herring on subtidal and intertidal vegetation or bedrock along the shoreline, and Longhead Dab in shallow, benthic habitat. Eggs incubate while attached to the substrate and hatch in 2-4 weeks, depending on water temperature. Juveniles disperse along the coast and offshore. Capelin and Pacific Herring are pelagic and feed on zooplankton. Longhead dab feeds on benthic prey.

Only one species is a fall spawner: Shorthorn Sculpin (November-December). Eggs are attached to the substrate and incubate over winter. They hatch in March-April and the juveniles adopt a benthic existence, feeding on small fish and crustaceans.

One species is a fall-winter spawner: Sand Lance (November-February). Eggs are laid in sandy habitat and the juveniles emerge from January to April. Juveniles are initially pelagic but adults are benthopelagic, living within sandy substrate and emerging to feed on copepods and other zooplankton.

Three species are winter spawners: Fourhorn Sculpin (January-February), Saffron Cod (February-March), and Arctic Shanny (February-March). Eggs are attached to the substrate and incubate over winter and early spring. Fourhorn Sculpin eggs hatch in April-May and the juveniles adopt a benthic existence, feeding on small fish and crustaceans. Saffron Cod eggs hatch in April-June and juveniles disperse along the coast, adopting a benthopelagic existence. Arctic Shanny eggs hatch in July and August and are initially pelagic before adopting a benthic existence as adults.

Four species have wide spawning periods that overlap winter and spring: Arctic Flounder (January-June), Greenland Cod (March-April), Banded Gunnel (uncertain), and Starry Flounder (March-May). All four species are demersal species that lay their eggs on the substrate. Juveniles emerge from February to July (Arctic Flounder), March to May (Starry Flounder), April to May (Greenland Cod), and May-June (Banded Gunnel). Very little is known of the spawning period of Banded Gunnel, but since its juveniles are found in May and June they are probably winter-spring spawners.

Finally, spawning timing is unknown for the Bering Wolffish. Information available suggests that they exhibit a nesting behavior and that the larvae are pelagic. They hatch sometime during the Arctic summer, and some larvae have been recorded in open water in May in the Bering Sea (COSEWIC 2002).

Saffron Cod: Marine Fish VEC

Saffron Cod is the second marine fish VEC. Its range spans the North Pacific, from Korea and the Sea of Okhotsk in the west to the northern Gulf of Alaska and eastern Banks Island in the east. It normally occurs in shallow coastal waters at less than 60 m depth but may also be found at depths up to 200 m, although unlikely (Wolotira Jr. 1985; Laurel et al. 2009; Copeman et al. 2016). They are commercially fished in many areas of the northwestern Pacific.

Saffron Cod spawn in February and March in nearshore habitat under the sea ice in strong tidal currents (Table 10.2-13). Spawning substrate is clean sand and gravel. Eggs incubate in the gravel for 2-3 months, depending on temperature and hatch in April-June. Juveniles disperse along the coast in shallow (<25 m), nearshore habitat, adopting a benthopelagic existence. They feed on fish and small crustaceans, mainly hunted along the sea floor, but pelagic prey are also consumed. Adults exhibit seasonal movements: inshore during winter for purposes of spawning and offshore during summer for feeding (Cohen et al. 1990).

Saffron Cod begin to mature during their third year of life and attain a maximum age of 15 years. Most probably do not exceed 10 years of age. Maximum reported length is 55 cm and maximum reported weight is 1.3 kg, but most specimens caught in Roberts Bay were substantially smaller in size.

Saffron Cod is the single most common member of the Roberts Bay fish community. Along with high relative abundance was high catch variability; Saffron Cod was caught in 8 of the 10 sampling years, but 90.9% of its numbers were caught in only two of those years: 38.8% in 2003 and 52.1% in 2005. This suggests that Saffron Cod use habitat in Roberts Bay on a seasonal basis during their onshore-offshore migrations.

Brackish Water Species

At least four of the remaining 16 fish species are marine but reside in brackish water habitat for part of their lives, at least during the open-water season (Tables 10.2-12 and 10.2-13). Arctic Flounder and Fourhorn Sculpin have been found in the Koignuk River and Little Roberts Outflow (Table 6.2-19), Greenland Cod has been found in the Koignuk River, and Starry Flounder has been found in Glenn Outflow. Both Arctic Flounder and Starry Flounder are known to enter low-salinity habitats (Walters 1955). The other two species are strictly marine fish species, so their capture in freshwater systems is likely a result of the fish remaining in areas of tidal influence (i.e., in the salt wedge underneath the surface freshwater layer).

Both Arctic Flounder and Starry Flounder spawn in winter-spring in shallow, inshore, marine and estuarine areas. Their juveniles rear in shallow, benthic habitat, often moving into brackish water habitats to rear. As they grow larger they move further out to sea. Greenland Cod spawns in spring in marine or brackish water habitat and juveniles rear in the same habitat. Fourhorn Sculpin spawns in mid-winter on gravel substrates in nearshore habitat and juveniles rear in marine and brackish water habitat.

<u>CRA Fisheries</u>

There is an established commercial Arctic Char fishery, based out of Cambridge Bay, which has a strong demand within and outside of Nunavut (Government of Nunavut and Nunavut Tunngavik Incorporated 2005; DFO 2014a). The Paliryuak (Surrey), Halokvik (Thirty-Mile), Palik (Lauchlan), Ekalluktok (Ekalluk), and Jayko (Jayco) rivers are currently commercially fished for anadromous Arctic Char(DFO 2014a). These rivers are located northeast of the RSA. Additionally, there is an emerging commercial fishery for Starry Flounder in the Coronation Gulf around Kugluktuk (Brubacher Development Strategies 2004), to the west of the RSA.

Table 10.2-13. Spawning and Fry Emergence Timing for Marine Fish Species Captured in Roberts Bay, 2002 to 2017

				Month											
Species	**Life stage**	**Habitat**	**Substrate**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Saffron Cod	Spawning	Marine, nearshore, under ice	Sand/gravel												
	Fry emergence	Marine, nearshore, under ice	Sand/gravel												
Greenland Cod	Spawning	Marine, benthic, nearshore	-												
	Fry emergence	Marine, benthic, nearshore	-												
Fourhorn Sculpin	Spawning	Marine, benthic, nearshore	Gravel	Mid winter											
	Fry emergence	Marine, benthic, nearshore	Gravel												
Shorthorn Sculpin	Spawning	Marine, nearshore	Rocky												
	Fry emergence	Marine, nearshore	Rocky												
Arctic Flounder	Spawning	Marine, Shallow coastal areas	Mud bottoms (fines)												
	Fry emergence	Marine, Shallow coastal areas	Mud bottoms (fines)												
Starry Flounder	Spawning	Marine, shallow nearshore	Sand				Spring								
	Fry emergence	Marine, shallow nearshore	Sand				Spring								
Capelin	Spawning	Marine, beaches with strong wave action	Sand/gravel							Mid					
	Fry emergence	Marine, beaches with strong wave action	Sand/gravel							Late		Early			
Pacific Herring	Spawning	Protected nearshore brackish areas	-							Little information on exact timing					
	Fry emergence	Protected nearshore brackish areas	-								Little information on exact timing				
Arctic Shanny	Spawning	Marine, subtidal	Cobble/boulder												
	Fry emergence	Marine, subtidal	Cobble/boulder												
Banded Gunnel	Spawning	Marine, benthic, shallow subtidal	-												
	Fry emergence	Marine, benthic, shallow subtidal	-												
Longhead Dab	Spawning	Marine, benthic, shallow	Mud (fines)/Sand												
	Fry emergence	Marine, benthic, shallow	Mud (fines)/Sand												
Poacher[a]	Spawning	Marine, bottom-dwellers	-												
	Fry emergence	Marine, bottom-dwellers	-												
Sand Lance[b]	Spawning	Marine, nearshore, bottom-dwellers	Sand												
	Fry emergence	Marine, nearshore, bottom-dwellers	Sand												
Snailfish[c]	Spawning	Marine	-												
	Fry emergence	Marine	-												
Bering Wolffishd	Spawning	Marine, nesting behavior	-												
	Fry emergence	Marine, pelagic	-												

Notes:
Species in bold were captured during most recent 2009 - 2010 surveys.
Dashes indicate data not available.
Yellow and green highlighted cells refer to spawning and fry emergence timing, respectively.
[a] Exact species unconfirmed, no information available on life history timing.
*[b] Species unconfirmed but likely northern sand lance (*Ammodytes americanus*), based on geographical position and inshore capture.*
[c] Exact species unconfirmed, but possibly Liparis fabricii*; no information available on life history timing.*
[d] Very little is known about the Bering Wolffish habitat and habits, most of the information was derived from the latest COSEWIC (2002) status report. No information on spawning timing. Indication of hatching during the Arctic summer.

The following recreational fish species are present in the RSA and are listed in the *Nunavut Sport Fishing Guide* (Government of Nunavut 2016): Arctic Char, Lake Trout, Lake Whitefish, Round Whitefish, Arctic Cisco, and Least Cisco. The RSA supports an existing Aboriginal fishery for Arctic Char, Saffron Cod, Arctic Cod, Lake Trout, Broad Whitefish, Arctic Cisco, sculpins, Capelin, Rainbow Smelt, Pacific Herring, flounders, wolfish, eels, crabs, oysters, and starfish (Banci and Spicker 2016).

10.3 VALUED COMPONENTS

10.3.1 Potential Valued Components and Scoping

Valued Ecological Components (VECs) are those components of the marine environment considered to be of scientific, ecological, economic, social, cultural, or heritage importance (Volume 2, Chapter 4). The selection and scoping of VECs considered biophysical conditions and trends that may interact with the proposed Madrid-Boston, variability in biophysical conditions over time, and data availability as well as the ability to measure biophysical conditions that may interact with Madrid-Boston and that are important to the communities potentially impacted by Madrid-Boston.

10.3.1.1 The Scoping Process and Identification of VECs

The scoping of VECs follows the process outlined in the Effects Assessment Methodology (Volume 2, Chapter 4). VECs were considered for inclusion in the marine fish effects assessment based on the role of fish and fish habitat in the marine environment, as well as the value placed on fish for commercial, recreational, traditional, and cultural use (NIRB 2012a).

The EIS guidelines (NIRB 2012a) propose a number of VECs that were considered for inclusion in the marine fish effects assessment:

- Marine ecology;
- Marine biota (including representative fish as defined in the *Fisheries Act*, benthic invertebrates, and other marine organisms including estuarine organisms);
- Species at Risk;
- Marine habitat including fish habitat as defined in the *Fisheries Act*; and
- Commercial, recreational, and Aboriginal (CRA) fisheries as defined in the *Fisheries Act*.

The identified VECs in the EIS guidelines represent an appropriate starting point to guide the identification and scoping of VECs (NIRB 2012a). The selection of VECs began with those proposed in the EIS guidelines and was further informed through consultation with communities, regulatory agencies, available TK, professional expertise, regulatory considerations, and the NIRB's final scoping report (Appendix B of the EIS Guidelines), as well as available baseline information. For an interaction to occur there must be spatial and temporal overlap between a VEC and Madrid-Boston components and/or activities. The determination of VECs and potential effects for inclusion in the marine fish effects assessment considered and was informed by:

- EIS guidelines and appendices (NIRB 2012a);
- Available traditional knowledge information from the *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project* (NTKP) report (Banci and Spicker 2016) which presents summary information and distribution maps of valued fish species, specific fishing locations, areas of general fishing activity, and traditional land use activities;

- Consultation and engagement with local and regional Inuit groups (for example, the KIA);
- The public, during public consultation and open house meetings held in the Kitikmeot communities (Volume 2, Chapter 3; Public Consultation and Engagement);
- Consultation with regulatory agencies;
- Regulatory consideration of the legislation that exists to protect fish and fish habitat including the *Fisheries Act*, MMER Regulations, and SARA (no SARA-listed fish species were identified in baseline studies); and
- Review of the marine fish and fish habitat sections of recently completed Nunavut EAs (e.g., Back River, Mary River).

The content and results of other EIS chapters were also reviewed to inform the selection of marine fish VECs and effects including Marine Water Quality and Marine Sediment Quality (Volume 5, Chapter 8 and 9, respectively) and the Human Health and Environmental Risk Assessment (Volume 6, Chapter 5). These chapters are referenced in the assessment, where appropriate.

10.3.1.2 NIRB Scoping Sessions

Scoping sessions hosted by NIRB (NIRB 2012b) with key stakeholders and local community members (i.e., the public) focused on identifying the components that are important to local residents, as related to Madrid-Boston. Comments made during these sessions were compiled and analysed as part of VEC scoping. Notably, the main remarks related to the marine environment and linked to marine fish were those concerned with water quality (fish habitat) and effects on fish and marine habitats due to sealift traffic and fuel resupply. The comments received can be summarized as follows.

<u>Marine Water Quality</u>

- Dust during spring-run off could impact the environment.
- Water should be left as clean as when the mine first started.

<u>Fish and Fish Habitat</u>

- Concern that char and breeding seals would be impacted from the number of ships between July and September.
- Concern regarding the docking area and impacts it may have on whales and char.

<u>Marine Habitat</u>

- Concern regarding the impact of ice breakers that come to the area every summer, and the barges that bring supplies seem as they are doing damage to the sea life.

10.3.1.3 TMAC Consultation and Engagement Informing VEC Selection

Community meetings for the Madrid-Boston Project were conducted in each of the five Kitikmeot communities as described in Chapter 3 of Volume 2. The meetings were a central component of engagement with the public and an opportunity to share information and seek public feedback. Overall, the community meetings were well attended, and public feedback (questions, comments, and concerns) about the proposed Project was obtained through open dialogue during Project presentations, through discussions that arose during the presentation of Project materials, and comments provided in feedback forms. Questions, comments, and concerns related to marine fish included:

- Workers ability/permission to fish while at camp;
- Impacts to fish and fish health; and
- Impacts of shipping activities on marine wildlife.

10.3.2 Valued Components Included in the Assessment

The scoping analysis identified the following VECs for inclusion in the assessment:

- Fish Habitat;
- Fish Community – Arctic Char (anadromous life history); and
- Fish Community – Saffron Cod.

The VECs selected to guide the assessment of the potential effects of Madrid-Boston on marine fish are those:

- that have potential to interact with the activities and components of Madrid-Boston;
- identified as important by local communities, Inuit organizations, governments, regulators, and other stakeholders during consultation and engagement;
- protected under legislation including the *Fisheries Act* and MMER Regulations; and
- informed by Inuit Qaujimajatuqangit (IQ) (Volume 2, Chapter 2; Traditional Knowledge) and professional judgement.

Table 10.3-1 summarizes the main reasons for selecting the three marine fish VECs (fish habitat, Arctic Char, and Saffron Cod) included in the marine fish assessment. The components of the marine environment proposed as VECs by the EIS guidelines (NIRB 2012a) were considered in the scoping process and recognized as being included in relevant marine environment assessment areas (e.g., marine water quality, marine sediment quality, etc.) or as belonging to one of two broader categories of marine fish VECs: 1) fish habitat; and 2) fish community, as represented by two VEC fish species (See Table 4.3-1, Volume 2, Chapter 4). Thus, VECs proposed by the EIS guidelines have either been included as indicated in Table 10.3-1 or are otherwise addressed elsewhere in the EIS.

Marine ecology (proposed as a VEC by the EIS guidelines) includes relationships between marine organisms (i.e., marine biota) and their environments, and relationships among marine organisms. Potential Madrid-Boston effects on the marine environment are assessed in the preceding chapters of Volume 5 of this EIS including, Chapter 8 (Marine Water Quality), and Chapter 9 (Marine Sediment Quality). In these chapters, effects on marine organisms through their interactions with the marine environment are also considered. For example, marine water quality and marine sediment quality indicators were used that have quantitative relationships or thresholds associated with supporting organisms and biogeochemical processes, including established guidelines (marine quality and sediment quality) for the protection of aquatic life established by the Canadian Council of Ministers of the Environment (CCME). These water quality guidelines define concentrations of water quality parameters that should present a negligible risk to marine and estuarine organisms. The assessment of effects on aquatic ecology is also incorporated into the assessment of the marine fish habitat VEC in this chapter through examination of potential effects on fish habitat, which includes physical characteristics (e.g., water quality, sediment quality, available area) and biological resources (e.g., primary and secondary producers). The marine fish habitat VEC assessment therefore considers aquatic ecology through potential project effects that may impact relationships between the marine environment (i.e., fish habitat) and marine organisms (i.e., components of fish habitat and fish.)

Table 10.3-1. Valued Ecosystem Components Included in the Marine Fish Assessment

VEC	Identified by: TK	Identified by: NIRB Guidelines	Identified by: Government	Rationale for Inclusion
Fish Habitat	X	X	X	TK and land users indicated marine fish habitats that are used as areas of general fishing effort in the Madrid-Boston area (Banci and Spicker 2016). Marine ecology, marine biota (including representative fish (i.e., CRA species) as defined in the *Fisheries Act*, benthic invertebrates, and other aquatic organisms) and habitat (including fish habitat as defined in the Fisheries Act which in this assessment comprises both biological resources and physical characteristics) were identified as candidate VECs in the EIS guidelines (NIRB 2012a). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish which includes any permanent alteration to, or destruction (PAD) of fish habitat. Information from TK, land users, and baseline studies in the Madrid-Boston area indicate that multiple marine fish habitats overlap with Madrid-Boston activities.
Fish Community – Arctic Char (anadromous life history)	X	X	X	TK and land users identified Arctic Char as an important food fish for Inuit (Banci and Spicker 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to a fish species that is part of a CRA fishery. As a CRA fishery species, Arctic Char was identified as a candidate VEC and information on Arctic Char was specifically requested in the EIS guidelines with respect to the biophysical environment and impact assessment (NIRB 2012a). Information from TK, land users, and baseline studies in the Madrid-Boston area indicate that the distribution of Arctic Char (anadromous life history) overlaps with Madrid-Boston activities. The distribution of other anadromous species including Cisco, Least Cisco, Lake Whitefish and Lake Trout will be covered by the Arctic Char (anadromous life history) VEC.
Fish Community - Saffron Cod (marine life history)	X	X	X	TK and land users identified Saffron Cod as a species fished by Inuit (Banci and Spicker 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish species that are part of a CRA fishery, which therefore includes Saffron Cod. Information from TK, land users, and baseline studies in the Madrid-Boston area indicate that the distribution of Saffron Cod overlaps with Madrid-Boston activities. Saffron Cod was the most common fish species captured in Roberts Bay – the marine fish LSA – during 9 years of baseline surveys.

Marine biota including benthic invertebrates and other marine organisms (proposed as a VEC by the EIS guidelines), are incorporate into the marine fish effects assessment as part of the fish habitat VEC. Fish habitat was assessed as defined in the *Fisheries Act*, and therefore includes both the physical characteristics of the habitat, and the forage fish and other biological resources (i.e., marine biota) that are essential to the productivity of fisheries.

Finally, fish habitat and commercial, recreational, and Aboriginal fisheries as defined in the *Fisheries Act* (proposed as VECs by the EIS guidelines) are incorporated as individual VECs in the marine fish effects assessment. Thus, all VECs proposed by the EIS guidelines have either been included in the marine fish effects assessment as indicated in Table 10.3-1 and/or are otherwise addressed elsewhere in the EIS.

The marine **fish habitat** VEC includes physical and biological habitat, i.e., the forage fish and other biological resources such as phytoplankton, zooplankton, and benthic invertebrates that are essential to the productivity of fisheries. Forage fish species are those species that are dietary resources for other fish and are included in the fish habitat VEC based of their role as food supply or "fish that support" CRA fisheries as informed by the EIS guidelines (NIRB 2012a) and the *Fisheries Act*, respectively. Biological resources, as defined here and informed by the EIS guidelines (NIRB 2012a), include the primary producers (phytoplankton) and secondary producers (zooplankton and benthic invertebrates) that make up the lower trophic levels that form the base of fish dietary resources. Marine water quality and/or marine sediment quality also form part of the marine environment that acts as habitat for fish and are considered under the fish habitat VEC.

This chapter assesses Madrid-Boston effects on the fish habitat VEC as defined above. Direct effects may result from specific Project/environment interactions between Project activities and components, and the marine fish habitat VEC. Indirect effects may be the result of direct effects on the environment that lead to secondary or collateral effects on the fish habitat VEC. The assessment of Madrid-Boston effects on the fish habitat VEC includes only the *direct* effects of Madrid-Boston infrastructure and activities on the physical aspects of the aquatic environment that provide distinct habitat for CRA fisheries and fish that support CRA fisheries (i.e., forage fish). These activities include the loss or alteration of fish habitat due to encroachment of the Madrid-Boston infrastructure footprint, and from accidents and malfunctions (e.g., accidental spills and releases of contaminants). *Indirect* effects of Madrid-Boston activities on the fish habitat VEC may result through effects on marine water quality and/or sediment quality, and biological resources. Marine Water Quality and Marine Sediment Quality are treated as stand-alone VECs in other chapters of this EIS (Volume 5, Chapters 8 and 9) and are considered to adequately assess the potential indirect effects of Madrid-Boston activities on aspects of the fish habitat VEC, including marine water quality, marine sediment quality, and biological resources based on the following logic:

1. Potential Madrid-Boston project-related effects on fish habitat are mediated *indirectly* through trophic interactions between fish and their biological/dietary resources (primary and secondary producers).
2. Potential Madrid-Boston project-related effects on primary and secondary producers predominantly arise *indirectly* from changes to marine water quality and/or marine sediment quality.
3. Potential Madrid-Boston project-related effects on marine water quality and/or marine sediment quality arise *directly* from project activities and are assessed individually through the VECs Marine Water Quality (Volume 5, Chapter 8) and Marine Sediment Quality (Volume 5, Chapter 9).
4. No significant residual effects are predicted for Marine Water Quality and Marine Sediment Quality after mitigation, management, and monitoring measures are considered (Volume 5, Chapters 8 and 9, respectively).

