Appendix V5-10G

Conceptual Marine Fisheries Offsetting Approach for Madrid-Boston

TMAC RESOURCES

Memorandum

Date: December 14, 2017

To: John Roberts and Oliver Curran; TMAC Resources Inc.

From: Véronique Thériault and Geneviève Morinville; ERM Consultants Canada Ltd.

Subject: **Conceptual Marine Fisheries Offsetting Approach for Madrid-Boston**

The purpose of this memorandum is to identify a procedural framework and potential offset options for completing a Marine Fisheries Offsetting Plan, should its development be deemed necessary by Fisheries and Oceans Canada (DFO) for the Madrid-Boston Project.

1. INTRODUCTION

All potential loss/alteration of fish habitat and fisheries productivity in the marine environment will result from the construction of a proposed cargo dock on the western shoreline of Roberts Bay. Anticipated fish habitat losses/alterations may include subtidal habitat underneath the footprint of the cargo dock and the rock embankment (i.e., rock armouring, riprap, placed around its perimeter), as well as intertidal habitat underneath the footprint of the causeway.

Based on the preliminary cargo dock design (Package P5-10; SRK 2017), the total habitat loss is estimated to reach approximately 9,675 m^2 (0.97 ha), which includes the causeway and the riprap armoring (approximately half of which fall below the high water mark (HWM). The riprap rock armouring is expected to provide self-offsetting fish habitat through the addition of large three-dimensional (3-D) rock substrates, increasing local habitat heterogeneity relative to the largely fines-dominated sub-littoral habitat characteristic of Roberts Bay.

Other related infrastructure (e.g., laydown areas) constructed near the Roberts Bay shoreline will be built above the HWM, and will be at least 31 m from the shoreline, and is therefore not considered to contribute to the overall loss or alteration of fish habitat. Best management practices will be followed to ensure there will be no impact on fish habitat adjacent to those facilities from construction activities such as the use of mobile machinery and overland flows of surface drainage and sediment.

As a consequence of the cargo dock being constructed below the HWM, fish habitat and fish populations may be adversely impacted in Roberts Bay resulting in the potential for *serious harm* to fisheries productivity. According to the *Fisheries Protection Policy Statement* (DFO 2013b), if a project is likely to cause *serious harm to fish* after the application of avoidance and mitigation measures, then the proponent as part of a *Fisheries Authorization* application must develop a plan to undertake offsetting measures to counterbalance the unavoidable residual *serious harm* to fish. These offsetting measures, also known as offsets, are implemented with the goal of maintaining or improving the productivity of commercial, recreational or Aboriginal (CRA) fisheries such that benefits from offsetting measures balance project impacts (DFO 2013a).

2. REGULATORY AND POLICY FRAMEWORK

The *Fisheries Protection Policy Statement* (DFO 2013b) supports the 2012 updates made to the *Fisheries Act (1985)*. The *Fisheries Protection Policy Statement* replaces Fisheries and Oceans Canada's (DFO) No Net Loss guiding principle for fish habitat within the *Policy for the Management of Fish Habitat* (DFO 1991). The changes to the *Fisheries Act* include a prohibition against causing *serious harm to fish* that are part of, or support, a CRA fishery (section 35 of the *Fisheries Act*); provisions for flow and passage (sections 20 and 21 of the *Fisheries Act*); and a framework for regulatory decision-making (sections 6 and 6.1 of the *Fisheries Act*). These provisions guide the Minister's decision-making process in order to provide for sustainable and productive fisheries.

The amendments center on the prohibition against *serious harm to fish* and apply to fish and fish habitat that are part of or support CRA fisheries. Proponents are responsible for avoiding and mitigating *serious harm to fish* that form part of or support CRA fisheries. When proponents are unable to completely avoid or mitigate *serious harm to fish*, their projects will normally require authorization under subsection 35(2) of the *Fisheries Act* in order for the project to proceed without contravening the Act.

DFO interprets *serious harm to fish* as:

- The death of fish.
- A permanent alteration to fish habitat of a spatial scale, duration, or intensity that limits or diminishes the ability of fish to use such habitats as spawning grounds, nursery, rearing, food supply areas, migration corridors, or any other area in order to carry out one or more of their life processes. The destruction of fish habitat of a spatial scale, duration, or intensity that results in fish no longer being able to rely on such habitats for use as spawning grounds, nursery, rearing, food supply areas, migration corridor, or any other area in order to carry out one or more of their life processes.