As a result of there being no predicted significant residual effects of the Madrid-Boston Project on marine water quality and/or marine sediment quality, indirect effects on fish habitat resulting from these VECs have not been further assessed in this chapter.

The marine **fish community** VEC comprises the survival and abundance of individual fish VECs including **Arctic Char** (anadromous life history) and **Saffron Cod** (marine life history). Rationale for the selection of individual species VECs relied on guidance from the EIS guidelines, TK information, and the definition of CRA fisheries species under the *Fisheries Act* (Table 10.3-1), as well as available baseline information.

Arctic Char was selected to represent the anadromous life histories of salmonids, although at least four other anadromous salmonids are present in Roberts Bay: Lake Trout, Cisco, Least Cisco, and Lake Whitefish. Arctic Char was selected because of its importance as a food source to the Inuit, and because of its relatively high abundance in Roberts Bay. Seasonal migrations of Arctic Char into Roberts Bay in spring and their return to freshwater in autumn are largely representative of all anadromous salmonids found in Roberts Bay, including habitat preferences, prey species, and life history timing considerations.

Saffron Cod was chosen because it is an Inuit food fish and the single most common fish species captured in Roberts Bay, and because it is an exclusively marine species.

This chapter assesses Madrid-Boston effects on fish community VECs. Direct effects may result from specific Project/environment interactions between Project activities and components, and the fish community VECs. *Indirect* effects may be the result of *direct* effects on the environment that lead to secondary or collateral effects on the fish community VECs. This chapter assesses the potential *direct* effects of Madrid-Boston on the survival and population abundance of individual fish species VECs. These *direct* effects may be caused by marine effluent discharge, sealift (e.g., introduction of exotic species and pathogens via ballast water exchanges) and/or by Madrid-Boston activities that physically harm fish (e.g., blasting, pile driving, fishing). Individual fish health and survival could also potentially be *indirectly* affected by Madrid-Boston through the contamination of marine water and/or sediment, as well as through the bioaccumulation of contaminants in fish through trophic interactions with primary and secondary producers. The *indirect* effects of Madrid-Boston activities on individual fish species VECs are not included in this chapter because they are assessed in other chapters within the EIS. The potential for adverse effects to fish health and survival due to changes in water quality and/or sediment quality has been scoped out of the assessment of fish community VECs because Marine Water Quality and Marine Sediment Quality are assessed in Volume 5, Chapters 8 and 9, respectively. The assessments of marine water quality and marine sediment quality consider the potential for adverse effects on fish health and survival as they are based on indicators that have quantitative relationships or thresholds associated with supporting aquatic organisms, including established guidelines for the protection of aquatic life. The potential for contaminant bioaccumulation in the VECs Arctic Char (anadromous life history) is quantitatively assessed in the Human Health and Environmental Risk Assessment (Volume 6, Chapter 5).

10.3.3 Valued Components Excluded from the Assessment

The marine environment VECs proposed in the EIS guidelines (NIRB 2012a) are included in this assessment as part of the selected marine fish habitat (inclusive of biological resources and physical characteristics) and fish species VECs or, have been adequately assessed by inclusion in one or more other relevant assessment areas such as Marine Water Quality (Volume 5, Chapter 8) and Marine Sediment Quality (Volume 5, Chapter 9). Thus, none of the proposed components of the marine aquatic environment VEC have been excluded from the assessment.

10.4 SPATIAL AND TEMPORAL BOUNDARIES

The spatial boundaries selected to shape this assessment are determined by the Project's potential impacts on the marine environment. These considered the maximum potential spatial extent of impacts associated with Madrid-Boston components/activities on marine fish over all Project phases.

Temporal boundaries are selected to consider the different phases of the Project and their durations. The Project's temporal boundaries reflect those periods during which planned activities will occur and have potential to affect a *VEC*.

The determination of spatial and temporal boundaries also takes into account the development of the entire Hope Bay Greenstone Belt. The assessment considers both the incremental potential effects of the Project as well as the total potential effects of the additional Project activities in combination with the existing and approved Projects including the Doris Project and advanced exploration activities at Madrid and Boston.

10.4.1 Project Overview

The Madrid-Boston Project consists of proposed mine operations at the Madrid North, Madrid South and Boston deposits. The Madrid-Boston Project is part of a staged approach to continuous development of the Hope Bay Project, comprised of existing operations at Doris and bulk samples followed by commercial mining at Madrid North, Madrid South, and Boston deposits. The Madrid-Boston Project would use and expand upon the existing Doris Project infrastructure.

The Madrid-Boston Project is the focus of this application. Because the infrastructure of existing and approved projects will be utilized by the Madrid-Boston Project, and because the existing and approved projects have the potential to interact cumulatively with the Madrid-Boston Project, existing and approved project are described below.

10.4.1.1 Existing and Approved Projects

Existing and approved projects include:

- the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
- the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
- the Madrid Advanced Exploration Program (NWB Type B Water Licence 2BB-MAE1727); and
- the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1727).

<u>The Doris Project</u>

The Doris Project was approved by NIRB in 2006 (NIRB Project Certificate 003) and licenced by NWB in 2007 (Type A Water Licence 2AM-DOH0713). The Type A Water Licence was amended in 2010, 2011 and 2012 and received modifications in 2009, 2010, and 2011.

Construction of the Doris Project began in early 2010. In early 2012, the Doris Project was placed into care and maintenance, suspending further Project-related construction and exploration activity along the Hope Bay Greenstone Belt. Following TMAC's acquisition of the Hope Bay Project in March of 2013, NWB renewed the Doris Project Type A Water Licence (Type A Water Licence 2AM-DOH1323), and TMAC advanced planning, permitting, exploration, and construction activities. In 2016, NIRB approved an amendment to Project Certificate 003 and NWB granted Amendment No. 1 to Type A Water Licence 2AM-DOH1323, extending operations from two to six years through mining two additional mineralized zones (Doris Connector and Doris Central zones) to be accessed via the existing Doris North portal. Amendment No. 1 to Type A Water Licence 2AM-DOH1323 authorizes a mining rate of approximately 2,000 tonnes per day of ore and a milling throughput of approximately 2,000 tonnes per day of ore. The Doris Project began production early in 2017.

The Doris Project includes the following components and facilities:

- The Roberts Bay offloading facility: marine jetty, barge landing area, beach laydown area, access roads, weather havens, fuel tank farm/transfer station, waste storage facilities and incinerator, and quarry;
- The Doris site: 280 person camp, laydown areas, service complex (e.g., workshop, wash bay, administration buildings, mine dry), two quarries (mill site platform and solid waste landfill), core storage areas, batch plant, brine mixing facilities, vent raise (3), air heating units, reagent storage, fuel tank farm/transfer station, potable water treatment, waste water treatment, incinerator, landfarm and handling/temporary hazardous waste storage, explosives magazine, and diesel power plant;
- Doris Mine works and processing: underground portal, overburden stockpile, temporary waste rock pile, ore stockpile, and ore processing plant (mill);
- Tailings Impoundment Area (TIA): Schedule 2 designation for Tail Lake with two dams (North and South dams), sub-aerial deposition of flotation tailings, emergency tailings dump catch basins, pump house, and quarry;
- All-season main road with transport trucks: Roberts Bay to Doris site (4.8 km, 150 to 200 tractor and 300 fuel tanker trucks/year);
- Access roads from Doris site used predominantly by light-duty trucks to: the TIA, the explosives magazine, Doris Lake float plane dock (previously in use), solid waste disposal site, and to the tailings decant pipe, from the Roberts Bay offloading facility to the location where the discharge pipe enters the ocean; and
- All-weather airstrip (914 m), winter airstrip (1,524 m), helicopter landing site and building, and Doris Lake float plane and boat dock.

Water is managed at the Doris Project through:

- freshwater input from Doris Lake for mining, milling, and associated activities and domestic purposes;
- freshwater input from Windy Lake for domestic purposes;
- process water input primarily from the TIA reclaim pond;
- surface mine contact water discharged to the TIA;
- underground mine contact water directed to the TIA or to Roberts Bay via the marine outfall mixing box (MOMB);
- treated waste water discharged to the TIA; and
- water from the TIA treated and discharged to Roberts Bay via a discharge pipeline, with use of a MOMB.

Hope Bay Regional Exploration Project

The Hope Bay Regional Exploration Project has been renewed several times since 1995. The current extension expires in June 2022. Much of the previous work for the program was based out of Windy Lake and Boston camps. These camps were closed in October 2008 with infrastructure either decommissioned or moved to the Doris site. All exploration activities are now based from the Doris site. Components and activities for the Hope Bay Regional Exploration Project include:

- operation of helicopters from Doris; and
- the use of exploration drills, which are periodically moved by roads and by helicopter as required.

Madrid Advanced Exploration

In 2017, the NWB issued a Type B Water Licence (2BB-MAE1727) for the Madrid Advanced Exploration Program to support continued exploration and a bulk sample program at the Madrid North and Madrid South sites, located approximately 4 km south of the Doris site. The program includes extraction of a bulk sample totaling 50 tonnes from each of the Madrid North and South locations, which will be trucked to the mill at the Doris site for processing and placement of tailings in the tailings impoundment area (TIA). All personnel will be housed in the Doris camp.

The Madrid Advanced Exploration Program includes the following components and activities.

- Use of existing infrastructure associated with the Doris Project:
  - camp facilities to support up to 70 personnel as required to undertake the advanced exploration activities;
  - mill to process ore;
  - TIA;
  - landfill and hazardous waste areas, particularly if closure and remediation becomes required for the Madrid Advanced Exploration Program infrastructure;
  - fuel tank farms; and
  - Doris airstrip and Roberts Bay facility for transport of personnel and supplies.
- Use of existing infrastructure at the Madrid and Boston areas:
  - borrow and rock quarry facilities: existing Quarries A, B, and D along the Doris-Windy all-weather road (AWR);
  - AWR between Doris and Windy Lake for transportation of personnel, ore, waste, fuel, and supplies; and
  - future mobilization of existing exploration site infrastructure, should it become necessary.
- Construction of additional facilities at Madrid North and South:
  - access portals and ramps for underground operations at Madrid North and at Madrid South;
  - 4.7 km extension of the existing AWR originating from the Doris to the Windy exploration area (Madrid North) to the Madrid South deposit, with branches to Madrid North, Madrid North vent raise, and the Madrid South portal;
  - development of a winter road route (WRR) from Madrid North to access Madrid South until AWR has been constructed;
  - borrow and rock quarry facilities; two quarries referenced as Quarries G and H;
  - waste rock and ore stockpiles;

    - water and waste management structures; and
    - additional site infrastructure, including compressor building, brine mixing facility, saline storage tank, air heating facility, four vent raises, workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station.
- Undertaking of advanced exploration access to aforementioned deposits through:
    - continue field mapping and sampling, as well as airborne/ground/downhole geophysics;
    - diamond drilling from the surface and underground; and
    - bulk sampling through underground mining methods and mine development.

<u>Boston Advanced Exploration</u>

The Boston Advanced Exploration Project Type B Water Licence No. 2BB-BOS1217 was renewed as Water Licence No. 2BB-BOS1727 in July 2017 and includes:

- the Boston camp (65 person), maintenance shops, workshops, laydown areas, water pumphouse, vent raise, warehouse, site service roads, sewage and greywater treatment plant, fuel storage and transfer station, landfarm, solid waste landfill and a heli-pad;
- mine works, consisting of underground development for exploration drilling and bulk sampling, waste rock and ore stockpiles;
- potable water and industrial water from Aimaokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

10.4.1.2 The Madrid-Boston Project

The Madrid-Boston Project includes: the Construction and Operation of commercial mining at the Madrid North, Madrid South, and Boston sites; the continued operation of Roberts Bay and the Doris site to support mining at Madrid and Boston; and the Reclamation and Closure and Post-closure phases of all sites. Excluded from the Madrid-Boston Project for the purposes of the assessment are the Reclamation and Closure and Post-closure components of the Doris Project as currently permitted and approved.

<u>Construction</u>

Madrid-Boston construction will use the infrastructure associated with Existing and Approved Projects. This may include:

- an all-weather airstrip at the Boston exploration area and helicopter pad;
- seasonal construction and/or operation of a winter ice strip on Aimaokatalok Lake;
- Boston camp with expected capacity for approximately 65 people during construction
- Quarry D Camp with capacity for up to 180 people;
- seasonal construction/operation of Doris to Boston WRR;
- three existing quarry sites along the Doris to Windy AWR;
- Doris camp with capacity for up to 280 people;
- Doris airstrip, winter ice strip, and helicopter pad;
- Roberts Bay offloading facility and road to Doris; and
- Madrid North and Madrid South sites and access roads.

Additional infrastructure to be constructed for the proposed Madrid-Boston Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, development of a west road to facilitate access, and quarrying, crushing, and screening of aggregate for the construction);
- construction of a cargo dock at Roberts Bay (including a fuel pipeline, mooring points, beach landing and gravel pad, shore manifold);
- construction of an additional tank farm at Roberts Bay (consisting of two 10 ML tanks);
- expansion of Doris accommodation facility (from 280 to 400 person), mine dry and administrative building, water treatment at Doris site;
- expansion of the Doris mill to accommodate concentrate handling on the south end of the building facility and rearrangement of indoor crushing and processing within the mill building;
- complete development of the Madrid North and Madrid South mine workings;
- incremental expansion of infrastructure at Madrid North and Madrid South to accommodate production mining, including vent raise, access road, process plant buildings;
- construction of a 1,200 tpd concentrator, fuel storage, power plant, mill maintenance shop, warehouse/reagent storage at Madrid North;
- all weather access road and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston (approximately 53 km long, nine quarries for permitting purposes, four of which will likely be used);
- all-weather airstrip, airstrip building, helipad and heliport building at Boston;
- construction of a 2,400 tpd process plant at Boston;
- all infrastructure necessary to support mining and processing activities at Boston including construction of a new 300-person accommodation facility, mine office and dry and administration buildings, additional fuel storage, laydown area, ore pad, waste rock pad, diesel power plant and dry-stack tailings management area (TMA);
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston; and
- wind turbines near the Doris (2), Madrid (2), and Boston (2) sites.

Operation

The Madrid-Boston Project Operation phase includes:

- mining of the Madrid North, Madrid South, and Boston deposits by way of underground portals and Crown Pillar Recovery;
- operation of a concentrator at Madrid North;
- transportation of ore from Madrid North, Madrid South, and Boston to the Doris process plant, and transporting the concentrate from the Madrid North concentrator to the Doris process plant;
- extending the operation at Roberts Bay and Doris;
- processing the ore and/or concentrate from Madrid North, Madrid South, and Boston at the Doris process plant with disposal of the detoxified tailings underground at Madrid North, flotation tailings from the Doris process plant pumped to the expanded Doris TIA, and discharge of the TIA effluent to the marine environment;

- operation of a concentrator at Madrid North and disposal of tailings at the Doris TIA;
- operation of a process plant and wastewater treatment plant at Boston with disposal of flotation tailings to the Boston TMA and a portion placed underground and the detoxified leached tailings placed in the underground mine at Boston;
- operation of two wind turbines for power generation; and
- on-going maintenance of transportation infrastructure at all sites (cargo dock, jetty, roads, and quarries).

Reclamation and Closure

Areas which are no longer needed to carry out Madrid-Boston Project activities may be reclaimed during Construction and Operation. At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Section 5.5):

- Camps and associated infrastructure will be disassembled and/or disposed of in approved non-hazardous site landfills.
- Non-hazardous landfills will be progressively covered with quarry rock, as cells are completed. At final closure, the facility will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- Rockfill pads occupied by construction camps and associated infrastructure and laydown areas will be re-graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re-established.
- Quarries no longer required will be made physically and geotechnically stable by scaling high walls and constructing barrier berms upstream of the high walls.
- Landfarms will be closed by removing and disposing of the liner, and re-grading the berms to ensure the area is physically and geotechnically stable.
- Mine waste rock will be used as structural mine backfill.
- The Doris TIA surface will be covered waste rock. Once the water quality in the reclaim pond has reached the required discharge criteria, the North Dam will be breached and the flow returned to Doris Creek.
- The Madrid to Boston AWR and Boston Airstrip will remain in place after Reclamation and Closure. Peripheral equipment will be removed. Where rock drains, culverts or bridges have been installed, the roadway or airstrip will be breached and the element removed. The breached opening will be sloped and armoured with rock to ensure that natural drainage can pass without the need for long-term maintenance.

A low permeability cover, including a geomembrane, will be placed over the Boston TMA. The contact water containment berms will be breached and the liner will be cut to prevent collecting any water. The balance of the berms will be left in place to prevent localized permafrost degradation.

10.4.2 Spatial Boundaries

10.4.2.1 Project Development Area

The Project Development Area (PDA) is shown in Figure 10.2-1 and is defined as the area which has the potential for infrastructure to be developed as part of the Madrid-Boston Project. The PDA includes engineering buffers around the footprints of structures. These buffers allow for latitude in the final placement of a structure through later design and construction phases, reflecting the certainty of design and construction. Compounds with buildings and other infrastructure in close proximity are defined as pads with buffers whereas roads are defined as linear corridors with buffers. The buffers for pads varied depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m either side.

Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of these features. In all cases, the PDA does not include the Madrid –Boston Project design buffers applied to potentially environmentally sensitive features. These are detailed in Volume 3, Chapter 2 (Project Design Considerations).

10.4.2.2 Local Study Area

The Local Study Area (LSA) is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on a VEC due to an interaction with a Project component(s) or physical activity. The LSA for marine fish is set to encompass Roberts Bay and is bounded by the shoreline around the bay and where it exchanges water with Melville Sound (Figures 10.2-1 and 10.2-2).

The marine LSA used for the assessment of effects on marine fish VECs has an area of approximately 14.3 km^2 and includes the PDA of the cargo dock and its near-shore marine waters, seabed, and shorelines (Figure 10.2-2). It is designed to reflect the scale at which direct, immediate, and localized disturbances to the marine environment (and therefore marine fish) have the potential to occur.

10.4.2.3 Regional Study Area

The Regional Study Area (RSA) is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur. The RSA encompasses the PDA and LSA, and is bounded by the shoreline of Melville Sound from the chain of islands just east of Ida Bay into the northern portion of Bathurst Inlet (Figure 10.2-1). The marine fish RSA included the proposed sealift lane within Bathurst Inlet and Melville Sound that will bring sealifts and fuel into the Roberts Bay LSA, and represents the maximum extent where potential direct or indirect effects to the marine environment may occur.

10.4.3 Temporal Boundaries

The Project represents a significant development in the mining of the Hope Bay Greenstone Belt. Even though this Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, the Madrid-Boston Project is a continuation of development currently underway. The Project has four separate operational sites: Roberts Bay, Doris, Madrid (North and South), and Boston. The development of these sites is planned to be sequential. As such, the temporal boundaries of this Project overlap with a number of Existing and Approved Authorizations (EAAs) for the Hope Bay Project and the extension of activities.

For the purposes of the EIS, distinct phases of the Project are defined (Table 10.4-1). It is understood that construction, operation and closure activities will, in fact, overlap among sites; this is outlined in Table 10.4-1 and further described in Volume 3, Chapter 2 (Project Design Considerations).

The assessment also considers a Temporary Closure phase should there be a suspension of Project activities during periods when the Project becomes uneconomical due to market conditions. During this phase, the Project would be under care and maintenance. This could occur in any year of Construction or Operation with an indeterminate length (one to two year duration would be typical).

Table 10.4-1. Temporal Boundaries for the Effects Assessment for Marine Fish

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Construction	1 - 4	2019 - 2022	4	• **Roberts Bay:** construction of access road (Year 1), marine dock and additional fuel facilities (Year 2 – Year 3); • **Doris**: expansion of the Doris TIA and accommodation facility (Year 1); • **Madrid North:** construction of concentrator and road to Doris TIA (Year 1 – Year 2); • **All-weather Road**: construction (Year 1 – Year 3); • **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 – Year 5).
Operation	5 - 14	2023 - 2032	10	• **Roberts Bay**: sealift operations (Year 1 – Year 14); • **Doris**: processing and infrastructure use (Year 1 – Year 14); • **Madrid North:** mining (Year 1 – 13); ore transport to Doris process plant (Year 1 -13); ore processing and concentrate transport to Doris process plant (Year 2 – Year 13); • **Madrid South:** mining (Year 11 – Year 14); ore transport to Doris process plant (Year 11 – Year 14); • **All-weather Road**: operational (Year 4 – Year 14); • **Boston**: winter access road operating (Year 1 – Year 3); mining (Year 4 – Year 11); ore transport to Doris process plant (Year 4 – Year 6); and processing ore (Year 5 – Year 11).
Reclamation and Closure	15 - 17	2033 - 2035	3	• **Roberts Bay**: facilities will be operational during closure (Year 15 – Year 17); • **Doris**: camp and facilities will be operational during closure (Year 15 – Year 17); mine, process plant, and TIA decommissioning (Year 15 – Year 17); • **Madrid North:** all components decommissioned (Year 15 – Year 17); • **Madrid South:** all components decommissioned (Year 15 – Year 17); • **All-weather Road**: road will be operational (Year 15 – Year 16); decommissioning (Year 17); • **Boston**: all components decommissioned (Year 15 – Year 17).
Post-Closure	18 - 22	2036 - 2040	5	• **All Sites:** Post-closure monitoring.
Temporary Closure	NA	NA	NA	• **All Sites:** Care and maintenance activities, generally consisting of closing down operations, securing infrastructure, removing surplus equipment and supplies, and implementing on-going monitoring and site maintenance activities.