After efforts have been made to avoid and mitigate impacts, any residual *serious harm to fish* is required to be offset, as deemed necessary by DFO. An offset measure is one that counterbalances unavoidable *serious harm to fish* resulting from a project with the goal of maintaining or improving the productivity of the CRA fishery. Where possible, offset measures should support available fisheries' management objectives and local restoration priorities.

3. FISHERIES OFFSETTING APPROACH

A procedural approach is proposed for developing a Marine Fisheries Offsetting Plan (the Offsetting Plan) for Madrid-Boston, if deemed necessary by DFO. This approach is proposed to satisfy the *Fisheries Protection Policy Statement* (DFO 2013b) and the federal *Fisheries Act*, and to allow for flexibility in finding a solution to offsetting Project-related effects.

The proposed approach for the development of an Offsetting Plan is identified below and will be discussed in the following four sections:

- Section 3.1 – Assessment of the amount (in m^2) of fish habitat to be lost/altered to meet TMAC's commitment associated with DEIS technical comments (for further information, refer to Annex V1-8).
- Section 3.2 – Assessment of the fish populations and their abundance in Roberts Bay that may use the lost/altered habitat.
- Section 3.3 – Development of a Habitat Suitability Index (HSI) for representative marine fish and subsequent use of a Habitat Evaluation Procedure (HEP) to assign quantity as well as quality to lost habitat.
- Section 3.4 – Identification of offsetting options in line with DFO guidance on offsetting and TMAC's understanding that the cargo dock design can be considered to be self-offsetting as discussed during November 2017 meeting with DFO and KIA (for further detail, refer to Appendix V5-6AB).

The proposed approach was developed based upon the guidance provided in the *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013a). The approach was also based upon the review of existing fisheries and fish habitat information for Madrid-Boston. Based upon the newest design and precedence for incorporating self-offsetting substrates into proposed infrastructure design as done for other similar arctic-based projects (e.g., Mary River Project, Nunavut), it is TMAC's position that this approach will be feasible and suitable for the Madrid-Boston Project.

The *Fisheries Protection Policy Statement* (DFO 2013b), the *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013a), and the federal *Fisheries Act* refer to fish productivity as the metric for offsetting. Since fish productivity, defined as the number of kilograms of fish tissue estimated per m^2 of habitat or per hectare of habitat per year, is difficult to measure in practice, fish habitat continues to be used as a practical surrogate for productivity when determining offsetting requirements (Bradford et al. 2016).

3.1 Assessment of Fish Habitat

The first step in developing an offsetting plan for the Roberts Bay cargo dock is to quantify the amount and quality of habitat that will be lost to development after avoidance and mitigation measures have been applied. Avoidance and mitigation measures are planned during the Madrid-Boston Project activities such that potential serious harm through permanent habitat loss/alteration will be minimized. These measures include mitigation by design, best management practices (including DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat*; (DFO 2016a), monitoring, and adaptive management (Volume 5, Chapter 10.5.3).

Habitat data form the basis of quantifying the potential serious harm to fisheries required to be offset, validate the habitat-based approach to offsetting, and support future monitoring (a federal requirement of a Fisheries Offsetting Plan, FOP). A FOP typically includes a habitat budget that quantifies the loss of habitat in terms of area (m^2), habitat equivalent units (HEU) if possible (to be explained below in Section 3.3 of this memo) and the expected gain (in m^2 and/or HEU) in the proposed offsetting habitat.

A comprehensive data set exists for describing fish habitat conditions at Roberts Bay, supporting an assessment of potential habitat losses (and relative value) associated with the construction of the cargo dock. Baseline surveys of marine physical habitat 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 2003a; Golder 2005; Rescan 2010a, 2011; ERM 2017). In 2000, aerial surveys of the shoreline and the intertidal zone 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. In 2009, the upper subtidal was also visually surveyed. In 2010, the subtidal at three locations along the western side of the bay was surveyed using hydroacoustic techniques ground-proofed by video cameras. Finally in 2017, the subtidal was surveyed at the preferred proposed cargo dock location using hydroacoustic techniques ground-proofed by Eckman grabs.