10.5 PROJECT-RELATED EFFECTS ASSESSMENT

10.5.1 Methodology Overview

This assessment follows a methodology used to identify and assess the potential environmental effects of the Madrid-Boston Project and is consistent with the requirements of Section 12.5.2 of the Nunavut Agreement and the EIS guidelines. The effects assessment evaluates the potential direct and indirect effects of the Madrid-Boston Project on marine fish comprising fish habitat (inclusive of biological resources and physical characteristics) and fish communities. It follows the general methodology described in Volume 2, Chapter 4 (Effects Assessment Methodology), and comprises a number of steps that collectively assess the manner in which the Madrid-Boston Project will interact with VECs defined in the assessment (Section 10.3).

To provide a comprehensive understanding of the potential effects for the Project, the Madrid-Boston components and activities are assessed on their own as well as in the context of the Approved Projects (Doris and exploration) within the Hope Bay Greenstone Belt. The effects assessment process is summarized as follows:

1. Identify potential interactions between the Madrid-Boston Project and the VECs or VSECs;
2. Identify the resulting potential effects of those interactions;
3. Identify mitigation or management measures to eliminate or reduce the potential effects;
4. Identify residual effects (potential effects that would remain after mitigation and management measures have been applied) for Madrid-Boston in isolation;
5. Identify residual effects of Madrid-Boston in combination with the residual effects of Approved Projects; and
6. Determine the significance of combined residual effects.

After the identification of potential interactions and potential effects (Steps 1 and 2), mitigation and management measures (including fisheries offsetting, see Section 6.2.3.1) were considered (Step 3). Madrid-Boston Project-related residual effects to freshwater fish VECs were then identified through characterization of the effect (Step 4). If the application of these measures were considered to effectively mitigate or offset the effect, the Madrid-Boston Project-related effects to freshwater fish VECs were characterized as *negligible* and not identified as residual effects. Potential effects of Madrid-Boston in combination with Approved Projects were also characterized to identify residual effects of the Hope Bay Project, and characterized as *negligible* if the mitigation and management measures were considered effective (Step 5).

The characterization of effects on marine fish VECs incorporated guidance from DFO's *Fisheries Protection Policy Statement* (DFO 2013c) and Request for Review (DFO 2014c) process regarding the determination of whether a project is likely to cause serious harm to fish as defined in the *Fisheries Act* (such as the duration, geographic scale, probability, and reversibility of the effect, as well as the availability and condition of nearby fish habitat and effectiveness of mitigation and management measures). Overall, effects were considered *negligible* and were not carried forward in the assessment as residual effects if:

- habitat changes and/or reduction in population abundance are unlikely and are unlikely to have an effect on fisheries productive capacity distinguishable from natural variation; or
- effects on fisheries productive capacity resulting from habitat changes and/or reduction in population abundance could be feasibly mitigated or offset through mitigation, management and fisheries offsetting measures.

If residual effects were identified, the significance of residual effects was determined (Step 6) by considering the characterization of each residual effect based on the primary criteria of direction and magnitude and additional attributes (Volume 2, Chapter 4 ; Table 4.3-6) including an assessment of the probability of occurrence of effects and the confidence in the baseline data and predictions of the effects of the Madrid-Boston Project on the marine environment (Volume 2, Chapter 4; Table 4.3-7).

10.5.2 Identification of Potential Effects

The Madrid-Boston Project has the potential to interact with the marine environment through a number activities, pathways and mechanisms. The potential effects of Madrid-Boston activities on the VECs of fish habitat and fish community (Arctic Char and Saffron Cod) were determined using the initial interaction matrix provided in Table 4.3-1 of Volume 2, Chapter 4, and further refined using the EIS guidelines (NIRB 2012a), DFO's PoEs (DFO 2014b), TK, professional judgement, and experience at other projects in Nunavut and the Northwest Territories. Activities throughout the duration of Madrid-Boston were considered for their potential interactions via pathways of effects on the fish habitat VEC and each fish community VEC.

10.5.2.1 Potential Effects on Marine Fish Habitat VEC

Marine fish habitat may interact with and be affected by Madrid-Boston Project activities along two general pathways: through a direct **loss or alteration of fish habitat** by permanent alteration or destruction (PAD), or through **changes to water and/or sediment quality** arising from the deposition of deleterious substances stemming from various activities, pathways and mechanisms (Table 10.5-1). An alteration of fish habitat is considered a permanent alteration if the spatial scale, duration, or intensity limits or diminishes the ability of fish use the habitat to carry out one or more of their life processes. Destruction of fish habitat occurs when fish can no longer rely upon the habitat to carry out one or more of their life processes.

A PAD is a *direct* **loss or alteration of fish habitat** area potentially incurred through planned construction (e.g., encroachment of infrastructure such as cargo dock on existing fish habitat; physical damage from sealift activities on sensitive habitat (e.g., wake effects, propeller wash) or spills, accidents and malfunctions (e.g., slope failures, unplanned releases). Spills, accidents and malfunctions are addressed in Volume 7, Chapter 1 (Accidents and Malfunctions) and in Package P4-3 (Hope Bay Project Spill Contingency Plan).

The introduction of deleterious substances could alter fish habitat *directly* by **changes to water quality and/or sediment quality** to the extent that fish health decreases and mortality occurs, or *indirectly*, through trophic interactions with biological resources used by fish. The *direct* effect on fish health and mortality potentially caused by the introduction of deleterious substances in water (e.g., via effluent discharged from site or sewage effluent from sealift, and mine surface drainage, via accidental releases and spills) is assessed as part of the fish habitat VEC. Spills, accidents and malfunctions that may result in changes to water and sediment quality are also addressed in Volume 7, Chapter 1 (Accidents and Malfunctions) and in Package P4-3 (Hope Bay Project Spill Contingency Plan). The *indirect* effect on fish habitat (i.e., through trophic interactions) potentially resulting from the introduction of deleterious substances into water and sediment is assessed in Volume 5, Chapters 8 and 9 for Marine Water Quality and Marine Sediment Quality, respectively. This approach assumes that if significant effects are concluded for either marine water quality and/or sediment water quality, that indirect effects to fish habitat (via trophic interactions) are also likely to occur.

The EIS guidelines identify potential impacts for inclusion in a comprehensive impact analysis of all Madrid-Boston components and activities on the marine environment. The potential impacts identified in the EIS guidelines and the corresponding potential effects used in the effects assessment for the marine fish habitat VEC are listed in Table 10.5-2. Specific Madrid-Boston activities that link potential interactions/effects with the VEC marine fish habitat are summarized in Table 10.5-3.

Table 10.5-1. Potential Effects of the Madrid-Boston Project on Marine Fish VECs

Marine Fisheries VEC	Potential Interaction/Effect	Cause	Description	General Project Activity	Regulation	Effects Assessment
Fish Habitat	Loss or alteration of fish habitat	Permanent alteration or destruction (PAD) of habitat	Loss or damage of fish habitat through encroachment of infrastructure, physical damage from sealift (e.g., wake effects, propeller wash), and spills, accidents and malfunctions	1. Infrastructure Footprint 2. Sealift	*Fisheries Act* (1985) Section 35(2)	1. This chapter: Vol. 5, Chapter 10 (Marine Fish); and 2. Vol. 7, Chapter 1 (Accidents and Malfunctions)
	Changes to water and sediment quality resulting in: 1. Direct fish mortality or reduction in fish health; and/or 2. Indirect reduction in biological resources of fish through trophic interactions	Deposition of deleterious substances	Mine effluent discharge, hydrocarbon contaminants, increased nutrient loading including through blasting activities, introduced sediment (increased TSS or deposition in spawning areas), sealift (e.g., wake effects and propeller wash), and spills, accidents and malfunctions	1. Management of Surface Drainage, Effluent, Dust and Infrastructure Development 2. Sealift	*Fisheries Act* (1985) Sections 36 Metal Mining Effluent Regulations (SOR/2002-222)	1. This chapter: Vol. 5, Chapter 10 (Marine Fish); 2. Vol. 5, Chapters 8 and 9 (Marine Water Quality and Marine Sediment Quality) 3. Vol. 7, Chapter 1 (Accidents and Malfunctions)
Fish Community: Arctic Char, Saffron Cod	Direct fish mortality and population abundance	Activities that physically harm fish or affect the ability of fish to carry out their life processes	Any impact that causes the death of fish directly (e.g., blasting, pile driving, fishing) or reduction in population abundance (e.g., noise, vibration and pressure, sealift and introduction of exotic species and pathogens), including spills, accidents and malfunctions	1. Infrastructure Footprint 2. Infrastructure Development 3. Sealift	*Fisheries Act* (1985) Sections 35, 36	1. This chapter: Vol. 5, Chapter 10 (Marine Fish); and 2. Vol. 7, Chapter 1 (Accidents and Malfunctions)
	Changes to water and/or sediment quality resulting in: 1. Indirect mortality; and/or 2. Reduction in fish health.	Deposition of deleterious substances	Any impact that affects individual health and longevity, tissue quality, or parasite load including mine effluent, increased nutrient and sediment loadings (including from infrastructure and sealift), including spills, accidents and malfunctions	1. Management of Surface Drainage, Effluent, Dust and Infrastructure Development 2. Sealift	*Fisheries Act* (1985) Sections 36 Metal Mining Effluent Regulations (SOR/2002-222)	1. Vol. 7, Chapter 2 (Human Health and Environmental Risk Assessment); 2. Vol. 5, Chapters 8 and 9 (Marine Water Quality and Marine Sediment Quality); and 3. Vol. 7, Chapter 1 (Accidents and Malfunctions)

Table 10.5-2. EIS Guidelines (NIRB) for Impact Assessment of the Madrid-Boston Project on the Marine Environment and Identified Potential Effects on Marine Fish VECs

	Potential Effect			
	Fish Habitat VEC		Fish Community VECs	
EIS Guidelines (NIRB 2012)	Loss or Alteration of Fish Habitat	Changes in Water and/or Sediment Quality	Direct Mortality and Population Abundance	Changes in Water and/or Sediment Quality
Potential changes in marine noise levels due to sealift activities, as well as noise propagation in the marine environment.			X	
Potential impacts of noise and vibration on the following: Fish in marine environments.			X	
Potential risks and impacts to the marine ecosystem through the introduction of exotic species, including pathogens, through seasonal sealift activities.			X	
Assess the effects of project activities (effluent discharge, accommodation barge, loading docks) on fish and fish habitat of Roberts Bay.	X	X	X	X
Potential impacts of wake effects from sealift activities on the shoreline stability and sensitive fish or marine mammal habitat, i.e., coastal wetlands.	X	X	X	X
Potential impacts of sedimentation from propeller wash on water quality, fish and fish habitat and, benthic invertebrates.	X	X	X	X
Potential impacts of ballast water discharge on water quality, fish and fish habitat, benthic invertebrates including cumulative impacts over the life of the project		X	X	X
Potential impact on marine environment and bio-accumulation in marine food chains, in particular on benthic organisms, from antifouling toxins (e.g., tributyltin) leaching from marine vessels.		X	X	X
Potential direct and indirect impacts to marine wildlife, marine fish and marine habitat from marine sealift activities including increased noise levels.			X	
Potential spills, malfunctions and other accidents associated with sealift operations and any resulting impacts to marine wildlife, marine habitat and marine fish.		X	X	X
Risk assessment of the potential introduction of non-native aquatic species due to ballast water discharge, ship wash and hull fouling.			X	X
Evaluation of the potential for contaminants to be released to the environment and taken up by VECs as a result of the Project.	X	X	X	X
Potential impacts to fish due to blasting in or near waterbodies, including noise and vibration impacts		X	X	X
Potential impacts on identified fish habitat critical for spawning, rearing, nursery and feeding, seasonal migration, winter refuges and migration corridors.	X	X	X	X
Potential impacts on contamination of traditional foods as a result of bioaccumulation, i.e., food chain uptake through air, water and soil, including a discussion of proposed monitoring.		X		X

Table 10.5-3. Summary of Potential Interactions between Marine Fish VECs and the Madrid-Boston Project

Project Phase and General Project Activity	Specific Project Activity	Project		Fish Habitat		Fish Community (Arctic Char - anadromous life history, Saffron Cod)	
		Madrid-Boston	Approved Projects	Loss or Alteration of Fish Habitat	Changes in Water Quality and/or Sediment Quality	Direct Mortality and Population Abundance	Changes in Water Quality and/or Sediment Quality
Construction							
Infrastructure Footprint	Cargo dock	●		X	X	X	X
	Dock access road	●	●		X		X
	Marine transport of goods (sealift)	●	●		X	X	X
Management of Surface Drainage, Effluent, Dust and Infrastructure Development	Quarry	●		X	X	X	X
	Road use and maintenance	●	●		X		X
	Equipment and Vehicle Emissions	●	●		X		X
	Fuel storage and handling	●		X	X	X	X
	Surface infrastructure	●	●		X		X
	Marine effluent discharge	●	●	X	X		X
Operation							
Infrastructure Footprint	Marine transport of goods (sealift)	●	●	X	X	X	X
Management of Surface Drainage Effluent, Dust and Infrastructure Development	Quarry	●			X	X	X
	Road use and maintenance	●	●		X		X
	Equipment and Vehicle Emissions	●	●		X		X
	Fuel storage and handling	●			X		X
	Surface and mining infrastructure	●	●		X		X
	Marine effluent discharge	●	●	X	X		X
Reclamation and Closure							
Infrastructure Footprint	Marine transport of goods (sealift)	●	●	X	X	X	X
Management of Surface Drainage, Effluent, Dust and Infrastructure Development	Road use and maintenance						
	Equipment and Vehicle Emissions	●	●		X		X
	Fuel storage and handling						
	Surface infrastructure	●	●		X		X
	Marine effluent discharge	●	●	X	X		X
Post-closure							
Infrastructure Footprint	Post-closure monitoring	●	●	X	X	X	X
Temporary Closure							
	Care and maintenance	●		X	X	X	X

● = *Project-specific activity anticipated*
X = Potential interaction between VEC and Project-specific activity

10.5.2.2 Potential Effects on Marine Fish Community VECs

The marine fish community may interact and be affected by Madrid-Boston activities along two general pathways: through *direct* **mortality and changes to population abundance**, or through decreased health and *indirect* mortality resulting from **changes to water quality and/or sediment quality** (Table 10.5-1).

The effects assessment for marine fish community VECs focuses on the interactions and potential effects associated with the pathway of *direct* **mortality and changes to population abundance**. Direct mortality and changes to population abundance of the VECs Arctic Char (anadromous life history) and Saffron Cod (marine life history) may potentially occur during the construction of in-water infrastructure and any Madrid-Boston activities that physically harm fish through impact injury (e.g., interactions with industrial equipment/materials during infrastructure development), blasting, pile driving, sealift activities (e.g., impact injury and introduction of exotics and pathogens), and spills, accidents and malfunctions (e.g., sealift accidents). For example, the permanent destruction of spawning habitat (direct effect on habitat) may reduce spawning opportunities or may result in direct mortality during burial, leading to potential effects on survival and reproduction. Spills, accidents, and malfunctions are addressed in Volume 7, Section 1 (Accidents and Malfunctions) and in Package P4-3 (Hope Bay Project Spill Contingency Plan). Fishing activities can also physically harm fish due to handling and hook and release mortality. However, although fish mortality rates may increase with increased fishing pressure, a “no fishing” policy for personnel and employees while on site will be in place. On-site monitoring activities targeting fish will also take the least invasive approach as appropriate to minimize impacts on fish. This policy/approach will remove potential effects on fish communities that may result from an increase in fishing pressure, therefore the effects of fishing are not discussed any further in the assessment for fish community VECs.

For the pathway of decreased health and indirect mortality, potential **changes in water quality and/or sediment quality** could affect the fish community VECs. These include changes in health and longevity, tissue quality, or parasite loading stemming from mine effluent discharge, and nutrient and sediment loadings. Effects assessments for the VECs of marine water quality and marine sediment quality are in Volume 5, Chapters 8 and 9, respectively. The potential for bioaccumulation of contaminants in marine fish (includes Arctic Char) is quantitatively assessed in the Human Health and Environmental Risk Assessment (Volume 6, Chapter 5). The primary exposure pathway for fish is direct contact with water and/or sediment. They could also be indirectly exposed through trophic effects if a bioaccumulative contaminant of potential concern (COPC; e.g., mercury) were present. Estimation of risk to aquatic life ecological receptors including fish from COPCs were evaluated through the calculation of hazard quotients for existing conditions (see Volume 6, Section 5.5.4.2 for further information); no adverse effects to marine life were anticipated via this pathway under existing conditions. Similarly, because marine water quality is anticipated to meet all CCME marine water quality guidelines, no significant residual effects were concluded, thus no COPCs were identified and carried forward; Madrid-Boston Project-related changes to the health of ecological receptors including fish are therefore not expected (Volume 6, Section 5.6.1.3). Spills, accidents and malfunctions may also result in changes to water and sediment quality and are addressed in Volume 7, Chapter 1 (Accidents and Malfunctions) and in Package P4-3 (Hope Bay Project Spill Contingency Plan)

The EIS guidelines identify potential impacts for inclusion in a comprehensive impact analysis of all Madrid-Boston components and activities on the marine environment. The potential impacts identified in the EIS guidelines and the corresponding potential effects used in the effects assessment for the marine fish community VEC are listed in Table 10.5-2. Specific Madrid-Boston activities that link potential interactions/effects with the VEC marine fish community VEC are summarized in Table 10.5-3.

10.5.3 Mitigation and Adaptive Management for Marine Fish VECs

Mitigation and adaptive management measures applicable to all marine fish VECs are described in this section. They were identified through a review of best management practices at similar mining projects in the Arctic, comments from community members during scoping meetings, regulatory guidance and considerations (DFO 2016b), scientific literature, and professional judgement. Mitigation and monitoring specific to potential effects on individual marine fish VECs are identified where necessary in the individual VEC effects assessments in Section 10.5.4 and Section 10.5.5.

10.5.3.1 Mitigation by Project Design

Madrid-Boston has been designed to avoid impacts on the marine fish VECs where possible. The major mitigations by design include site selection and offsetting by design.

<u>Site Selection</u>

The site chosen for the cargo dock – site C2 (Annex V1-7, Package P5-10) was chosen to minimize loss or disturbance of marine habitat and to avoid sensitive spawning habitats from being lost or altered. There are three mitigation elements: (1) reducing the footprint of the dock on non-limiting habitat (e.g., fines), (2) avoiding high quality fish habitat by building on poor quality fish habitat, and (3) building on bedrock to avoid erosion.

The footprint of the cargo dock, as measured below the high water mark (HWM), was reduced by choosing a site with deep water immediately adjacent to the shoreline. This reduced the length of the causeway from the access road out to the dock.

In addition to environmental considerations mentioned above, Site C2 was also selected as the preferred location for the cargo dock because it is in deep water, has a relatively short access road, and does not interfere with any other planned infrastructure at Roberts Bay (Annex V1-7, Package P5-10). Site C2 was preferred over sites C3 and C4 because the water at that site is deeper and consequently the dock can be shorter than it would at sites C3 and C4. Therefore, the selection of site C2 alternative is mitigative because it will reduce the footprint of the dock and hence the amount of lost habitat.

Baseline surveys of the nearshore areas to the north and south of site C2 showed that mud is the predominant substrate type along the western shore of Roberts Bay with some aggregations of cobble surrounded by gravel (Figure 10.2-12). At the proposed dock design, the majority of the impacted habitat consists of bedrock at nearshore areas, gravel, cobble and larger rock for the first 5 metre

s where the causeway is being proposed, transitioning to low complexity and low productivity substrates (i.e., fines), as the dock extends to deeper areas. The causeway that leads from the dock to the access road will cover a bedrock substrate in the intertidal zone (Figure 10.2-12). Similar habitat (i.e., mud in the subtidal zone and bedrock in the intertidal zone) is present at site C1 in the embayment north of site C2 (Figure 10.2-12). Hence, the quality of fish habitat at site C2 is similar to that at site C1. However, site C3, south of C2, has more gravel and cobble in both the subtidal and intertidal zones than sites C1 and C2. Since fish generally prefer cobble and gravel to mud and bedrock for spawning and egg incubation, the quality of fish habitat at site C3 is higher than at sites C1 and C2. Therefore, the selection of site C2 is mitigative because it will avoid loss of higher quality habitat at site C3.

DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2016b)* recommends avoiding building structures on alluvial fans, active floodplains, or any other area that is inherently unstable and may result in erosion and scouring of fish habitat or the built structures. The selection of site C2 is mitigative because the cargo dock will be built on bedrock in the intertidal and its foundations in the deep subtidal will be driven through sediment to bedrock. Building on these stable locations will minimize erosion.

Offsetting by Design

Three mitigation elements were incorporated into the design of the cargo dock: (1) adding rock armouring consisting of self-offsetting substrates (i.e., large, structurally complex substrates that are typically limiting in Roberts Bay in deeper waters) along its perimeter to the extent possible that will create new fish habitat to offset losses caused by the installation of the dock, (2) designing the facility so the causeway meets the cargo dock at right angles, thereby minimizing affected habitat, and (3) locating as many elements of the cargo dock as possible out of water.

Riprap/armor rock placed below the HWM has been incorporated in the design of the cargo dock. This rock embankment will act to protect the cargo dock from vessel collision and ice damage. This rock embankment will also create new habitat for fish and their benthic invertebrate prey that will serve to offset habitat loss due to the footprint of the cargo dock. The amount, angle, and wetted surface area of the armor rock will be designed to ensure that fish habitat will be created to the extent possible. Creation of artificial reefs (consistent with rock armouring proposed) at sites with homogenous, low relief substrate is beneficial, increasing habitat complexity and heterogeneity resulting in colonization by invertebrates and fish (DFO 1990).

DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* recommends designing and constructing approaches to the waterbody such that they are perpendicular to the watercourse to minimize loss or disturbance to riparian vegetation. This is the design recommended by SRK (Annex V1-7, Package P5-10); the approach causeway is at right angles to the cargo dock, minimizing disturbance to intertidal substrate. TMAC commits to working with DFO to determine the necessary mitigation and monitoring as required.