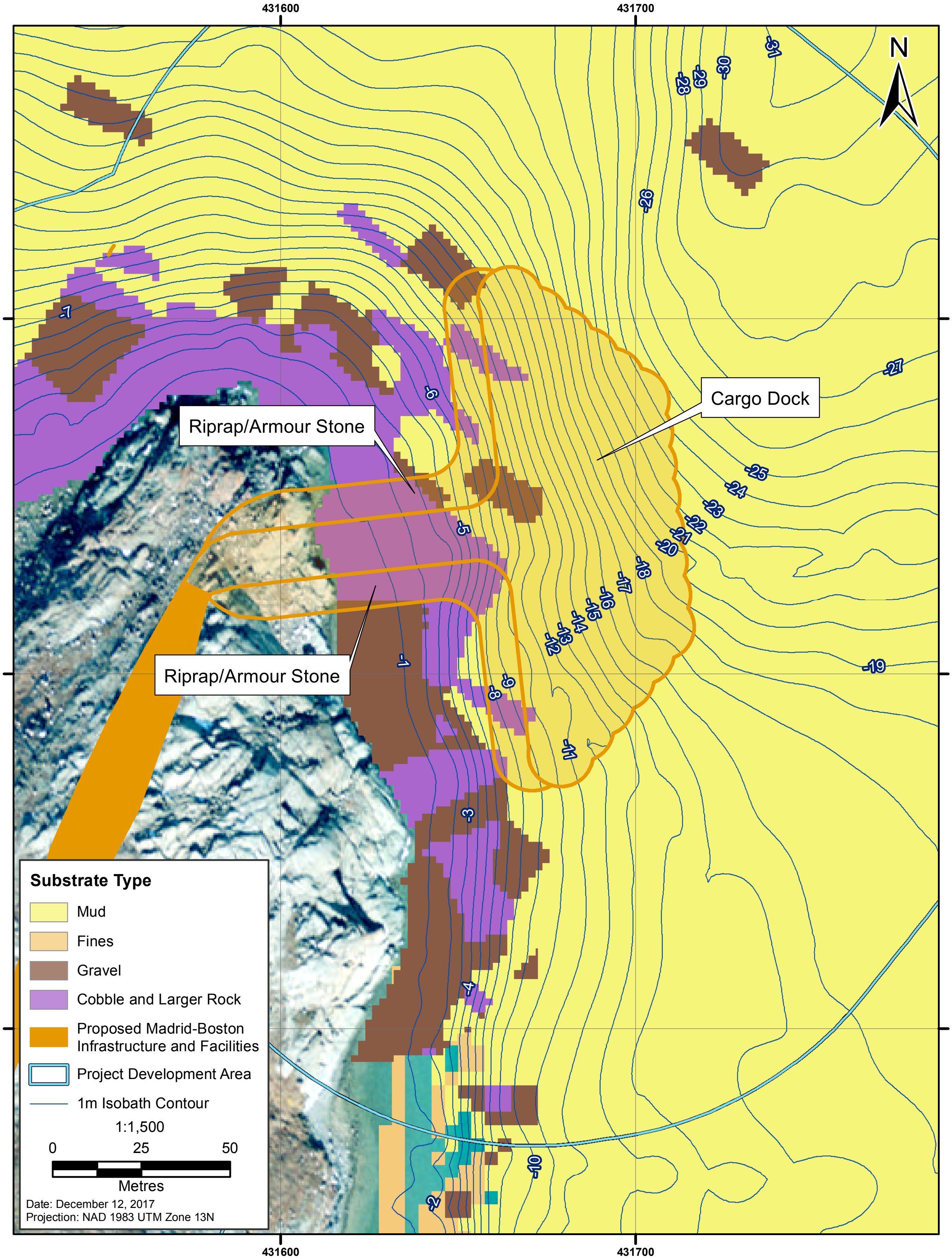
Taken together, these data form the basis for characterizing typical habitat in the subtidal and intertidal of Roberts Bay. Shoreline substrates consist mainly of bedrock in the northwest and south portions of Roberts Bay; however, gravel and sand are present in bays and at stream outlets. The eastern portion of the bay is dominated by boulder, gravel, and sand substrates. None of the areas surveyed over the years were vegetated. Generally, habitat quality was rated fair to good in the northern areas of Roberts Bay and good to excellent in the southern region on the basis of cover provided for fish and invertebrates and on potential for supporting benthic invertebrates.

At the specific cargo dock location, the detailed intertidal and subtidal substrate and bathymetric surveys of 2017 showed that water depths at the furthest offshore footprint limit reach 19 to 25 m. Nearshore areas are dominated by bedrock or gravel substrates, and subtidal substrates consist primarily of mud (i.e., fines) with small patches of cobble and/or boulder (Figure 3.1-1). No unique features such as stream outlets or uncommon substrates were observed at the site of the cargo dock. In summary, the habitat can be rated from low to high productive value for fish (refer to Section 3.3.3 for further information).

A total of 9,675 m^2 (0.97 ha) of habitat will be lost under the footprint, rock embankment, and causeway of the cargo dock based on a three-dimensional footprint that considers area and slope. However, a large portion of the lost/altered area (i.e., 77%) is comprised of non-limiting silt substrates, found throughout Roberts Bay. Furthermore, this area represents less than 0.07% of the total area of Roberts Bay (14.3 km^2). The addition of larger complex substrates through the addition of riprap/armour stone as incorporated within the cargo dock design can be thus considered a form of self-offsetting.