Other aspects of mitigation by design include the following:

- Using existing infrastructure associated with the Doris Project wherever possible;
- To the extent possible, elements of the cargo docking facility, including mooring points, have been located outside of fish-bearing water.
- Minimum setbacks of 31 m were applied near water features to avoid affecting riparian functions, 51 m setbacks where ever possible, with the exception of the causeway leading to the dock.
- Only geochemically suitable rock quarries will be used to construct roads, pads, and structures.
- Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and transport of potentially poor quality water into the active layer, and ultimately to the marine environment.
- Ships will be conventional double-hulled, compartmentalized petroleum tankers, with Shipboard Oil Pollution Emergency Plans and appropriate response gear.
- The location and depth of the Approved discharge outfall in Roberts Bay was selected to promote mixing and rapid dilution of the effluent in Roberts Bay, and to minimize potential for contact with the bottom sediments or the surface layers.

The design of the Madrid-Boston Project will also adhere to regulatory requirements relevant to the mitigation of potential effects on the marine environment. These regulatory requirements include the following:

- Incinerators will be operated to comply with Nunavut standards (Nunavut 2011), Canada-Wide Standards for Dioxins and Furans (CCME 2001), and Canada-Wide Standards for Mercury emissions (CCME 2000). Modern incineration equipment will be installed to minimize airborne contaminant loading of polycyclic aromatic hydrocarbons.
- Ships will carry out their operations in accordance with federal and territorial acts and regulations relating to vessel discharges, the transportation of dangerous goods, and anti-fouling surface treatments including the Arctic Waters Pollution Prevention Regulations (2016) under the *Arctic Waters Pollution Prevention Act* (1985a), the Vessel Pollution and Dangerous Chemicals Regulations (2012) and the Ballast Water Control and Management Regulations (2011) under the *Canada Shipping Act* (2001), and the *Transportation of Dangerous Goods Act* (1992).
- The bulk fuel storage facility and all transfer-related equipment will be inspected and maintained, with complete documentation.
- Effluent will be managed and discharged in compliance with MMER requirements. Routine characterization of the effluent will confirm compliance and the EEM sampling program will monitor for potential effects (see 10.5.3.3).

10.5.3.2 Best Management Practices

Madrid-Boston will be constructed and managed following government guidelines and industrial best management practices as much as possible to avoid, minimize or eliminate impacts to marine fish habitat and fish communities. Government guidelines to avoid harm to fish habitat and fish communities include DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016b), federal and territorial guidelines to preserve water and air quality, and federal and territorial environmental protection regulations. In addition, standard industrial best management practices will be implemented, those specific to marine water and/or sediment quality and to the protection of aquatic life are provided in Volume 5, Chapters 8 and 9, and in Package P4-18.

<u>Construction Timing</u>

Following the guidance of DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016b), a first line of action with regards to implementing effective mitigation is timing of construction. Specifically, respecting timing windows to protect fish, including their eggs, juveniles, spawning adults, and/or the organisms upon which they feed. The Nunavut government has defined freshwater fish timing windows, but it has not defined them for marine fish. A timing window is recommended as a mitigation measure for construction of the cargo dock in Roberts Bay; however it may prevent completion of the cargo dock within one ice-free season. Also, there are mixed precedents for application of marine timing windows in Nunavut.

There is not a strong case for interrupting construction in mid-summer to protect fish based on spawning timing. Three of the 25 fish species caught in Roberts Bay from 2002 to 2017 are summer spawners: Capelin (July-August), Pacific Herring (June-September), and Longhead Dab (June-September). Longhead Dab is a minor component of the fish community, making up only 0.26% of all fish captured in the bay. The other 22 species are fall, winter or spring spawners. Saffron Cod, one of the two marine fish VECs, is a winter spawner (February-March) and their eggs incubate on sand-gravel substrate during spring (April-June). Neither Capelin nor Pacific Herring are known to spawn in Roberts Bay. However, a no work window during the start of the open water season (July 15) until August 15 protects outmigrating salmonids such as Arctic Char accessing summer feeding areas in marine waters, as well as their upstream return to overwintering habitat.

There is, however, a case for completing all in-water work on the cargo dock of Roberts Bay within as short a period as possible. DFO (DFO 2016b) recommends minimizing the duration of in-water work (as well as conducting it at low tide and scheduling it to avoid wet, windy and rainy periods that may increase erosion). A mid-summer no work timing window may prevent construction of the cargo dock in one season, however it is considered the most protective approach to avoid effects on migrating Arctic Char.

Precedents for a mid-summer marine timing window are mixed. The *Fisheries Authorization* for the expansion of the Doris Jetty (DFO file 10-HCAA-CA7-00028) defined a timing window of July 15 to August 15 during which no in-water construction was allowed to occur to protect critical spawning and rearing periods for all fish species in Roberts Bay. However, no timing window was defined for the Milne Inlet dock at Baffin Island that was approved for the Mary River iron ore project (*Fisheries Authorization* DFO file 14-HCAA-00525). Given the precedence for previously conducted works in Roberts Bay, the least risk window of August 15 to September 15 is most protective. However, the exact timing may be reconsidered following discussions with DFO should it be preferable to complete construction of the cargo dock in as short a period as possible, without interruption.

Contamination and Spill Management

As part of project planning prior to construction, DFO (DFO 2016b) recommends developing a plan to prevent discharge to the water of materials such as paint, primers, blasting abrasives, rust solvents, degreasers, grout, or other chemicals. This is addressed through the implementation of the management plans discussed in Volume 8 (Environmental Management Systems), and other existing management plans (Volume 1, Annex V1-7, Package 5), which ensure that contaminants to water, as well as wastes are managed appropriately and in a manner that reduces risk and impact to the environment. Project design has ensured that all infrastructure and stockpiled materials will be stored above the high water mark, including refuelling locations. Construction phase-specific protection measures will be outlined in the Environmental Protection Plan (EPP; Volume 8, Section 2.1), and may include staking of alignments, boundaries, and limits for the work and staging areas and equipment refueling and maintenance areas prior to construction. Construction activity will be required to stay within the alignments so as to ensure that the footprint of the operation will be controlled.

As recommended by DFO (DFO 2016b), a Hope Bay Spill Contingency Plan (for further information, refer to Package P4-3, and Annex V8-1, OPPP/OPEP and Spill Contingency Plan, respectively) will be prepared that will be implemented immediately in the event of a sediment release or spill of a deleterious substance. The plan requires that emergency spill kits are located at each construction site, and outlines the available mobile marine spill response materials located at Roberts Bay. This response plan will be part of an Environmental Protection Plan (EPP; Volume 8, Section 2.1) for the cargo dock.

As recommended by DFO (DFO 2016b), the building material used for construction of the cargo dock will be handled and treated in a manner to prevent the release or leaching of substances into the water that may be deleterious to fish. Specifically, the coarse quarried geochemically stable rock will be used for the box cells of the dock will be geochemically stable and will be washed of particulate material.

Erosion and Sediment Control

The third step in DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* after construction timing and spill management, is to prevent erosion and sedimentation at the work site (DFO 2016b). The employment of erosion control measures is indicated in the Aquatics Effects Monitoring Program described in Package P4-18 (Hope Bay Project Aquatic Effects Monitoring Plan). Best management practices which may be employed to avoid introducing sediment into the water include:

- Prior to construction, a silt/turbidity curtain will be installed around the cargo dock and remain in place throughout construction (Annex V1-7, Package 5-10). It will limit the area impacted by turbidity to an area slightly larger than the construction footprint.
- The curtain will be inspected regularly during the course of construction and all necessary repairs will be made if any damage occurs.
- The curtain and all other associated materials will be removed from the site after the end of construction.
- Turbidity will be monitored inside and outside the barriers on a daily basis with an electronic meter. These measurements will be recorded and reported to regulatory agencies.
- If turbidity increases above CCME guideline limits outside the turbidity barrier, then additional prevention and control measures will be applied. These may include changes in size of infill material, altered methods of infill, or suspension of infilling until turbidity decreases.
- Only coarse geochemically stable rock will be used for the box cells.
- Material used for all works will not be taken from below the high water mark.
- Spoils and vegetation outside of the footprint will remain undisturbed and permafrost will be preserved to reduce or eliminate surface flow of sediment from the work site to the bay.
- Waste material such as rock or mud will be stored above the high water mark.
- All stockpiled equipment and material will be stored above the high water mark.

Another issue related to erosion and sediment control is the potential effect of the cargo dock on transport of sediment along the western shoreline of Roberts Bay. The area down-drift of the dock may be deprived of sediment while up-drift areas may receive sediment accumulations (Brown and McLachlan 2002). Monitoring of the seafloor around the cargo dock may be part of overall monitoring activities.

A third related issue is the erosive effect on shoreline habitat of wakes generated by ships. Potential effects of wakes will be mitigated by keeping ship speed low for travel within Roberts Bay. The potential effects of propeller wash on shoreline habitat will also be mitigated by speed reductions.

<u>Shoreline Stabilization</u>

The fourth component in DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2016b)* is to stabilize and restore the shoreline at the work site. This is the best way of preventing future erosion and discharge of sediment into Roberts Bay. As part of its EPP (Volume 8, Section 2.1), TMAC is committed to the following:

- Stabilize all shoreline or banks that were disturbed by construction to prevent erosion and/or sedimentation by restoring the original contour and gradient.
- If armouring is required to stabilize eroding or exposed areas, then appropriately-sized, geochemically stable, clean quarried rock will be used and the rock will be installed at a similar slope to maintain a uniform shoreline alignment.
- Materials such as boulders that were removed from the footprint of the work site to allow installation of the box cell will either be: (1) relocated to an area of similar depth and not removed altogether from the bottom or shoreline or (2) placed in the rock embankment surrounding the cargo dock or (3) stored in a permanent location above the high water mark (in descending order of desirability).

- Sediment and erosion control measures shall be retained in place and maintained until all disturbed areas have been stabilized.
- Restore disturbed areas to the pre-disturbed state or better through re-vegetation with native species suitable for the site, if those areas were previously vegetated, to the extent possible.
- Remove all construction materials from the site after project completion.

Fish Protection

DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016b) also includes measures to protect fish from direct mortality and from restricted access to habitat.

One of the first measures will be to use an environmental monitor to observe and report on fish protection at the cargo dock work site, and to advise construction workers on how to protect fish.

As rock fill is placed within the box cells of the cargo dock or the rock embankment, fish may be crushed and/or smothered if not able to escape. Although it is expected that fish will be displaced prior to rock placement due to avoidance behavior produced by the noise of the vibratory hammer and of the placement of rock, there is a possibility that some may not have time or the chance to leave the zone of impact. The silt curtain that will be installed prior to construction will act as a barrier to entry to the work area for fish that swim in the vicinity.

In the unlikely event of direct fish mortality at site, the environmental monitor will report the time and place of the fish kill and the number and species affected. The monitor has the authority to issue a stop work order and investigate the cause of mortality, if justified by the frequency and magnitude of mortality events.

Explosives will not be used in water so there will be no ammonium nitrate residue left in the water and shock waves will not be produced. Shock waves with an overpressure more than 100 kPa can damage a fish swim bladder and rupture internal organs or kill or damage fish eggs or larvae (Wright and Hopky 1998).

Noise produced by machinery during construction may cause fish to avoid habitat adjacent to the work area. The majority of the work will be carried out with a vibratory hammer, which produces significantly less noise compared to an impact hammer. The silt curtain will attenuate noise transmission.

Fish movement in Roberts Bay will not be impeded by the cargo dock. Loss of fish access to the habitat underneath the footprint of the cargo dock will be offset by habitat created by the rock armouring around the perimeter of the cargo dock.

Operation of Machinery

A sixth component in DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016b) are measures to protect fish from the machinery that will be used during construction of the cargo dock. They will include the following:

- The vibratory hammer will be operated from a location on shore that is above the high water mark or from a barge.
- All mobile equipment will be clean, degreased, and free of fluid leaks before working in water.
- Vehicle and equipment refueling and maintenance will occur above the high water mark.

- The employment of a Spill Contingency Plan (Package P4-3) will ensure spills of hazardous materials are first avoided, or identified and managed appropriately, if they occur.
- All crews working on the jetty will be trained and aware of protocols for storing, re-fueling, and waste disposal.
- Petroleum products (oils, grease, gasoline, diesel or other fuels) will be stored at least 50 m from any water bodies and will be located within secondary containment.
- An emergency spill kit will be kept on site in case of fluid leaks or spills from machinery and a complete marine response spill kit is located within the Roberts Bay jetty laydown area.

Given the high confidence in the effectiveness of these measures for fully minimizing or eliminating the pathway of direct mortality effects on fish community VECs from operation of machinery (including use of industrial equipment), the potential for this effect will not be considered any further in subsequent assessment sections.

10.5.3.3 Proposed Monitoring Programs and Adaptive Management

<u>Proposed Monitoring Plans</u>

Marine Environmental Effects Monitoring Program

A Marine Environmental Effects Monitoring Program (Marine EEM Program; Volume 8, Environmental Management System; Section 2.17) established under the Metal Mining Effluent Regulations will be in place that outlines the monitoring program in the marine environment that will be carried out during all phases of the Project. The Marine EEM Program will include the following:

- monitoring the marine environment at locations potentially affected by the Project and at reference areas well away from Project activities;
- monitoring marine water quality, sediment quality, and aquatic biology.

<u>Fisheries Offsetting Plan</u>

A Fisheries Offsetting Plan (FOP) typically contains the design, implementation, and monitoring actions required to offset potential serious harm to CRA fisheries resulting from a project, as concluded by DFO and as per the guidance of DFO's *Fisheries Protection Policy Statement* (DFO 2013c). If deemed necessary by DFO through the *Fisheries Authorization* process, the FOP will eventually address all potential serious harm to CRA fish through mitigation and/or offsetting using methods from DFO's *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013b) such as the restoration or enhancement of habitats or the creation of habitat elsewhere in the landscape. TMAC therefore commits to working with DFO's FPP and local Inuit to develop a marine fisheries offsetting plan commensurate with anticipated effects. Discussions with DFO and other stakeholders have already been initiated (refer to Appendix V5-6AB for additional information). A monitoring program will be developed to monitor the effectiveness of the FOP. The monitoring program will be developed in conjunction with regulatory agencies, and will assess the effectiveness of the offsetting activities over time in reference to specific performance objectives. These performance objectives may include:

- stability of constructed habitat;
- primary productivity;
- benthic invertebrate community;
- fish presence/habitat use; and

- local density, production, or population size estimated for fish species.

For the purposes of this EIS where the effects conclusion relies on the successful implementation of a FOP where deemed necessary to mitigate residual effects resulting from Madrid-Boston, a conceptual approach to developing a FOP is provided in Appendix V5-10G. If deemed necessary by DFO, a final FOP will be developed, satisfying the requirements of the EIS guidelines (NIRB 2012a), as described in Volume 8, Chapter 1.

Other Management Plans

Other management plans which form the Environmental Management System (Volume 8, Environmental Management System), and other existing management plans (Volume 1, Annex V1-7, Package 5) address particular issues through specific mitigation and management measures to maintain air and water quality through the management of contaminants and waste, with details provided in Volume 8. These plans address spills and contingencies, management of water, waste, waste rock, ore and tailings, as well as air quality and noise management and monitoring.

Adaptive Management

The need for any corrective actions to on-site emission management or installation of additional control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include:

- results from the Marine Environmental Effects Monitoring Program, which will monitor the receiving environment of Roberts Bay, show adverse effects to fish habitat and/or fish communities; and
- results from the Fisheries Offsetting Monitoring Program, should this be required as part of a *Fisheries Authorization*, show that the offsetting program is not successful.

10.5.4 Characterization of Potential Effects – Fish Habitat VEC

Project residual effects are the effects that remain after mitigation and management measures are taken into consideration. If the implementation of mitigation measures eliminates a potential effect and no residual effect is identified on that VEC, then the effect is eliminated from further analyses. If the proposed implementation controls and mitigation measures are not sufficient to eliminate an effect, then a residual effect is identified and carried forward for additional characterization and a determination of significance. Residual effects of the Project can occur directly or indirectly. Direct effects result from specific Project/environment interactions between Project activities and components, and VECs. Indirect effects are the result of direct effects on the environment that lead to secondary or collateral effects on VECs.

The following characterization of specific potential Project effects on the fish habitat VEC describes the potential effects of interactions of fish habitat with specific Madrid-Boston activities, identifies specific mitigation measures (including fisheries offsetting), and assesses whether Madrid-Boston residual effects remain after mitigation and management measures are taken into consideration.

Residual effects from project-related interactions associated with the fish habitat VEC may be avoided and/or considered mitigated even when serious harm (as per the *Fisheries Act*) may be concluded by DFO, as long as the offsetting required for the magnitude of serious harm is considered feasible.

Accidental events that result in the spill or release of deleterious substances can affect fish indirectly, for example, by affecting the availability of forage fish and biological resources, either through mortality or contamination. Effects associated with spills (e.g., hydrocarbons), accidents (e.g., accidental releases of untreated effluent), and malfunctions (marine infrastructure slope failures, blasting exceedances) are discussed in Volume 5, Chapters 8 and 9, as well as in Volume 7, Chapter 1 Accidents and Malfunctions, and will thus not be considered further in this assessment.

10.5.4.1 Loss or Alteration of Fish Habitat: Infrastructure Footprint

Characterization of Madrid-Boston Potential Effect

Madrid-Boston Project infrastructure has the potential to interact with the VEC marine fish habitat wherever the locations of infrastructure overlap with the marine environment (i.e., in-marine water works). Potential effects on the VEC marine fish habitat may occur during all phases of the Madrid-Boston Project, though particularly during the Construction phase when the building of the cargo dock will be undertaken. Potential effects associated with the proposed road leading to the cargo dock is considered in Volume 5, Chapter 6 (Section 6.5.4.1) and will thus not be considered any further in this assessment.

Roberts Bay Facility: Cargo Dock

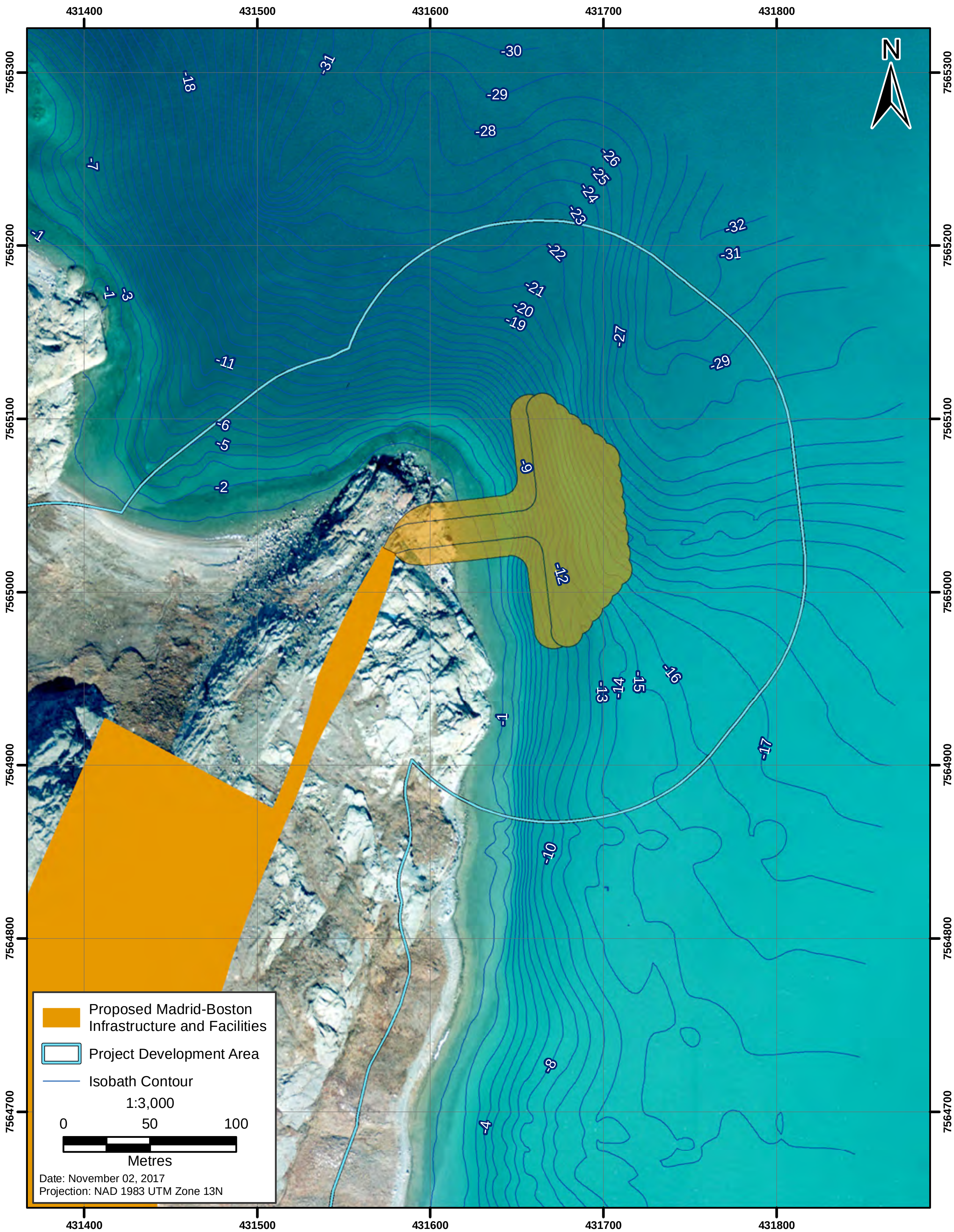
The expansion of the Roberts Bay facility will include the construction of a cargo dock along the western shoreline of Roberts Bay (Figure 10.5-1). This dock will serve to accommodate unloading of supplies directly from ships, rather than through the use of lightering barges. Fuel ships will anchor offshore and unload via a fixed hose. Preliminary design criteria for the dock facilities include geometry and load capacity required to support the design vessel(s) and estimated equipment loads. Design environmental criteria include site geotechnical characteristics and loads associated with ice, surge and wave interaction. The dock will include mooring points established on shore with rock anchors or large blocks, to fix the temporary containment boom to shore. Specific details of the design criteria are presented in Package P5-10.

The proposed cargo dock is designed to berth cargo vessels (sea-lifts), fuel vessels and barges. The preliminary design consists of an overall length of 125 m and a total draft depth of minimum 12 m, consisting of an approximately 75-m long causeway and a 50 m long, 150 m wide-dock face (Annex V1-7, Package P5-10). Towards the seaward end of the structure, the cargo dock will have a vertical face, extending 2 m above the normal high water level (HWL) with a scalloped appearance. The sheet pile box structure will be surrounded by an embankment of armor rock designed to protect the sheet pile structure from ice scour. The total habitat loss based on the 3-D footprint of the cargo dock and known species distributions and associated habitat requirements, amounts to approximately 9,675m^2, which includes the causeway and the riprap/armor rock (approximately half of which falls below HWM). In terms of the amount of habitat in Roberts Bay (approximately 15 km^2), the loss of 9,675m^2 represents less than 0.07% of the habitat available to fish utilizing Roberts Bay.

Based on baseline surveys (refer to Figure 10.2-12 for additional information), the majority of the impacted habitat consists of bedrock at nearshore areas, gravel, cobble and larger rock for the first 5 metres where the causeway is being proposed, and transitioning to low complexity and low productivity substrates (i.e., fines), as the dock extends towards deeper areas. Existing land-based features include a non-vegetated riparian zone as the Roberts Bay facility is being constructed on bedrock outcrop typical of the western shoreline of Roberts Bay.

The proposed cargo dock will be constructed by vibrating sheet piles into the sediment, filling the resulting box structure with clean quarry material and a compacted rock cap. At closure, the cargo dock and the jetty will be partially removed, to an elevation 0.3 m below the low water level. The mooring points and buoys will be removed from site (Package P4-21).

Figure 10.5-1
Marine Cargo Dock Footprint in Roberts Bay



Mitigation and Management Measures for Specific Potential Effects

Considerations have been made to minimize and avoid, to the extent possible, the construction of infrastructure in fish-bearing water, and, wherever possible, to avoid encroaching on marine fish habitat by adhering to a minimum 31 m setback from all water. The application of best management practices, summarized in Section 10.5.3.2, provide the basis to minimize and/or avoid causing harm to fish. Notwithstanding, the following additional mitigation will be implemented to avoid adverse effects on fish habitat resulting from the design, construction and use of the Madrid-Boston Project cargo dock.

Although the final placement of the marine outfall dock falls below the HWM, sensitive and limiting fish habitat features will be avoided. Furthermore, although currently the dock's preliminary design comprises approximately only 2,663 m^2 of fish usable riprap/armor rock (i.e., falls below high water mark), the final dock design will consider further how to include riprap/armor rock as a form of "self-offsetting", through the consideration of how the amount, angle, and wetted surface area can help to make up (i.e., maximize offset) for the loss of fish habitat from the dock's construction. At closure, the cargo dock and the jetty will be partially removed, to an elevation 0.3 m below the low water level. The mooring points and buoys will be removed from site (Package P4-21).

Fisheries Offsetting

The purpose of a Fisheries Offsetting Plan (Appendix V5-10G), as per the guiding policies of DFO, is to maintain or improve the productivity of CRA fisheries. The Offsetting Plan will address fish habitat losses related to the encroachment of Madrid-Boston Project infrastructure as deemed necessary by DFO. Localized areas of fish-bearing marine habitat loss or permanent alteration will occur in Roberts Bay as a result of the construction of the marine dock, including unavoidable habitat loss or alterations due to the current cargo dock's design footprint, as well as the riprap/armour rock which is considered self-offsetting habitat. Where deemed necessary by the *Fisheries Authorization* process, final mitigation and monitoring requirements for the lost/altered habitat will be incorporated during the development of a FOP in consultation with DFO and discussed through NIRB and NWB processes.

The objective of the FOP is to compensate for the alteration or destruction of fish-bearing habitat by creating or modifying fish habitat elsewhere on the landscape should a Fisheries Authorization be deemed necessary for Madrid-Boston to proceed (see section 10.5.3.4). TMAC will work with DFO's FPP and local Inuit to develop a marine FOP. All habitat losses related to Madrid-Boston will be offset with the objective of maintaining the productivity of CRA species. The conceptual approach to fisheries offsetting proposed to balance all losses of fish habitat from Madrid-Boston Project infrastructure can be found in Appendix V5-10G. Recent communication with DFO and other stakeholders is provided in Appendix V5-6AB. The requirement for a FOP will be determined as described in Volume 8, Environmental Management Systems (Section 2.19) with the intention of meeting the EIS guidelines requirement for a No Net Loss Plan as the *Fisheries Protection Policy Statement* (DFO 2013c) no longer includes the "no net loss" principle.

As a result of mitigation and balancing potential fisheries losses with fisheries offsetting, and monitoring plans, there are no residual effects anticipated on the VEC marine fish habitat due to interaction with the Madrid-Boston infrastructure (i.e., cargo dock) footprint.

Characterization of Hope Bay Project Potential Effects

Fish habitat loss and/or alteration resulting from the infrastructure footprint of Approved Projects generally have been or will be limited to one time construction events. Habitat loss and/or alteration resulting from the infrastructure footprint of Approved Projects has been or will be mitigated or will be offset (i.e., through the implementation of offsetting plans or through commitments to develop and implement fisheries offsetting plans; Table 1.1-1 in Volume 8, Environmental Management System), resulting in no potential for residual effects on fish habitat to combine with Madrid-Boston effects.

As a result of mitigation and balancing fisheries losses with fisheries offsetting, and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on the VEC marine fish habitat due to Hope Bay Project infrastructure footprint.

10.5.4.2 Loss or Alteration of Fish Habitat: Shipping

Characterization of Madrid-Boston Potential Effect

Cargo ships and tankers will deliver fuel, equipment, and supplies during the open water season typically from August through October dependent on ice conditions. Ocean-going vessels will offload their cargo and fuel at either the Roberts Bay jetty (3 m depth) or the cargo dock (23 to 25 m water depth based on newest design and bathymetric data). Larger fuel tankers with deeper drafts will moor offshore using two fixed mooring points onshore and the ship's anchor to hold the ship's position during fuel transfer activities.

The main pathways by which sealift activities could interact with marine sediments include physical processes such as wake effects or propeller wash which could cause sediment resuspension and redistribution, and potential damage of natural shoreline. Physical disturbance to marine sediments by sealift can result from the wake produced by a ship as it moves through water and from propeller action. Propellers create jets of water that can contact and disturb sediments. Like vessel wakes, propeller wash interacts with the marine environment through the physical pathway. The jets created by propellers could disturb and rework sediments, which may cause changes in the water column concentrations of TSS, nutrients, and metals. These processes can cause all sediments to be mobilized and redistributed. The redistribution of sediments could affect the grain-size composition of sediments.

Effects from the direct physical damage of propeller wash and wake effects to the natural shoreline and seabed from sealift activities and associated wake is therefore most likely to occur in Roberts Bay. Approximately six or seven vessels will report annually to the Roberts Bay facility during Construction and Operations, and potentially during Closure. As part of the Madrid-Boston Project, vessel traffic will be extended beyond the six-year lifespan of the Approved Projects for an additional 14 years. The assessment of residual effects on the VECs Marine Water Quality and Marine Sediment Quality can be found in Volume 5, Chapters 8 and 9.

Mitigation and Management Measures for Specific Potential Effects

The mitigation and management measures to avoid potential Madrid-Boston effects on the VEC marine fish habitat can be found in the assessment of Project effects on Marine Water Quality and Marine Sediment Quality in Volume 5, Chapters 8 and 9. Key mitigation includes the reduction of average vessel speeds (estimated at 13.5 knots or 25 km/hr) once vessels enter Roberts Bay, particularly in the most sheltered and shallow areas.

The analysis of vessel wakes with mitigation was carried out for the marine water quality VEC (Volume 5, Chapter 8). The results showed that wakes created by ships entering Roberts Bay (0.04 m at 10 knots) are expected to be well within natural ranges of wave heights in the bay (0.5 m; Volume 5, Chapter 7), with their influence expected to occur far less frequently (3 to 4 per month, most in August and September) and over shorter timeframes (seconds to minutes) than natural wave action (i.e., consistently greater than the 0.04 m predicted from wake induced wave heights) and occurring over hours and days (Rescan 2012b). This indicates the effects from ship wakes are expected to be negligible in Roberts Bay compared to the natural physical processes such as ice scour and wind-driven re-suspension that continuously re-work the shallow, near-shore sediments of the bay.

The analysis of propeller wash with mitigation was also carried out for the marine water quality VEC (Volume 5, Chapter 8). The results predicted that propeller wash has the potential to mobilize sand-sized particles (speed greater than 0.25 m/s) from depths shallower than 35 m when vessels are operating between 10% (20 m depth) and 50% (35 m depth) as they would while approaching the shallow environment near the marine cargo dock. This corresponds to an approximate path length of 1.5 km where sediments could be mobilized and redistributed as vessels move from the 35-m isobaths to the marine cargo dock on the southwestern shore of Roberts Bay.

Although there is potential for these effects to occur in Roberts Bay, no significant residual effects were concluded because expected effects are anticipated to be minor, and infrequent in comparison to naturally occurring events such as storms. Furthermore, natural physical processes such as waves, currents, tides, and ice scour should nullify any short-term effects observed from vessel wakes and/or propeller wash over the long-term.

As a result of mitigation and further evaluation of potential risks following mitigation (i.e., reduction in vessel speed) and comparison to natural variation, there are no residual effects anticipated on the VEC marine fish habitat due to interaction with Madrid-Boston sealift activities.

Characterization of Hope Bay Project Potential Effect

Effects on fish habitat through physical damage from sealift activities resulting from the Approved Project activities generally have been or will be mitigated such that there are no residual effects on fish habitat.

As a result of mitigation for both the Madrid-Boston Project and the Approved Projects, there are no residual effects anticipated on the VEC marine fish habitat due to physical damage from sealift activities resulting from Hope Bay Project activities.

10.5.4.3 Changes to Water and Sediment Quality: Management of Surface Drainage, Effluent, Dust, and Infrastructure Development

Characterization of Madrid-Boston Potential Effect

Potential effects of Project activities on the VEC marine fish habitat may occur through discharge the deposition of deleterious substances in surface drainage (through runoff), effluent discharge (discharge of TIA and saline groundwater from the Roberts Bay Discharge System and the release of treated greywater or sewage from ocean-going vessels), dust (blasting and quarry operations) and/or infrastructure development (e.g., pile driving). The deposition of deleterious substances could affect fish habitat through effects on biological resources (primary and secondary producers, forage fish). As justified in Section 10.3.2, Madrid-Boston activities that affect primary and secondary producers through the deposition of deleterious substances result from *indirect* trophic level interactions which are ultimately due to changes in water quality and/or sediment quality. The assessment of Madrid-Boston effects on Marine Water Quality and Marine Sediment Quality were completed separately and independently in Volume 5, Chapters 8 and 9. As no significant residual effects are identified due to changes in marine water quality and/or sediment quality, the potential for these effects are not carried forward into subsequent sections of the assessment of the VEC marine fish habitat, as explained in Section 10.3.2.

Project activities that result in the deposition of deleterious substances could also affect fish habitat through effects on forage fish species including mortality and/or reduction in fish health. The assessment of Project effects on the mortality and population abundance of fish community VECs is found in

Section 10.5.5.4 of this chapter. Fish community VEC species of Arctic Char, and Saffron Cod assessed for effects can be considered as representative species for other species of inhabiting Roberts Bay.

Mitigation and Management Measures for Specific Potential Effects

The mitigation and management measures to avoid potential Madrid-Boston effects on the VEC marine fish habitat can be found in the assessment of Project effects on Marine Water Quality and Marine Sediment Quality in Volume 5, Chapters 8 and 9. As justified in Section 10.3.2, Madrid-Boston activities that affect biological resources through the deposition of deleterious substances result from *indirect* trophic level interactions which are ultimately due to changes in water quality and/or sediment quality. Please refer to Section 10.3.2.1 for the rationalization to exclude the water quality and sediment quality in the effects assessment for the VEC marine fish habitat.

The assessment of residual effects on the VECs Marine Water Quality and Marine Sediment Quality can be found in Volume 5, Chapters 8 and 9.

As a result of mitigation and monitoring plans there are no residual effects anticipated on the VEC marine fish habitat due to changes in water quality and/or sediment quality through Management of Surface Drainage, Effluent, Discharge, Dust and Infrastructure Development during Madrid-Boston Project activities.

Characterization of Hope Bay Project Potential Effect

Effects on fish habitat resulting from changes in marine water quality and/or sediment quality resulting from Approved Project activities generally have been or will be mitigated such that there are no residual effects on fish habitat which would combine with Madrid-Boston effects.

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and the Approved Projects, there are no residual effects anticipated on the VEC marine fish habitat due to changes in water quality and/or sediment quality through Management of Surface Drainage, Effluent, Discharge, Dust and Infrastructure Development associated with Hope Bay Project activities.

10.5.4.4 Changes to Water and Sediment Quality: Shipping

Characterization of Madrid-Boston Potential Effect

Cargo ships and tankers will deliver fuel, equipment, and supplies during the open water season typically from August to October dependent on ice conditions. Ocean-going vessels will offload their cargo at either the Roberts Bay jetty (3 m depth) or the cargo dock (23 to 25 m water depth based on newest design and bathymetric data). Larger fuel tankers with deeper drafts will moor offshore using two fixed mooring points onshore and the ship’s anchor to hold the ship’s position during fuel transfer activities.

Effects from propeller wash and wake effects from sealift activities may occur in Roberts Bay are further described in Section 10.5.4.2. The assessment of residual effects on the VECs Marine Water Quality and Marine Sediment Quality can be found in Volume 5, Chapters 8 and 9.

Mitigation and Management Measures for Specific Potential Effects

The mitigation and management measures to avoid potential Madrid-Boston effects on the VEC marine fish habitat through changes in water quality and/or sediment quality can be found in the assessment of Project effects on Marine Water Quality and Marine Sediment Quality in Volume 5, Chapters 8 and 9. These assessments both concluded no significant residual effects. As justified in Section 10.3.2, Madrid-Boston activities that affect biological resources through the deposition of deleterious substances result from *indirect* trophic level interactions which are ultimately due to changes in water quality and/or sediment quality. Please refer to Section 10.3.2.1 for the rationalization to exclude the water quality and sediment quality in the effects assessment for the VEC marine fish habitat.

As a result of mitigation and monitoring plans there are no residual effects anticipated on the VEC marine fish habitat due to changes in water quality and/or sediment quality resulting from sealift-related activities during Madrid-Boston Project activities.

<u>Characterization of Hope Bay Project Potential Effect</u>

Effects on fish habitat resulting from changes in marine water quality and/or sediment quality resulting from Approved Project activities generally have been or will be mitigated such that there are no residual effects on fish habitat which would combine with Madrid-Boston effects.

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and the Approved Projects, there are no residual effects anticipated on the VEC marine fish habitat due to changes in water quality and/or sediment quality resulting from sealift-related activities.

10.5.5 Characterization of Potential Effects – Fish Community VECs

Project residual effects are the effects that remain after mitigation and management measures are taken into consideration. If the implementation of mitigation measures eliminates a potential effect and no residual effect is identified on that VEC, then the effect is eliminated from further analyses. If the proposed implementation controls and mitigation measures are not sufficient to eliminate an effect, then a residual effect is identified and carried forward for additional characterization and a determination of significance. Residual effects of the Project can occur directly or indirectly. Direct effects result from specific Project/environment interactions between Project activities and components, and VECs. Indirect effects are the result of direct effects on the environment that lead to secondary or collateral effects on VECs.

The following characterization of specific potential Project effects on the fish habitat VEC describes the potential effects of interactions of fish community with specific Project activities, identifies specific mitigation measures (including fisheries offsetting), and assesses whether Project residual effects remain after mitigation and management measures are taken into consideration.

Residual effects from project-related interactions associated with the fish community VECs may be avoided and/or considered mitigated even when serious harm (as per the *Fisheries Act*) may be concluded by DFO, as long as the offsetting required for the magnitude of serious harm is considered feasible.

Effects associated with spills (e.g., hydrocarbons), accidental releases (e.g., untreated effluent), and malfunctions (marine infrastructure slope failures, blasting exceedances) are discussed in Volume 7, Chapter 1 and as such will not be considered further as part of this assessment.

10.5.5.1 Direct Mortality and Population Abundance: Infrastructure Footprint

<u>Characterization of Madrid-Boston Potential Effects</u>

Madrid-Boston Project infrastructure has the potential to interact with the marine fish community VECs wherever there is infrastructure being constructed in fish-bearing marine waters. Potential effects on marine fish community VECs are anticipated during all phases of the Madrid-Boston project, beginning in the Construction phase when the cargo dock is being constructed, and continuing through Post-Closure (Table 10.5.3).

The potential for direct mortality or reduction in population abundance of Arctic Char (anadromous life history) and Saffron Cod during the construction of the cargo dock may exist if in-water work is completed outside of appropriate timing windows (i.e., outside of least risk window of August 15 – September 15 based on known species/life stage occurrences) and if appropriate mitigation is not followed (Section 10.5.5.1 Mitigation and Management Measures for Specific Potential Effects). In the absence of proposed mitigation, in-water work directly placed over fish habitat has the potential to cause direct mortality of fish and their eggs, inclusive of Saffron Cod which are known to spawn on sand-gravel substrates during winter (February to March), with egg incubation occurring between April and June. Based on baseline habitat information, it is likely that the site of the proposed cargo dock falls within Saffron Cod spawning habitat, even if the substrate characteristics are not uncommon to Roberts Bay. In addition, working outside of least risk timing windows has the potential for restricting migration and access to spawning, rearing and feeding habitat. There is thus the potential for restricting access of Arctic Char to its seasonal use of Roberts Bay in the summer or its return migration to overwintering freshwater habitats.

Mitigation and Management Measures for Specific Potential Effects

The application of best management practices as described in sections 10.5.3.2 and 10.5.4.1 which includes working during least risk windows and the use of isolated work areas and silt/turbidity curtains, spill prevention and contingency measures, erosion and sediment control measures, and other measures for fish protection will mitigate potential effects on marine fish community VECs. Mitigation by project design (Section 10.5.3.1) will further avoid causing harm to marine fish community VECs.

Fisheries Offsetting

The purpose of a Fisheries Offsetting Plan (Appendix V5-10G), as per the guiding policies of DFO, is to maintain or improve the productivity of CRA fisheries. Where deemed necessary by DFO through the *Fisheries Authorization* process, serious harm to fish resulting from Madrid-Boston activities could be mitigated through the application of offsetting measures. However, mitigation and management measures other than offsetting that will be applied to the construction and operation of the marine cargo dock, have high anticipated effectiveness in preventing the death of fish or any effects on fish population abundance (excludes the habitat loss associated with the infrastructure footprint discussed in Section 10.5.4.1). Thus, fisheries offsetting is not anticipated to be required to mitigate residual effects on the survival and population abundance of fish marine VECs due to Madrid-Boston activities.

As a result of mitigation, and monitoring plans associated with the construction of the cargo dock, there are no residual effects anticipated on marine fish community VECs due to interaction with the Madrid-Boston Project infrastructure footprint.

Characterization of Hope Bay Potential Effects

The potential for direct mortality and reduction in population abundance of fish community VECs due to interaction with the infrastructure footprint of the Approved Projects has been or will be mitigated through the implementation of mitigation and management strategies and approved monitoring plans.

As a result of mitigation, and monitoring plans both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on marine fish community VECs due to interactions with the Hope Bay Project infrastructure footprint.

10.5.5.2 Direct Mortality and Population Abundance: Infrastructure Development

<u>Characterization of Madrid-Boston Potential Effect</u>

Underwater Noise and Pressure from Pile Driving

The primary underwater noise source that will affect the VEC and CRA species in Roberts Bay is that from the construction of the cargo dock infrastructure which requires the placement of sheet piles using vibratory hammer tools Annex V1-7, Package P5-10).

The impact of pile driving results in substantial sound energy propagation within a localized water column. Several factors are critical in determining the level of sound produced by pile driving and these factors vary by the type of impact equipment used (e.g., direct impacts or vibratory hammering) and include: soil/sediment conditions, piling energy, length and size of piles, water depth, salinity, local bathymetry and temperature. Pile driving in or near the water produces a pulsed sound with a strong initial sound pressure level and dissipates rapidly with distance and oceanographic condition (Popper et al. 2014).

Underwater sound impacts can be measured using different units. Direct propagation of over pressure (e.g., due to explosions and pile driving) is measured in energy units (Pascal [Pa]), while sound pressure level (SPL) is measured in decibels (dB) relative to the energy of 1 µPa (one micro-Pascal). Typical monitoring events for underwater sound due to high intensity events like explosions and pile driving are measured in Pa. Pascals can be converted to dB if they cannot be directly measured in dB. Sound impacts and thresholds for non-lethal effects are generally described and published in dB units.