A more detailed description of the lost/altered habitat and its value in terms of habitat quality as well as habitat area is further discussed in Section 3.3.

Figure 3.1-1
Cargo Dock Footprint in Roberts Bay



3.2 Assessment of Fish Populations and their Abundance

An associated step in developing an offsetting plan is to map and identify the fish species that use habitat in Roberts Bay and assess their relative or absolute numbers, considering information on migration patterns and seasonal habitat use. This assists in determining the value of habitat.

From 2002 to 2017, the marine fish community in Roberts Bay was surveyed using gillnets, fyke nets, angling, minnow traps, beach seines, crab traps, and long-lines. Most of this sampling was conducted along the southern and western shores of the bay, with the 2017 sampling located at the site of anticipated works. 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 off-loading facility similar to the currently proposed cargo dock. The most intensive sampling was conducted in 2009 and 2010 (Rescan 2010b, 2011). In 2017, sampling focused on the fish and macrobenthos community at the proposed site of the anticipated cargo dock (ERM 2017).

A total of 25 fish species have been captured in Roberts Bay. Of the 9,690 fish captured, 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 (1.89%), and Greenland Cod (1.47%). The remaining 15 species each made up between 0.01% (unidentified Snailfish) and 0.60% (Lake Trout).

The two most common species, Saffron Cod and Capelin, had the most variable catches. This may be the result of the variable gear types used among years and/or may suggest that both species are migratory and may use habitat in Roberts Bay for only part of the year. 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 individuals in each of those seven years. It is reasonable to assume that some 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.

It is reasonable to assume that most if not all 25 species have migrated through habitat near the cargo dock at some point in their life histories, but it may be difficult to determine the value that the potentially lost/altered habitat has relative to other surrounding areas in Roberts Bay exhibiting similar habitat.

3.3 Habitat Evaluation Procedure

In order to better determine the value in the potential habitat lost/altered at the cargo dock site, a preliminary habitat evaluation procedure (HEP) was initiated and developed. This model is preliminary and serves as an illustration of the approach intended to be used for the calculation of potential habitat losses associated with final cargo dock designs. TMAC will work with DFO through the FPP to determine the most suitable approach to estimating potential fisheries productivity losses as final designs are developed.

HEP is a generalized procedure for assessing habitat suitability that was developed by the US Fish and Wildlife Service more than 35 years ago (USFWS 1980). It has been widely used throughout North America and is a standard tool for developing habitat budgets for offsetting planning in Canada (e.g., (Diavik 1998; Billiton 2002; RL&L/Golder 2003b; Rescan 2005, 2007; Rescan Environmental Services Ltd. 2012). The general concepts developed through its application in freshwater systems, though less frequently in marine environments (e.g. (SEM 2011, 2017), is applied to Roberts Bay.

The HEP approach has two advantages. First, it provides an objective method for characterizing the quality or importance of affected habitats to fish species and marine resources. Second, it allows standardization of habitat quality ratings relative to other habitats that have different physical characteristics (e.g., subtidal versus intertidal, complex versus simply substrate structure). This facilitates comparisons among habitat types and ultimately allows affected habitats to be evaluated as a single group for the offsetting calculation.

The HEP produces habitat equivalent units (HEU, m^2) that are indices of both habitat quantity and quality. HEU are calculated by multiplying the lost habitat area (measured in m^2) by a habitat suitability index (HSI) with values ranging from 0.0 (no value – habitat not utilized) to 1.0 (excellent value). HEP relies upon HSI models for such attributes as water depth, slope, surface salinity, substrate type (Lauria et al. 2011; Lauria, Gristina, et al. 2015; Lauria, Power, et al. 2015). Habitat suitability models, although developed using a number of assumptions, have been developed by the U.S. Fish and Wildlife Service (USFWS 1981) for estuarine fish and invertebrate species based on specific variables. Published models and suitability indices are based on hypotheses that consider the best data available and assume a relationship with carrying capacity of a system, providing an estimate of habitat quality. Relevant HSI models for CRA representative fish species were reviewed where available, developed and/or refined for applicability to Roberts Bay.

3.3.1 Species Selection

3.3.1.1 Representative Species

Species chosen to be part of the offsetting assessment were those retained as a Valued Ecosystem Component (VEC) in the EIS (Section 10.3 of Volume 5). 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*, as well as available baseline information.