The effect of underwater noise on fishes varies and can include behavioral changes such as avoidance, temporary threshold shifts (TTS), in which the auditory organs of a fish are temporarily affected, and direct mortality (Popper et al. 2014). The level of impact from underwater noise on fishes depends primarily on the magnitude of the sound energy produced, proximity of the organism to the sound source and the nature (i.e., frequency band, variance in intensity) of the sound itself. Hearing ranges and sensitivity varies widely between species. Fish morphology also plays a large part in the impact associated with underwater sound. Fishes can be grouped into hearing generalists and hearing specialists (Kenyon, Ladich, and Yan 1998). Hearing generalists such as flatfish (e.g., bothids and pleronectids), and, elasmobranchs utilize auditory organs made up of bony structures (otoliths) contained in three chambers that make up the inner ear of the fish. This inner ear structure is highly sensitive to particle motion in the water (Popper et al. 2014). This basic form of hearing is common to all fishes. Additionally, some fishes are hearing specialists such as scorpenids and clupeids, and have evolved secondary structures that enable them to perceive both particle movement and sound pressure. Morphological adaptations such as swim bladders, gas filled pockets near the inner ear, and swim bladder extensions or lobes function to focus sound pressure changes into mechanical movement to facilitate hearing in a wider frequency range. Marine invertebrates are less sensitive to noise than fishes or marine mammals, primarily due to the lack of internal air structures (Popper et al. 2014).

The vibratory hammer tool used to push the sheet piles into the sea floor generates sound in a continuous manner through its vibration energy and generates peak sound pressure levels that are lower than those generated by more traditional impact techniques (Laughlin 2007). This generally results in overall lower impact levels to marine organisms.

Underwater Pressure and Vibrations from Blasting during Quarry Development

As part of the construction of infrastructure (i.e., cargo dock) and associated maintenance needs, on-shore blasting is planned at two quarries located along the western (AE) and southern (AF) shoreline of

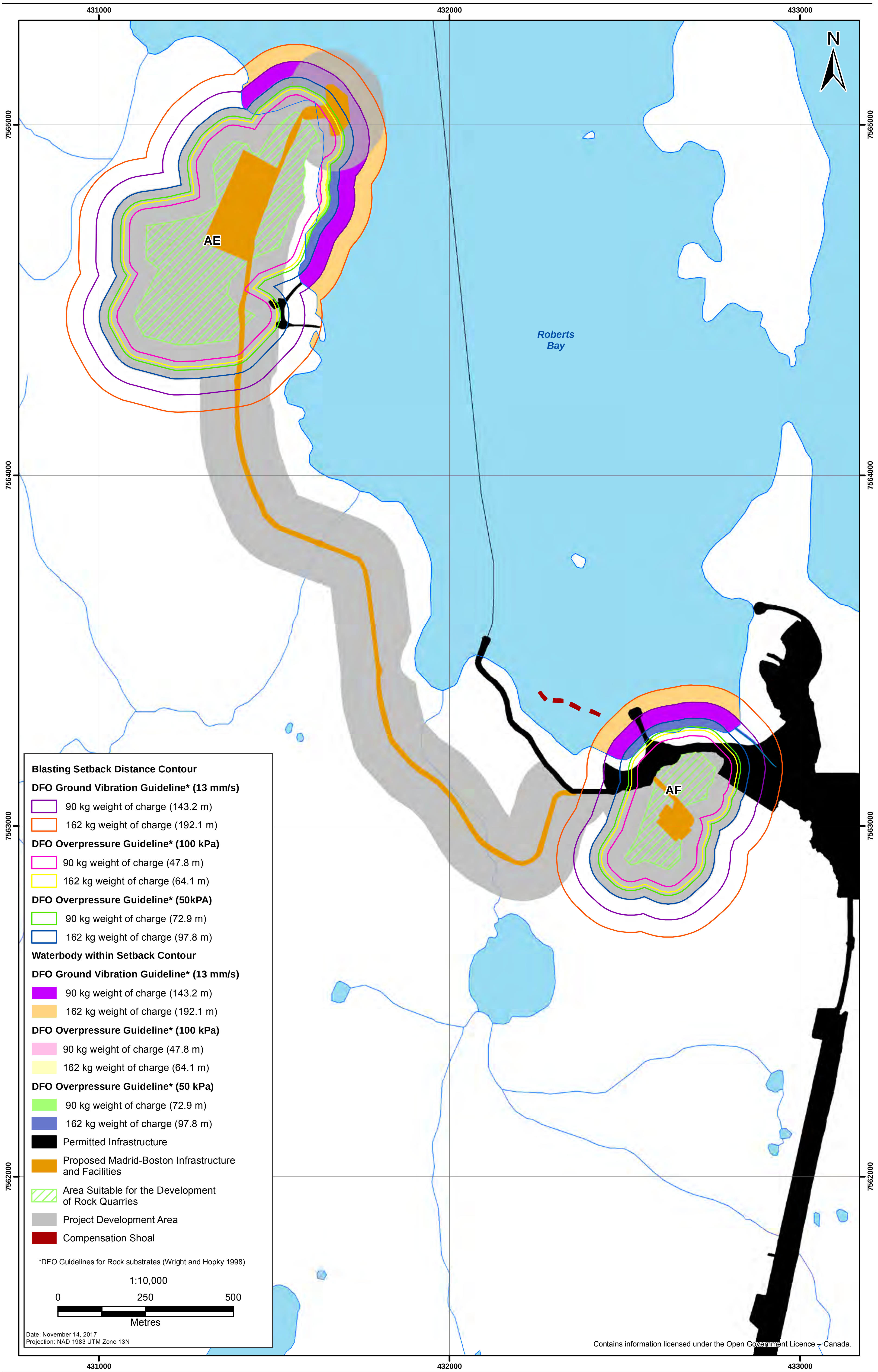
Roberts Bay for borrow materials to build laydown pads and the access road. Quarry AE is located adjacent to the cargo dock and stretches approximately 30 to 500 m from the shoreline, whereas Quarry AF is located adjacent to the existing jetty and extends approximately 30 to 250 m from the shoreline.

Effects on fish community VECs from blasting are most likely to occur where Phase 2 quarries are located adjacent to waterbodies that may contain Arctic Char and Saffron Cod. Detonation of explosives in or adjacent to fish habitat has been demonstrated to cause mortality, injury, and/or behavioural changes in fish and/or fish eggs and larvae (Wright and Hopky 1998; Faulkner et al. 2006). The detonation of explosives in or near water produces post-detonation compressive shock waves that result in a pressure deficit that can cause adverse impacts on fish such as swimbladder damage, hemorrhaging in various organs (e.g., kidney, liver, spleen and sinus venous), as well as death of fish eggs and larvae (Wright 1982; Faulkner et al. 2006; Faulkner et al. 2007; Kolden and Aimone-Martin 2013 and references therein). Vibrations from the detonation of explosives may also cause damage to incubating eggs (Wright 1982). Finally, noise produced by explosives can cause sublethal effects, such as changes in behaviour of fish. These effects may be intensified near ice and hard substrates.

Because the detonation of explosives in or adjacent to fish habitat may cause harm to fish or fish habitat (DFO 2016b), works involving the use of explosives near waterbodies must follow at minimum the recommendations developed by DFO provided in the “Guidelines for the use of explosives in or near Canadian fisheries waters” (Wright and Hopky 1998). These guidelines provide minimum setback distances for safe detonation based on type of fish habitat (e.g., active spawning [includes egg incubation] versus non-spawning-specific habitat). It is stipulated that no explosive can be detonated in or near fish habitat that produces, or is likely to produce, a peak particle velocity that is greater than 13 mm/s at spawning habitat during the period of egg incubation. Furthermore, no explosive can be detonated such that an instantaneous pressure change (IPC; i.e., overpressure) greater than 100 kPa in the swimbladder of a fish is produced. Further DFO recommendations suggest that instantaneous pressure change should be limited to 50 kPa in order to be effectively protective of fish. Proper adherence to these guidelines is not limited to, but may include knowing which waterbodies are in the vicinity of proposed blasting activities, the distance separating each waterbody and the point of detonation, species composition and associated life history information of each waterbody (i.e., critical timing windows, including spawning and egg incubation), and substrate type where the explosive will be detonated (Wright and Hopky 1998).

Given the close proximity of the proposed quarry sites to nearshore marine fish habitat and the setback distance contours calculated based on DFO guidelines of 100 kPa and 50 kPa for overpressure and 13 mm/s for ground vibration (Wright and Hopky 1998), it is possible that fish may be impacted by blasting activities. Representative worst-case blasting charges (two charge values were assessed based on historic blasting data at Doris; 90 kg and 162 kg) show overlap with marine fish habitat in proximity of both quarry locations (Figure 10.5-2). Setback distances were calculated for rock substrates because areas suitable for quarry development are located in hard rock benches. Noise from on-shore blasting was evaluated for potential effects on marine mammals and birds (Volume 5, Section 11.9). As indicated in Annex V1-8, prior to initiating blasting activities, TMAC will engage further with DFO to determine the most appropriate threshold limit to use to reduce the risk of serious harm to fish, including consideration of "Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2016b), and Wright and Hopky (1998).The same representative blasting charges were used to assess noise and vibration effects on human and wildlife receptors (Volume 4, Chapter 3 Noise and Vibration).

Figure 10.5-2
Quarry Blasting Setbacks in Roberts Bay



Mitigation Measures for Specific Potential Effects on Fish Community VECs

Underwater Noise and Pressure from Pile Driving

Data have been compiled and published on pile driving noise thresholds for the protection of fish, eggs and larvae (Popper et al. 2014). These data indicate that mortality can occur with underwater pile driving sound energy above 22.4 kPa (207 dB re: 1 μPa) when fish are exposed within a few metres of the sound source. At greater distances several studies have shown that no fish mortality or damage to fishes can be attributed to pile driving sound (Abbott, Reyff, and Marty 2005; Nedwell et al. 2006; Ruggerone, Goodman, and Miner 2008; Houghton et al. 2010). Non-lethal impairment of fish hearing including temporary threshold shifts (TTS) can occur with energy much lower, however Casper et al. (2012; 2013) have shown that fish readily recover from injuries that are not lethal. While project-related sound below the lethal level, may have the ability to alter fish movements, and thereby illicit an avoidance behavior for certain habitat areas, the duration and frequency of the noise generating activities is not expected to be such that the resulting impact be classified as a residual effect. Taken together these studies support the conservative sound threshold of 22.4 kPa (207 dB re: 1 μPa) to not be exceeded outside of the turbidity curtain, for avoiding potential effects to fish from underwater pile driving, and is considered protective of both adult and juvenile fish. Marine mammal-specific noise thresholds and mitigation measures associated with pile driving are discussed in the Marine Wildlife Volume 5, Section 11.5.3.

Several general methods are available to mitigate the effects of pile driving noise in the marine environment. These range from engineering controls to project activities. All mitigation measures included below are designed to provide protection from fish mortality. These measures also generally concur with those described in the Marine Wildlife Volume 5, Chapter 11, Section 11.5-3 for protection of marine mammal:

- Conduct project when affected species are not present (seasonal distributions and consideration of least risk timing windows, i.e., August 15 to September 15) and establishment of no-work windows wherever feasible (i.e., July 15 to August 15) to avoid critical spawning and rearing periods.
- Use vibratory pile driving versus impact pile driving (to reduce impacts to fish).
- Establish underwater noise thresholds to not be exceeded outside the isolated work area (i.e., outside the area sectioned off with a turbidity curtain). In the event they are exceeded, additional mitigation measures are triggered. During all noise generating events, sub-surface hydroacoustic monitoring using hydrophone technology will be conducted. Sub-surface hydroacoustic recordings of sound energy during operation of pile driving operation will occur to confirm predictions on sound generation. Mean and maximum sound energy will be measured during use of vibratory hammer and any other activities having the potential of creating sound energy. When sound levels breach the established maximum threshold outside the turbidity curtain, exceedances should be reported to the contractor for the immediate stoppage of work and implementation of any additional mitigation measures. Observations for fish kills or impairment will occur throughout the period of sound generation.
- In the event that thresholds are exceeded, the implementation of an attenuation device (e.g., bubble curtain) will be considered when vibratory pile driving is occurring to reduce peak underwater noise.
- The use of bubble curtains have been shown to lessen underwater noise impacts through the attenuation of the sound energy by the suspended air bubbles in the water column and can achieve up to a 20 dB reduction in ambient noise level (Vagle 2003). Bubble curtains should be installed around each pile prior to the start of driving activity and be in operation throughout

all noise generating activity. Care should be made in the installation and operation to ensure that the pile is completely surrounded by bubbles throughout the water column. The use of bubble curtains will also help to eliminate the potential of fish mortality from direct contact with piles by temporarily displacing fish out of the area.

As a result of effective mitigation and associated monitoring plans there are no residual effects anticipated on the VEC marine fish community from underwater noise and pressure generated during pile driving activities.

Underwater Pressure and Vibrations from Blasting during Quarry Development

Tables 10.2-12 and 10.2-13 describe the life characteristics, spawning timing, and fry emergence timing for fish species present in the marine LSA where blasting activities are anticipated. Blasting activities will consider seasonal variations in habitat use by the species present over the year. Potential effects of blasting on fish present in Roberts Bay will be mitigated by adjusting the timing of blasting to avoid sensitive life stages of fish (e.g., incubating eggs) and/or by limiting the weight of explosive charges detonated simultaneously to avoid producing overpressure or ground vibrations that exceed DFO guidelines (Wright and Hopky 1998).

Specifically, explosive use will employ, at minimum, the following additional guidelines for the use of explosives in or near waters taken from Wright and Hopky (1998):

- No explosive is to be detonated in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (i.e., overpressure) greater than 100 kPa (14.5 psi) in the swimbladder of a fish. TMAC commits to engaging further with DFO to determine the most appropriate threshold limit to use to reduce the risk of serious harm to fish.
- For confined explosives, setback distances from the land-water interface (e.g., the shoreline), or burial depths from fish habitat that will ensure that explosive charges meet the 100 kPa overpressure guideline are shown in Table 1 of Wright and Hopky (1998).
- No explosive is to be detonated that produces, or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation.
  - For confined explosives, setback distances or burial depths from spawning beds that will ensure that explosive charges meet the 13 mm/s guideline criteria are shown in Table 2 of Wright and Hopky (1998).
  - For unconfined explosives, the appropriate DFO Regional/Area authorities will be contacted for further guidance.

Explosive products will be stored on site in accordance with Territorial and Federal regulations. The main storage of ammonium nitrate is located at Doris, with secondary storage areas at Boston. The handling and manufacture of explosives will be contracted to a licensed operator.

In addition, similar to that being proposed during pile driving activities done for pile driving as described in above section, timing of works will occur during least risk windows provided in Section 10.5.3.2 unless explosive charges being used are small enough to not affect any fish habitat (i.e., distance of blasting site is far enough to not result in any detectable overpressure or vibration changes in fish habitat). In addition, the following activities are proposed:

- Hydroacoustic/vibration Monitoring: during all blasting events, hydroacoustic/vibration monitoring using hydrophone technology will be conducted. Observations for fish kills or impairment will occur throughout the period of sound generation. If overpressure levels breach the recommended maximum threshold of 100 kPa and/or a 13 mm/s peak particle velocities (Wright and Hopky 1998) at the edge of marine fish habitat, this should be reported to the contractor for the immediate stoppage of work and implementation of any additional mitigation measures. In the unlikely event that active migration and/or spawning is observed for sandy beach spawners such as capelin (though spawning has never been documented to occur in Roberts Bay), a stop work order will be put in place.

As a result of successful implementation of mitigation measures there are no residual effects anticipated on marine fish community VECs due to blasting during quarry development associated with Madrid-Boston Project activities.

Characterization of Hope Bay Project Potential Effects

The potential for direct mortality and reduction in population abundance of fish community VECs due to blasting has been and will continue to be mitigated through the implementation of mitigation strategies and approved monitoring plans.

As a result of the ongoing successful implementation of mitigation measures and monitoring plans for both the Madrid-Boston Project and the Approved Projects, there are no residual effects anticipated on marine fish community VECs due to Infrastructure Development activities associated with Hope Bay Project activities.

10.5.5.3 Direct Mortality and Population Abundance: Shipping

Characterization of Madrid-Boston Potential Effect

There is the potential for sealift activities occurring in Roberts Bay to interact with the fish community VECs through a number of effects pathways namely noise which can result in area avoidance and physical stress, and through the introduction of exotic species and pathogens via ballast water exchanges. Approximately six or seven vessels will report annually to the Roberts Bay facility during Construction and Operations, and potentially during Closure, all during the open-water season (August to October) as no ice breakers will be used, preventing sealift over winter months.

With regards to sealift activities outside of Roberts Bay and along the commercial sealift route (Volume 3), only open-water sealifting (no ice breaking) will occur, further limiting interactions with marine fish VECs. Furthermore, it is unlikely that marine fish VECs will come in contact or be affected by vessels traveling via the commercial sealift lane, regardless of the number of vessels, because of their distribution and preferred habitats, including sensitive habitat such as spawning habitats. The commercial sealift lane is positioned well offshore, following deep-water sealift channels and avoids nearshore and shallow areas for safety and for avoiding interactions with marine wildlife (refer to Chapter 11 Marine Wildlife for further information). Arctic Char are known to remain close to coastal rivers during their seasonal summer feeding migrations from freshwater to coastal and marine waters for feeding (A. D. Spares, M.J.W. Stokesbury, R.K. O'Dor and T.A. Dick. 2012; J.-S. Moore, L.N. Harris, S.T. Harris, L. Bernatchez, R.F. Tallman and A.T. Fisk. 2016). Similarly, Saffron Cod, typically utilize nearshore areas for both rearing and spawning, and are often found in areas of tidal influence at the mouths of coastal rivers in demersal habitats (Wolotira Jr. 1985; Laurel et al. 2009; Copeman et al. 2016). The potential for interaction via sealift lanes is therefore considered negligible, and for this reason, will not be considered further.

Noise

There is potential for direct mortality or reduction in population abundance of Arctic Char (anadromous life history) and Saffron Cod stemming from noise during sealift activities occurring in Roberts Bay.

Offshore sealift activities often produce sound waves that can be high enough in amplitude to potentially affect some members of nearshore fish communities, even after the sound waves propagate several kilometres through the marine environment (McKenna et al. 2012). Hearing specialists would experience the strongest such effects (Popper 2003). In contrast, the magnitude of such effects would be smaller on hearing generalists such as salmonids (i.e., Arctic Char), which have poorer hearing than specialists (Popper 2003). For some fish species, anthropogenic noise produced by sealift activities may cause stress- induced reduction in growth and reproductive output, and interfere with critical functions such as acoustic communication, predator avoidance, and prey detection (Slabbekoorn et al. 2010). Other indirect effects of introduced noise may result in the fish leaving a feeding ground or an area in which they would normally reproduce (Popper 2003). Based on the closely-related species Atlantic salmon (*Salmo salar*), the marine fish/aquatic habitat VEC Arctic Char (also a salmonid) could potentially hear sealift activities in the vicinity of the PDA (Hawkins and Johnstone 1978). Arctic Char in the vicinity of the PDA may elicit startle responses to very high amplitude noise caused by the propellers of ships arriving at or departing from the MLA (Knudsen, Enger, and Sand 1992, 1994). Arctic Char are not known to produce sounds for communication; therefore, the anthropogenic sounds of sealift activity have no opportunity to interfere with Arctic Char fish communication. However, it is unknown whether Saffron Cod require sound communication similar to other cod species (Rowe and Hutchings 2003, 2006) for spawning aggregations to occur. However, since Saffron Cod spawn in the winter and no sealift will occur during this season, there is no potential for interaction via this pathway.

Commercial vessels cruising in open water typically emit low-frequency underwater noise from 10 to 100 Hz (NRC 2003; Hildebrand 2009; McKenna et al. 2012). Noise modeling conducted for the Mary River Project (Baffinland Iron Ore Corporation 2012) reported that noise would attenuate to 70 dB within approximately 200 m from the vessel. For a large vessel of 190 m × 30 m, the area where noise would exceed 70 dB would be approximately 0.21 km^2. Using an estimated ship speed of 25 km/h, a fish that does not move away from a vessel would be exposed to noise above 70 dB for approximately 1.4 minutes, which would be the incremental increase in noise disturbance for each ship associated with the Madrid-Boston development.

Outside of Roberts Bay, any disturbance to fish community VECs along the sealift route would be transitory. Given the estimated source levels, infrequency of traffic, the disturbance is expected to be minor or brief, lasting less than 20 minutes per year on the sealift route and affecting only fish found within 250 m of the ship.

Ballast Water

Although unlikely, there is the potential for direct mortality or reduction in population abundance of Arctic Char (anadromous life history) and Saffron Cod through the ballast water exchange (discharge) pathway associated with sealift activities. Ballast water is used to stabilize a ship and ensure that the propeller remains submerged by counterbalancing changes in weight as cargo is loaded or offloaded. Ballast water (including any organisms or sediments suspended in the water) can be taken in at one port and discharged in another.

For the Hope Bay Development, it is not anticipated that vessels will be discharging ballast water at the port in Roberts Bay since ships will be coming in loaded and therefore will not be carrying ballast water. Ballast water will most often be taken on in Roberts Bay to counterbalance offloaded fuel and cargo, thus the discharge of ballast water is expected to occur relatively infrequently. If the discharge of ballast water is required, ocean-going vessels will follow the Ballast Water Control and Management Regulations (2011) under the *Canada Shipping Act* (2001). This will ensure that ballast water is exchanged offshore outside of Roberts Bay.

Generally during sealift, the release of ballast water has the potential to result in the introduction of exotic species and/or pathogens; species invasions via hull fouling are not expected to occur because ships will carry out their operations in accordance with shipping regulations, as discussed in Section 10.5.3.1, and thus this potential effect will not be carried foward. Introduced species may compete for resources with, or transmit disease (via pathogens) to marine community VECs, negatively affecting their population abundance. Nonindigenous species regularly enter coastal waters in the ballast waters of commercial ships, a leading vector of aquatic species invasions (CCFAM 2004; Hulme 2009; Briski et al. 2013). These aquatic invasions have been indicated as causing or contributing to declines in populations of threatened and endangered species, habitat alteration and loss, shifts in food webs and nutrient cycling, declines in fish populations, disease outbreaks, species extinctions, and biotic homogenization (Tang 2013). The effects of invasive species may become enhanced by climate change, with northern climates becoming more at risk from invasion by southern species as temperatures become warmer (Rahel, Bierwagen, and Taniguchi 2008).

To provide additional support that introductions are unlikely even if ballast water exchanges were to occur in Roberts Bay (and representative of other vector modes including hull fouling even if unlikely), various approaches can be used to model the probability of invasion of a range of organisms. Recently, invasion models based on global sealift patterns combined with environmental conditions and biogeography have simplified understanding patterns of ship-mediated bio-invasionthe probability of invasion of a range of organisms can be made using invasion models based on global sealift patterns that investigate patterns of ship-mediated bio-invasion (Keller et al. 2011; Seebens, Gastner, and Blasius 2013).

The following calculations assume a worst-case scenario, in which no prophylactic ballast water exchange occurs in the open ocean; it is therefore likely that the following scenario overestimates the invasion risk. In this model, the probability of a native species in one port being a non-native in another port can be estimated by biogeographical dissimilarity (Seebens, Gastner, and Blasius 2013) and is a function of distance between the two ports. The probability that a given species is an alien in the recipient port increases with distance from the host port. In Arctic waters like Roberts Bay, the majority of vessels would be travelling more than 1,000 km, and so for most donor ports, the probability of a species being alien to the recipient port would be relatively high (probabilities of 0.004 to 0.46 at 1,000 to 10,000 km away).

For a species in the donor port that is non-native to the recipient port, the probability of introduction depends on the survival within ballast tanks (Seebens, Gastner, and Blasius 2013) which decays exponentially with travel time, but increases with volume of ballast water discharged. For the proposed project in Roberts Bay, with an example vessel of approximately 30,000 DWT, maximum discharge per vessel would be about 10,000 m^3 (or metric tons). With typical journey times of about 30 days for international vessels, the probability of introduction would be relatively high, as observed for other international ports (Seebens, Gastner, and Blasius 2013).

Once introduced, the probability of establishment of a given non-native species increases with the environmental similarity between ports, and this can be modelled as a function of the differences in temperature and salinity between the ports (Seebens, Gastner, and Blasius 2013). In the case of Arctic waters such as Roberts Bay as a recipient port, the environmental similarity will be low for most international donor ports, and temperature and salinity differences will be high. In summer, surface water temperature can be high and salinity low in Roberts Bay, but the strong gradients observed in the pycnocline (about 10 m depth) mean that dense oceanic ballast water will mix with deeper water of very low temperature and higher salinity. With a temperature difference between host and recipient ports of about 10°C, the probability of establishment of an alien species decreases.

The product of these three probabilities determines the overall likelihood of an invasion of a nonnative species through ballast water release. Assuming a full ballast discharge of 10,000 m^3, overall probability of an invasion increases as a function of distance between ports. Journey times of 10 and 30 days have little influence on overall probability of invasion, but a temperature difference of 10°C and salinity difference of 20 (which is likely to occur given that originating ports will likely be from warmer and/or less saline waters) decreases likelihood of invasion by a factor of approximately 106.

Anti-fouling Agents

Vessels can be generally associated with the use of anti-fouling agents such as tributyltin (TBT) to prevent the accumulation of organisms such as barnacles or mussels that can interfere with the drag of a ship, increase fuel costs, and damage propulsion systems. Leaching from anti-fouling paints may cause increased concentrations of TBT in sediments, which could affect the health of marine organisms. The potential leaching of toxic anti-fouling agents from ships will be eliminated by the adherence of vessels to Canadian regulatory requirements, and are therefore not assessed further as potential effects. Additional information is provided in Volume 5, Section 9.5.4.1.

<u>Mitigation and Management Measures for Specific Potential Effects</u>

Vessel travel in Roberts Bay will be limited to only the open-water season thereby limiting the potential for noise stemming from sealift; ice breakers will also not be used over the life of Madrid-Boston activities. Vessels will also travel at reduced speeds in order to minimize effects from propeller wash and wake effects, which will serve to further reduce generation of noise from propellers.

The management of ballast water and its contents is the responsibility of the ship owner, and federal guidelines set forth by (Canada 2017) are expected to be adhered to. Ballast water from ships will be mitigated and managed by having ocean-going vessels follow the Ballast Water Control and Management Regulations (2011) under the *Canada Shipping Act* (2001). The *Canada Shipping Act* provides an overall mechanism to protect safety and the environment for vessels operating in Canadian jurisdiction, i.e., waters out to the 200 nautical mile limit. Its regulations include requirements for a vessel's construction, how it manages ballast water, its pollution control equipment, arrangements for emergency response, and its crew qualifications. The *Arctic Waters Pollution Prevention Act* (1985a) provides enhanced protection for vessels operating in Canadian jurisdiction north of 60° North latitude. It provides specific construction standards for vessels engaged in Arctic sealift activities, a system of sealift safety control zones, a ban on discharges of oil, hazardous chemicals, and garbage, and requirements for vessels to carry insurance to cover damages from any of these discharges. The application of these methods will ensure ballast water is exchanged offshore outside of Roberts Bay, nullifying any potential effect on marine community VECs.

Existing shipping regulations which includes, though not exclusively, the mandatory offshore exchange of ballast water outside of Roberts Bay, and the vast dissimilarity of habitat in Roberts Bay from source ports make it very unlikely that introduced species will have a residual effect on the marine fish community VECs.

As a result of successful implementation of mitigation measures and application of regulatory requirements, there are no residual effects anticipated on marine fish community VECs due to vessel-related noise, vessel impacts or ballast water (introduction of exotics and pathogens) associated with Madrid-Boston Project activities.

<u>Characterization of Hope Bay Project Potential Effect</u>

Effects on fish community VECs resulting from sealift from the Approved Project activities generally have been or will be mitigated such that there are no residual effects on fish communities.

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and the Approved Project, there are no residual effects anticipated on the VEC marine fish community due to sealift resulting from Hope Bay Project activities.

10.5.5.4 Changes to Water and Sediment Quality: Management of Surface Drainage, Effluent, Dust and Infrastructure Development

Characterization of Madrid-Boston Potential Effect

Potential effects of Project activities on the marine fish community VECs may occur through the deposition of deleterious substances in surface drainage (through runoff), effluent (discharge of TIA and saline groundwater from the Roberts Bay Discharge System and the release of treated greywater or sewage from ocean-going vessels), dust (blasting and quarry operations) and/or infrastructure development (e.g., pile driving). The deposition of deleterious substances and resulting potential changes in water quality and/or sediment quality could affect fish community VECs through the pathway of decreased health and indirect mortality. The assessment of Project effects on Marine Water Quality and Marine Sediment Quality were completed separately and independently in Volume 5, Chapters 8 and 9. As no significant residual effects are identified for marine water quality and/or sediment quality, the potential for these effects are not carried forward into subsequent sections of the assessment of the marine fish community VECs. The potential for bioaccumulation in Arctic Char and other marine fish) is quantitatively assessed in the Human Health and Environmental Risk Assessment chapter (Volume 6, Chapter 5). The primary exposure pathway for fish is direct contact with water and/or sediment. They could also be indirectly exposed through trophic effects if a bioaccumulative contaminant of potential concern (COPC; e.g., mercury) were present. Estimation of risk to aquatic life ecological receptors including fish from COPCs were evaluated through the calculation of hazard quotients for existing conditions (see Volume 6, Section 5.5.4.2 for further information); no adverse effects to marine life were anticipated via this pathway under existing conditions. Similarly, because marine water quality is anticipated to meet all CCME marine water quality guidelines, no significant residual effects were concluded, thus no COPCs were identified and carried forward; Madrid-Boston Project-related changes to the health of ecological receptors including fish are therefore not expected and not carried further as a potential effect (Volume 6, Section 5.6.1.3).

Mitigation and Management Measures for Specific Potential Effects

The mitigation and management measures to avoid potential Project effects on the VEC marine fish community can be found in the assessment of Project effects on marine water quality and marine sediment quality in Volume 5, Chapters 8 and 9. The assessment of residual effects on the VECs Marine Water Quality and Marine Sediment Quality both conclude no significant residual effects, therefore the potential for an interaction with marine fish community VECs is considered negligible via these pathways. Furthermore, as mentioned above, Madrid-Boston Project-related changes to the health of ecological receptors including fish are not expected (Volume 6, Chapter 5).

As a result of mitigation and monitoring plans there are no residual effects anticipated on the VEC marine fish community due to changes in marine water quality and/or marine sediment quality resulting from Management of Surface Drainage, Effluent, Dust and Infrastructure Development during Madrid-Boston Project activities.

Characterization of Hope Bay Project Potential Effect

Effects on fish community VECs resulting from changes in marine water quality and/or marine sediment quality resulting from the Approved Project activities generally have been or will be mitigated such that there are no residual effects on fish communities.

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and the Approved Projects, there are no residual effects anticipated on the VEC marine fish community due to changes in water quality and/or sediment quality resulting from Management of Surface Drainage, Effluent, Dust and Infrastructure Development during Hope Bay Project activities.

10.5.5.5 Changes to Water and Sediment Quality: Shipping

<u>Characterization of Madrid-Boston Potential Effect</u>

Although unlikely, there is the potential for vessel activities occurring in Roberts Bay to directly interact with the fish community VECs through ballast water exchanges during sealift activities leading to changes in water and sediment quality. Between six and seven vessels will report annually to the Roberts Bay facility during Construction and Operations, and potentially during Closure. However, as indicated in Section 10.5.5.3, ballast water exchange related-effects are not anticipated to occur in Roberts Bay because vessels are not anticipated to be discharging at the port because ships will be coming in loaded (and will thus not be carrying or discharging ballast water).

<u>Mitigation and Management Measures for Specific Potential Effects</u>

The mitigation and management measures to avoid potential Project effects on the VEC marine fish community can be found in the assessment of Project effects on marine water quality and marine sediment quality in Volume 5, Chapters 8 and 9, in addition to Section 10.5.5.3 of this chapter. No significant residual effects were identified from the assessment on the VECs Marine Water Quality and Marine Sediment Quality.

As a result of mitigation and monitoring plans there are no residual effects anticipated on the VEC marine fish community due to changes in marine water quality and/or marine sediment quality stemming from sealift activities during Madrid-Boston Project activities.

<u>Characterization of Hope Bay Project Potential Effect</u>

Effects on fish community VECs resulting from changes in marine water quality and/or marine sediment quality resulting from Approved Project activities generally have been or will be mitigated such that there are no residual effects on fish habitat which would combine with Madrid-Boston effects.

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on marine fish community VECs due to changes in water quality and/or sediment quality resulting from vessel associated with Hope Bay Project activities.

10.5.6 Characterization of Project-related Residual Effects

10.5.6.1 Characterization of Residual Effect for Marine Fish Habitat VEC

After considering the anticipated successful implementation of mitigation measures, fisheries offsetting, and associated monitoring, **no residual effects** on the VEC fish habitat are anticipated as a result of Project-related activities. Consequently, no potential residual effects were evaluated for significance or carried forward to a cumulative effects assessment.

10.5.6.2 Characterization of Residual Effects for Marine Fish Community VECs

After considering the anticipated successful implementation of mitigation measures, and associated monitoring, **no residual effects** on the VECs Arctic Char (anadromous life history), or Saffron Cod are anticipated as a result of Project-related activities. Consequently, no potential residual effects were evaluated for significance or carried forward to a cumulative effects assessment.

10.6 CUMULATIVE EFFECTS ASSESSMENT

10.6.1 Methodology Overview

The potential for cumulative effects arises when the potential residual effects of the Project affect (i.e., overlap and interact with) the same VEC that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities. When residual effects are present, the cumulative effects assessment (CEA) follows the general methodology described in Volume 2, Chapter 4 (Effects Assessment Methodology).

10.6.2 Potential Interactions of Residual Effects with Other Projects

10.6.2.1 Fish Habitat VEC

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VEC fish habitat are predicted. Thus, there exists no potential for interactions with Projects – past, existing, or in the foreseeable future – for the VEC marine fish habitat and a CEA was not conducted (see CEA Methodology; Volume 2, Chapter 4).

10.6.2.2 Fish Community VECs

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VECs Arctic Char (Anadromous life history) and Saffron Cod are predicted. Thus, there exists no potential for interactions with Projects – past, existing, or in the foreseeable future – for the marine fish community VECs and a CEA was not conducted (see CEA Methodology; Volume 2, Chapter 4).

10.7 TRANSBOUNDARY EFFECTS

10.7.1 Methodology Overview

The Project EIS guidelines define transboundary effects as those effects linked directly to the activities of the Project inside the NSA, which occur across provincial, territorial, international boundaries or may occur outside of the NSA (NIRB 2012a) Transboundary effects of the Project have the potential to act cumulatively with other projects and activities outside the NSA.

10.7.2 Potential Transboundary Effects

10.7.2.1 Fish Habitat VEC

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VEC fish habitat are predicted. Thus, no transboundary effects on the VEC marine fish habitat are expected to occur.

10.7.2.2 Fish Community VECs

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VECs Arctic Char (anadromous life history), and Saffron Cod are predicted. Thus, no transboundary effects on the marine fish community VECs are expected to occur.

10.8 IMPACT STATEMENT

The VEC marine fish habitat comprises both the biological resources and physical characteristics that are necessary for the productivity of fisheries species. Marine fish habitat may interact with and be affected by Madrid-Boston activities along two general pathways: through a direct loss or alteration of fish habitat by permanent alteration or destruction (PAD), or through changes to water quality and/or sediment quality arising from the deposition of deleterious substances.

PADs occur whenever there is loss or alteration of fish habitat through encroachment of infrastructure. Based on the current cargo dock design, a direct loss of fish-bearing habitat in Roberts Bay will amount to 9,675 m^2 (includes 2,663 m^2 of self-offsetting habitat created by riprap/armour rock), or approximately <0.07% of the habitat available to fish in Roberts Bay, due to the construction of the cargo dock. Additional design refinements will occur prior to submission of the final EIS to further minimize anticipated habitat losses. Unavoidable habitat loss or alteration due to Madrid-Boston infrastructure will be mitigated through fisheries offsetting to balance all fish habitat losses, as deemed necessary by DFO. A Fisheries Offsetting Plan, including the detailed description of habitat losses, fisheries offsetting options and proposed monitoring plan, will be developed prior to an Application for a *Fisheries Act Authorization* and prior to effects occurring.

The introduction of deleterious substances could alter fish habitat *directly* by changes in water quality and/or sediment quality to the extent that fish health decreases and mortality occurs, or *indirectly*, through trophic interactions with biological resources used by fish. Potential effects of Madrid-Boston Project activities on the VEC marine fish habitat may occur through the deposition of deleterious substances in surface drainage, effluent (water discharge to the receiving environment), dust and/or infrastructure development. The deposition of deleterious substances could affect fish habitat through effects water quality, sediment quality, and/or on biological resources (primary and secondary producers, forage fish). Project activities that affect primary and secondary producers through the deposition of deleterious substances result from *indirect* trophic level interactions which are predominantly due to changes in water quality and/or sediment quality. No significant residual effects were concluded for either the Marine Water Quality and/or Marine Sediment Quality VECs (Volume 5, Chapters s 8 and 9, respectively).

As a result of mitigation, management, and balancing all fish-bearing habitat losses with offsetting should a *Fisheries Authorization* be required if serious harm is concluded, there are no residual effects anticipated on the VEC marine fish habitat due to Madrid-Boston Project infrastructure. The primary mitigation by design measures to avoid or minimize serious harm include DFO's measures to avoid causing serious harm to fish and fish habitat, in addition to specific mitigation targeting effects associated with, for example, blasting and sealift. Furthermore, project planning including avoiding causing serious harm to fish by completing in-water works during least risk windows and by minimizing the footprint area (and maximizing self-offsetting habitat) required for the cargo dock serves to further minimize potential effects. For any remaining habitat losses, offsetting will allow for fisheries productivity to remain stable or be enhanced over time.

As no residual effects are anticipated for Madrid-Boston Project, there are no potential residual effects that could act cumulatively with other project potential effects. Therefore no cumulative effects or transboundary effects are expected on the VEC marine fish habitat.

The marine fish community comprises the survival and abundance of individual fish VECs including Arctic Char (anadromous life history), and Saffron Cod (marine life history). The marine fish community may interact and be affected by Madrid-Boston activities along two general pathways: through *direct* mortality and changes in population abundance, or through decreased health and *indirect* mortality resulting from changes in marine water quality and/or marine sediment quality.

Direct mortality and population abundance of marine fish community VECs (Arctic Char and Saffron Cod) may be affected by Madrid-Boston activities through several routes: infrastructure footprint (e.g., smothering of eggs during construction of cargo dock) and infrastructure development (direct impact and noise from pile driving, blasting at quarry sites), sealift and fishing activities. Direct mortality is not expected due to implementation of effective mitigation measures including working during least risk windows, site isolation during in-water works and implementation of blasting measures that consider appropriate over-pressure and vibration guideline that are protective of fish. Reduced population abundance effects are also not anticipated because of the successful implementation of effective mitigation measures. A no fishing policy will be in place nullifying any effects from fishing.

For the pathway of effects on fish community VECs of decreased health and *indirect* mortality, potential changes in water quality and/or sediment quality resulting from surface drainage , fugitive dust, and planned discharge of water/effluent to the receiving environment could have chronic effects on fish community VECs. The deposition of deleterious substances and resulting potential changes in water quality and/or sediment quality could affect fish community VECs through the pathway of decreased health and indirect mortality. The assessment of Project effects on Marine Water Quality and Marine Sediment Quality were completed separately and independently in Volume 5, Chapters 8 and 9 using indicators that have quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life; no significant residual effects were concluded for either of these VECs. The potential for bioaccumulation of contaminants in marine fish representative of different trophic levels through trophic interactions with primary and secondary producers was quantitatively assessed through the Human Health and Environment Risk Assessment (Volume 6, Chapter 5). Because marine water quality is anticipated to meet all CCME marine water quality guidelines, no significant residual effects were concluded, thus no COPCs were identified and carried forward; Madrid-Boston Project-related changes to the health of ecological receptors including fish were therefore not expected

As a result of mitigation, management, and balancing all fish-bearing habitat losses with the possible development and implementation Offsetting Plan as required during submission of the final EIS should a *Fisheries Authorization* be deemed necessary by DFO to offset serious harm, there are no residual effects anticipated on marine fish community VECs Arctic Char, and Saffron Cod. The primary mitigation measures include siting Madrid-Boston Project infrastructure to avoid sensitive fish habitats when constructing in fish-bearing waters and working during least-risk windows. Any losses to fisheries productivity will be fully compensated as deemed necessary by DFO by developing a Fisheries Offsetting Plan in consultation with DFO and discussed through NIRB and NWB processes. The plan would be approved by DFO as a condition of the *Fisheries Authorization* required for the development of the Madrid-Boston Project.

As no Madrid-Boston residual effects are anticipated, there are no potential residual effects that could act cumulatively with other project potential effects. Therefore no cumulative effects or transboundary effects are expected on the VEC marine fish community.

10.9 REFERENCES

1985a. *Arctic Waters Pollution Prevention Act* RS, 1985, c A-12.

1985b. *Canada Water Act*, RSC 1985. C. C-11.

1985c. *Fisheries Act*, RSC, 1985, c F-14.

1992. *Transportation of Dangerous Goods Act* 1992, c 34.

2001. *Canada Shipping Act*, SC 2001, c 26.

2002a. *Canada Species at Risk Act*, SC 2002. C. 29.

2002b. *Nunavut Waters and Nunavut Surface Rights Tribunal Act*, SC 2002, c 10.

2002c. *Species at Risk Act*, SC. C. 29.

2011. Ballast Water Control and Management Regulations SOR/2011-237.

2012. Vessel Pollution and Dangerous Chemicals Regulations, SOR/2012-69.

2016. Arctic Shipping Pollution Prevention Regulations, CRC, c 354.

Metal Mining Effluent Regulations, SOR/2002-222.

Abbott, R., J. Reyff, and G. Marty. 2005. Final report: Monitoring the effects of conventional pile driving on three species of fish. *Manson Construction Company, Richmond, CA*:

Arai, T. and A. Goto. 2005. Flexible life histories of ninespine sticklebacks, genus *Pungitius*. *Environmental Biology of Fishes*, 74: 43–50.

Baffinland Iron Ore Corporation. 2012. *Marry River Project Final Environmental Impact Statement*.

Banci, V. and R. Spicker, (Compilers, Editors & GIS). 2016. *Inuit Traditional Knowledge for TMAC Resources Inc. Proposed Hope Bay Project, Naonaiyaotit Traditional Knowledge Project (NTKP)*. Prepared for TMAC Resources Inc. Kitikmeot Inuit Association: Kugluktuk, NU.

Briski, E., L. E. Allinger, M. Balcer, A. Cangelosi, L. Fanberg, T. P. Markee, N. Mays, C. N. Polkinghorne, K. R. Prihoda, E. D. Reavie, D. H. Regan, D. M. Reid, H. J. Saillard, T. Schwerdt, H. Schaefer, M. TenEyck, C. J. Wiley, and S. A. Bailey. 2013. Multidimensional Approach to Invasive Species Prevention. *Environmental Science & Technology*, 47 (3): 1216-21.

Brown, A. C. and A. McLachlan. 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation*, 29: 62-77.

Brubacher Development Strategies. 2004. *An Overview of Nunavut Fisheries: Background Paper*. Ottawa, ON.

Canada Gazette. 2006. *Regulations Amending the Metal Mining Effluent Regulations Amendments, P.C. 2006-1071*. Vol. 140, No. 21. Ottawa, ON.

Canada Gazette. 2012. *Regulations Amending the Metal Mining Effluent Regulations Amendments, P.C. 2012-215*. Vol. 146, No. 6. Ottawa, ON.

Canada, T. 2017. Ballast Water Control and Management Regulations.

Casper, B. M., M. B. Halvorsen, F. Matthews, T. J. Carlson, and A. N. Popper. 2013. Recovery of barotrauma injuries resulting from exposure to pile driving sound in two sizes of hybrid striped bass. *PloS one*, 8 (9): e73844.

Casper, B. M., A. N. Popper, F. Matthews, T. J. Carlson, and M. B. Halvorsen. 2012. Recovery of Barotrauma Injuries in Chinook Salmon, Oncorhynchus tshawytscha from Exposure to Pile Driving Sound. *PLOS ONE*, 7 (6): e39593.

CCFAM. 2004. *A Canadian Action Plan to Address the Threat of Aquatic Invasive Species*. Canadian Council of Fisheries and Aquaculture Ministers, Aquatic Invasive Species Task Group: Ottawa, ON.

CCME. 2000. *Canada-Wide Standards for Mercury Emissions*. Canadian Council of Ministers of the Environment: Quebec City, QC.

CCME. 2001. *Canada-Wide Standards for Dioxins and Furans*. Winnipeg, MB.

Coad, B. W. and J. D. Reist. 2004. *Annotated List of the Arctic Marine Fishes of Canada*. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2674.

Cohen, D. M., T. Inada, T. Iwamoto, and N. Scialabba. 1990. Macrouridae., Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers, and other gadiform fishes known to date. *FAO species catalogue*, 10: 90-317.

Copeman, L. A., B. J. Laurel, K. M. Boswell, A. L. Sremba, K. Klinck, R. A. Heintz, J. J. Vollenweider, T. E. Helser, and M. L. Spenser. 2016. Ontogenetic and spatial variability in trophic biomarkers of juvenile saffron cod *(Eleginus gracilis*) from the Beaufort, Chukchi and Bering Seas. *Polar Biology*, 39: 1109 – 26.

COSEWIC. 2002. *COSEWIC assessment and update status report on the Bering Wolffish Anarhichas orientalis in Canada*. Committee on the Status of Endangered Wildlife in Canada: Ottawa.

Craig, P. C., W. B. Griffiths, L. Haldorson, and H. McElderry. 1984. Distributional patterns of fishes in an Alaskan Arctic Lagoon. *Polar Biology*, 4 (1): 9-18.

DFO. 1986. *The Department of Fisheries and Oceans: Policy for the Management of Fish Habitat*. Department of Fisheries and Oceans: Ottawa, ON.

DFO. 1990. *Fish habitat enhancement: a manual for freshwater, estuarine, and marine habitats*. Department of Fisheries and Oceans Canada DFO.

DFO. 2004. *Cambridge Bay Arctic Char*. DFO Canadian Science Advisory Section Stock Status Report 2004/010.

DFO. 2008. *Beaufort Sea Large Ocean Management Area: Ecosystem Overview and Assessment Report*. Fisheries and Aquatic Sciences 2780. Fisheries and Oceans Canada, Central and Arctic Region: Winnipeg, MB.

DFO. 2013a. *An Applicant's Guide to Submitting an Application for Authorization under Paragraph 35(2)(b) of the Fisheries Act*. http://www.dfo-mpo.gc.ca/pnw-ppe/reviews-revues/Applicant_Guide-Guide_autorisation-eng.pdf.

DFO. 2013b. *Fisheries Productivity Policy: A Proponent's Guide to Offsetting*. Ottawa, ON: Ecosystem Programs Policy, Fisheries and Oceans Canada.

DFO. 2013c. *Fisheries Protection Policy Statement*. Fisheries and Oceans Canada: Ottawa, ON.

DFO. 2014a. *Cambridge Bay Arctic Char Commercial Fishery (Summary Version)*. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/arctic-char-omble-chev/arctic-char-omble-chev-eng.htm (accessed October 2015).

DFO. 2014b. *Pathways of Effects*. http://www.dfo-mpo.gc.ca/pnw-ppe/pathways-sequences/index-eng.html.

DFO. 2014c. *Request for Project Review*. http://www.dfo-mpo.gc.ca/pnw-ppe/reviews-revues/index-eng.html.

DFO. 2016a. *Fisheries Protection Program*. http://www.dfo-mpo.gc.ca/pnw-ppe/fpp-ppp/index-eng.html.

DFO. 2016b. *Measures to Avoid Causing Harm to Fish and Fish Habitat*. http://www.dfo-mpo.gc.ca/pnw-ppe/measures-mesures/measures-mesures-eng.html (accessed December 1, 2016).

Ennis, G. P. 1970. Reproduction and associated behaviour in the shorthorn sculpin, Myoxocephalus scorpius in Newfoundland waters. *Journal of the Fisheries Research Board of Canada*, 27: 2037-45.

Environment Canada. 1992. *Biological test method: fertilization assay with echinoids (sea Urchins and sand dollars). Ottawa, ON*. Environmental Technology Centre. Report EPS 1/RM/27, December 1992, Amended in November 1997.

Environment Canada. 2002. *Arctic Environmental Sensitivity Atlas*. Environmental Protection Division, Environment Canada (accessed 11-Aug-2007).

ERM. 2015. *Doris North Project: 2014 Aquatic Effects Monitoring Program*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd. : Yellowknife, NT.

ERM. 2016. *Doris North Project: 2015 Aquatic Effects Monitoring Program Report*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd.: Yellowknife, NT.

ERM. 2017a. *Doris Project: 2016 Aquatic Effects Monitoring Program Report*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd.: Yellowknife, NT.

ERM. 2017b. *Doris Project: 2016 Roberts Bay Marine Baseline Report*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd.: Vancouver, BC.

ERM. 2017c. *Hope Bay Project: 2017 Marine Fish and Fish Habitat Baseline Report*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd.: Yellowknife, NT.

ERM Rescan. 2014. *Doris North Project: 2013 Aquatic Effects Monitoring Program Report*. Prepared for TMAC Resources Inc. by ERM Rescan: Yellowknife, NT.

Farwell, M. K., J. M. Green, and V. A. Pepper. 1976. Distribution and known life history ofStichaeus punctatus in the Northwest Atlantic. *Copeia*: 598-602.

Faulkner, S. G., W. M. Tonn, M. Welz, and D. R. Schmitt. 2006. Effects of explosives on incubating lake trout eggs in the Canadian Arctic. *North American Journal of Fisheries Management*, 26: 833-42.

Faulkner, S. G., M. Welz, W. M. Tonn, and D. R. Schmitt. 2007. Effects of simulated blasting on mortality of rainbow trout eggs. *Transactions of the American Fisheries Society*, 137 (1): 1-12.

Fechhelm, R. G., L. R. Martin, B. J. Gallaway, W. J. Wilson, and W. B. Griffiths. 1999. Prudhoe Bay causeways and the summer coastal movements of Arctic cisco and least cisco. *Arctic*, 52 (2): 139-51.

Freeman, M. 1976. *Inuit land use and occupancy project*. Prepared for Indian Affairs Branch of the Government of Canada by Milton Freeman Research Ltd.

Froese, R. and D. Pauly. 2017. *FishBase*.

Gallaway, B. J., W. B. Griffiths, P. C. Craig, W. J. Gazey, and J. W. Helmericks. 1983. An assessment of the Colville River Delta stock of Arctic cisco - migrants from Canada? *University of Alaska Biological Papers*, 21: 4-23.

GN. 2011. *Environmental Guideline for Ambient Air Quality*. Government of Nunavut, Environmental Protection Service.

Golder. 2005. *Doris North Project - Aquatic Studies 2004*. Miramar Hope Bay Ltd. by Golder Associates Ltd.: North Vancouver, BC.

Golder. 2006. *Doris North Project - Aquatic Studies 2005*. Miramar Hope Bay Ltd. by Golder Associates Ltd.: North Vancouver, BC.

Golder. 2007a. *Doris North Project - Aquatic Studies 2006*. Miramar Hope Bay Ltd. by Golder Associates Ltd.: North Vancouver, BC.

Golder. 2007b. *Doris North Project "No Net Loss" Plan*. Miramar Hope Bay Ltd. by Golder Associates Ltd.: Edmonton, Alberta.

Golder. 2008a. *2008 Roberts Bay Fisheries Authorization Monitoring Report*. No. 08-1373-0026-8000. Report prepared for Hope Bay Mining Ltd., North Vancouver: Edmonton, AB.

Golder. 2008b. *Doris North Project - Aquatic Studies 2007*. Miramar Hope Bay Ltd. by Golder Associates Ltd.: North Vancouver, BC.

Golder Associates Ltd. 2008. *Boston and Madrid Project Areas: 2006-2007 Aquatic Studies*. Prepared for Hope Bay Mining Ltd. by Golder Associates Ltd.: Edmonton, AB.

Government of Nunavut. 2016. *Nunavut Sport Fishing Guide*. -http://gov.nu.ca/sites/default/files/sport_fishing_guide_2016-17.pdf (accessed December 2016).

Hawkins, A. D. and A. D. F. Johnstone. 1978. The hearing of the Atlantic salmon, *Salmo salar*. *Journal of Fish Biology*, 13: 655-74.

Hildebrand, J. A. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series, 395: 5-20. *Marine Ecology Progress Series*, 395: 5-20.

Hobson, K. A. and H. E. Welch. 1992. Determination of trophic relationships within a high Arctic marine food web using $\delta^{13}C$ and $\delta^{15}N$ analysis. *Marine Ecology Progress Series*, 84: 9-18.

Houghton, J. P., J. E. Starkes, J. P. Stutes, M. A. Harvey, J. A. Reyff, and D. E. Erikson. 2010. Acoustic monitoring of in situ exposures of juvenile coho salmon to pile driving noise at the Port of Anchorage Marine Terminal redevelopment project, Knik Arm, Alaska. *Alaska Marine Science Symposium Book of Abstracts*: 83.

Houston, J. and D. E. McAllister. 1990. Status of the Bering Wolffish, *Anarhichas orientalis,* in Canada. *Canadian Field Naturalist*, 104 (1): 20-23.

Hulme, P. E. 2009. Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology*, 46 (1): 10-18.

Johnson, L. 1980. The Arctic charr, Salvelinus alpinus. In *Charrs, Salmonid Fishes of the Genus Salvelinus*. Ed. E. K. Balon. 87 pp. The Hague, Netherlands: W. Junk.

Keller, R. P., J. M. Drake, M. B. Drew, and D. M. Lodge. 2011. Linking environmental conditions and ship movements to estimate invasive species transport across the global shipping network. *Diversity & Distributions*, 17 (1): 93-102.

Kenyon, T. N., F. Ladich, and H. Y. Yan. 1998. A comparative study of hearing ability in fishes: the auditory brainstem response approach *Journal of Comparative Physiology*, 182 (3): 307-18.

Knudsen, F. R., P. S. Enger, and O. Sand. 1992. Awareness reactions and avoidance responses to sound in juvenile Atlantic salmon, Salmo salar L. *Journal of Fish Biology*, 40 (4): 523-34.

Knudsen, F. R., P. S. Enger, and O. Sand. 1994. Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, Salmo salar. *Journal of Fish Biology*, 45 (2): 227-33.

Kolden, K. D. and C. Aimone-Martin. 2013. *Blasting effects on salmonids*. June 2013. Prepared for the Alaska Department of Fish and Game – Division of Habitat Under Agency Contract IHP-13-051 by Alaskan Seismic & Environmental LLC.

Koops, M. A., M. Koen-Alonso, K. E. Smokorowski, and J. C. Rice. 2013. *A Science-Based Interpretation and Framework for Considering the Contribution of the Relevant Fish to the Ongoing Productivity of Commercial, Recreational or Aboriginal Fisheries*. DFO. Can. Sci. Advis. Sec. Res. Doc. 2012/141. Fisheries and Oceans Canada: Ottawa, ON.

Laughlin, J. 2007. *Effects of Pile Driving on Fish and Wildlife*. Presentation to the National Academy of Sciences Washington State Dept. Tranportation. Seattle, WA.

Laurel, B. J., C. H. Ryer, B. Knoth, and A. W. Stoner. 2009. Temporal and ontogenetics shifts in habitat use of juvenile Pacific cod (*Gadus microcephalus*). *Experimental Marine Biology and Ecology*, 277: 28-35.

McKenna, M. F., D. Ross, S. M. Wiggins, and J. A. Hildebrand. 2012. Underwater radiated noise from modern commercial ships. *Journal of Acoustical Society of America*, 131 92-103.

McMeans, B. C., N. Rooney, M. T. Arts, and A. T. Fisk. 2013. Food web structure of a coastal Arctic marine ecosystem and implications for stability. *Marine Ecology Progress Series*, 482: 17-28.

Mikhail, M. Y. and H. E. Welch. 1989. Biology of Greenland cod, Gadus ogac, at Saqvaqjuac, northwest coast of Hudson Bay. *Environ Biol Fishes*, 26: 49-62.

Moore, J.-S., L. N. Harris, S. T. Harris, L. Bernatchez, R. F. Tallman, and A. T. Fisk. 2016. Preference for nearshore and estuarine habitats in anadromous Arctic char (*Salvelinus alpinus*) from the Canadian high Arctic (Victoria Island, Nunavut) revealed by acoustic telemetry. *Canadian Journal of Fisheries and Aquatic Sciences*, 73: 1434-45.

Moore, J.-S., L.N. Harris, S.T. Harris, L. Bernatchez, R.F. Tallman and A.T. Fisk. 2016. Preference for nearshore and estuarine habitats in anadromous Arctic char (*Salvelinus alpinus*) from the Canadian high Arctic (Victoria Island, Nunavut) revealed by acoustic telemetry. *Canadian Journal of Fisheries and Aquatic Sciences*, 73: 1434-45.

Morin, B., C. Hudon, and F. Whoriskey. 1991. Seasonal distribution, abundance, and life-history traits of Greenland cod, Gadus ogac, at Wemindji, eastern James Bay. *Canadian Journal of Zoology*, 69: 3061-70.

Nedwell, J. R., A. W. H. Turnpenny, J. M. Lovell, and B. Edwards. 2006. An investigation into the effects of underwater piling noise on salmonids. *The Journal of the Acoustical Society of America*, 120 (5): 2550-54.

NIRB. 2012a. *Guidelines for the Preparation of an Environmental Impact Statement for Hope Bay Mining Ltd.'s Phase 2 Hope Bay Belt Project* (NIRB File No. 12MN001). Nunavut Impact Review Board: Cambridge Bay, NU.

NIRB. 2012b. *Public Scoping Meetings Summary Report for the NIRB's Review of Hope Bay Mining's Ltd.'s "Phase 2 Hope Bay Belt Project* NIRB File No.: 12MN001. Nunavut Impact Review Board: Cambridge Bay, NU.

NRC. 2003. Ocean Noise and Marine Mammals. In Vol. of Washington, D.C.: National Academic Press.

Nunavut Planning Commission. 2016. *Draft Nunavut Land Use Plan*. Nunavut Planning Commission: Iqaluit, NU.

Ochman, S. and J. Dodson. 1982. Composition and structure of the larval and juvenile fish community of the Eastmain River and estuary, James Bay. *Naturaliste Canadien,* 109: 803-13.

Popper. 2003. Effects of Anthropogenic Sounds on Fishes. *Fisheries,* 28 (10): 24-31.

Popper, A. D. Hawkins, R. R. Fay, D. A. Mann, S. Bartol, T. J. Carlson, S. Coombs, W. T. Ellison, R. L. Gentry, and M. B. Halvorsen. 2014. *Sound exposure guidelines for fishes and sea turtles*. Springer: New York.

Rahel, F. J., B. Bierwagen, and Y. Taniguchi. 2008. Managing Aquatic Species of Conservation Concern in the Face of Climate Change and Invasive Species. *Conservation Biology,* 22 (3): 551-61.

Randall, R. G., M. J. Bradford, K. D. Clarke, and J. C. Rice. 2013. *A Science-Based Interpretation of Ongoing Productivity of Commercial, Recreational or Aboriginal Fisheries*. DFO. Can. Sci. Advis. Sec. Res. Doc. 2012/112. Fisheries and Oceans Canada: Ottawa, ON.

Reist, J. D. and K. T. J. Chang-Kue. 1997. *The life history and habitat usage of broad whitefish in the lower Mackenzie River basin*. R. F. R. Tallaman, J. D., Ed. The proceedings of the broad whitefish workshop: the biology, traditional knowledge and scientific management of broad whitefish (Coregonus nasus (Pallus)) in the lower Mackenzie River. Canadian Technical Report of Fisheries and Aquatic Sciences.

Rescan. 1993. *Boston Property N.W.T.: Environmental Data Report*. Prepared for BHP Minerals Canada Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 1998. *Hope Bay Belt Project: 1997 Environmental Data Report*. Prepared for BHP World Minerals by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 1999. *Hope Bay Belt Project: 1998 Environmental Data Report*. Prepared for BHP Diamonds Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2001. *2000 Supplemental Environmental Baseline Data Report, Hope Bay Belt Project*. Prepared for Hope Bay Joint Venture by Rescan Environmental Services Ltd.: Yellowknife, NT.

Rescan. 2009a. *Baseline Review and Data Gap Report*. Prepared for the Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Yellowknife, NT.

Rescan. 2009b. *Doris North Gold Mine Project: 2009 Roberts Bay Jetty Fisheries Authorization Monitoring Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2010a. *2009 Marine Baseline Report, Hope Bay Belt Project*. Prepared for Hope Bay Mining Limited. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2010b. *2009 Marine Fish and Fish Habitat Baseline Report, Hope Bay Belt Project*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2010c. *Doris North Gold Mine Project: 2010 Roberts Bay Jetty Fisheries Authorization Monitoring Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011a. *2010 Marine Fish and Fish Habitat Baseline Report, Hope Bay Belt Project*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011b. *Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011c. *Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program (AEMP) Marine Expansion Baseline Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011d. *Hope Bay Belt Project: 2010 Ecosystems and Vegetation Baseline Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011e. *Hope Bay Belt Project: 2010 Marine Baseline Report*. Prepared for Hope Bay Mining Limited. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011f. *Hope Bay Belt Project: 2010 Regional Marine Baseline Report*. Prepared for Hope Bay Mining Limited. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012a. *Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012b. *Doris North Gold Mine Project: 2011 Roberts Bay Physical Oceanography Baseline Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013a. *Back River Project: Draft Environmental Impact Statement Supporting Volume 7: Marine Environment* Prepared for Sabina Gold and Silver Corp. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013b. *Doris North Gold Mine Project: 2012 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

RL&L Environmental Services Ltd./Golder Associates Ltd. 2003a. *Doris North Project Aquatic Studies 2002*. Prepared for Miramar Hope Bay Ltd. by RL&L Environmental Services Ltd./Golder Associates Ltd.: Edmonton, AB.

RL&L Environmental Services Ltd./Golder Associates Ltd. 2003b. *Doris North Project: Aquatic Studies 2003*. Prepared for Miramar Hope Bay Ltd. by RL&L Environmental Services Ltd./Golder Associates Ltd.: Edmonton, AB.

RL&L/Golder. 2003. *Doris North Project - Aquatic Studies 2003*. Miramar Hope Bay Ltd.: North Vancouver, BC.

Rowe, S. and J. A. Hutchings. 2003. Spawning behaviour and acoustic communication in Atlantic cod. *Journal of Fish Biology*, 63: 240.

Rowe, S. and J. A. Hutchings. 2006. Sound production by Atlantic cod during spawning. *Transactions of the American Fisheries Society*, 135: 529-38.

Ruggerone, G. T., S. E. Goodman, and R. Miner. 2008. Behavioral response and survival of juvenile coho salmon to pile driving sounds. *Prepared by Natural Resources Consultants, Inc, Seattle, WA, and Robert Miner Dynamic Testing, Inc Prepared for Port of Seattle, Seattle, WA*: 42.

Rysgaard, S. and T. G. Nielsen. 2006. Carbon cycling in a high-arctic marine ecosystem - Young Sound, NE Greenland. *Progress in Oceanography*, 71: 426-45.

Scott, W. B. and E. J. Crossman. 1973. *Freshwater Fishes of Canada*. Bulletin of the Fisheries Research Board of Canada 184. Ottawa, ON: Fisheries Research Board of Canada.

Seebens, H., M. T. Gastner, and B. Blasius. 2013. The risk of marine bioinvasion caused by global shipping. *Ecology Letters*, 16 (6): 782-90.

Slabbekoorn, H., N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, and A. N. Popper. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. *Trends in Ecology & Evolution*, 25 (7): 419-27.

Spares, A. D., M.J.W. Stokesbury, R.K. O'Dor and T.A. Dick. 2012. Temperature, salinity and prey availability shape the marine migration of Arctic char, *Salvelinus alpinus*, in a macrotidal estuary. *Marine Biology* 159: 1633 - 46.

Spares, A. D., M. J. W. Stokesbury, R. K. O'Dor, and T. A. Dick. 2012. Temperature, salinity and prey availability shape the marine migration of Arctic char, *Salvelinus alpinus*, in a macrotidal estuary. *Marine Biology* 159: 1633 - 46.

Stewart, D. B., R. A. Ratynski, L. M. J. Bernier, and D. J. Ramsey. 1993. *A Fishery Development Strategy for the Canadian Beaufort Sea-Amundsen Gulf Area* 1910.

Tang, Y. 2013. Applying the precautionary principle in the risk management of invasive species via ballast water. *Applied Mechanics and Materials* 295-298: 2167-71.

Vagle, S. 2003. On the Impact of Underwater Pile-Driving Noise on Marine Life. *Institute of Ocean Sciences (Fisheries & Oceans Canada, DFO/Pacific, Canada)*: 41.

Walters, V. 1955. Fishes of western Arctic America and eastern Arctic Siberia. *Bulletin of the American Museum of Natural History*, 106: 225–368.

Wolotira Jr., R. J. 1985. *Saffron cod, Eleginus gracilis, in western Alaska, the resource and its potential*. NOAA Technical Memorandum NFMW-F/NWC-79. US Department of Commerce.

Wright, D. G. 1982. *A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories*. Canadian Technical Report of Fisheries and Aquatic Sciences 1052.

Wright, D. G. and G. E. Hopky. 1998. *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters*. 2107.