Arctic Char was selected to represent the anadromous life histories of salmonids, although at least six other anadromous salmonids are present in Roberts Bay: Lake Trout, Cisco, Least Cisco, Lake Whitefish, Rainbow Smelt, and Inconnu. Arctic Char was selected because of its importance as a food source to the Inuit, and thus a CRA fishery species, and because of its relatively high encounter rates 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. Information from baseline studies in the Madrid-Boston area indicates that the distribution of Arctic Char (anadromous life history) overlaps with the proposed cargo dock activities over the life of the Project.

Saffron Cod was chosen because it is an Inuit food fish, and thus a CRA fishery species, and because it is an exclusively marine species. It is also the single most common fish species captured in Roberts Bay during the baseline surveys. Information from baseline studies in the Madrid-Boston area indicates that the distribution of Saffron Cod may overlap with the proposed cargo dock activities over the life of the Project.

3.3.1.2 Literature review

A literature review of the life histories and the marine requirements of Arctic Char and Saffron Cod were completed to support the development of an appropriate HSI. The relevant information is summarized below.

Arctic Char

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. Only the anadromous form is expected to interact with the proposed Madrid-Boston marine infrastructure.

In the central Canadian Arctic, spawning of Arctic Char takes place in lakes, because most rivers freeze completely in winter (Johnson 1980). Spawning occurs in those lakes in the fall, usually September or October, over gravel or cobble shoals and shorelines of lakes. 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. Hatching occurs in early April and fry emerge in July (Scott and Crossman 1973).

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), though Arctic Char as young as 3 years of age have been captured in Roberts Bay (ERM 2017); Appendix V5-10F). Smolts out-migrate to the sea in spring at ice breakup and early summer and feed throughout summer (Spares et al. 2012; 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 (McCart 1980). They are pelagic and feed in nearshore areas along the coast for the duration of the summer (Klemetsen et al. 2003). More abundant and larger food resources in marine waters allow anadromous Arctic Char to grow faster and larger than the freshwater, resident form. Anadromous populations are primarily piscivorous. In the autumn, all Arctic Char return to freshwater to escape freezing in the sea to spawn and/or overwinter in lakes (Johnson 1980). The time they spent in the marine environment is variable depending on geographical location and environment conditions, but is usually within five to eight weeks (Johnson 1980; Dempson and Kristofferson 1987). In Roberts Bay, the marine environment is likely used for a period of three months, extending from mid-June to mid-September.

Nearshore coastal habitats are the preferred feeding grounds for Arctic Char. Reported depth preferences range from 1.2 m (Norway;(Rikardsen et al. 2007) to 5-10 m in the western Arctic (DFO 2011). Reported maximum diving depths range from 16 m (Rikardsen et al. 2007) and 52.8 m (Spares et al. 2012)

No specific substrate preference was mentioned in the literature, likely the result of Arctic Char's general pelagic nature in the marine environment. Similarly, no affinity to marine vegetation has been reported. However, Arctic Char may dive to depths to access benthic organisms in both inter-tidal and sub-tidal habitats (Spares et al. 2012).

The Arctic Char captured in Roberts Bay from 2002 to 2017 were likely a mixture of out-migrants from rearing and overwintering lakes connected to Roberts Bay 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. However, tagging studies with the objective of identifying lake source, as done around Cambridge Bay and Baffin Island, have never been completed within the Roberts Bay drainage basin (Moore 2012; Moore et al. 2016; Moore et al. 2017).

<u>Saffron Cod</u>

Saffron Cod 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 (Cohen et al. 1990; Mueter et al. 2016). It is a true marine species and 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, mostly in trap nets on the south-east side of Roberts Bay. This may suggest that Saffron Cod use habitat in Roberts Bay on a seasonal basis during their onshore-offshore migrations.

In contrast to Polar Cod and Arctic cod, Saffron Cod primarily inhabit brackish to marine waters at relatively shallow depths up to 75 m but may also be found at depths up to 200 m, although inhabiting these depths are unlikely (Wolotira Jr. 1985; Laurel et al. 2009; Copeman et al. 2016). They are often found in areas of tidal influence at the mouths of coastal rivers (Wolotira Jr. 1985), supporting their presence in Roberts Bay, though the location of the proposed cargo dock is approximately 1 km from the nearest river mouth. They feed on fish and small crustaceans, mainly preyed upon along the sea floor, though pelagic preys are also consumed.

Saffron Cod begin to mature during their third year of life and attain a maximum age of 15 years. They most probably do not exceed 10 years of age. Maximum reported length is 550 mm and maximum reported weight is 1.3 kg, but most specimens caught in Roberts Bay were substantially smaller in size (mean = 167 – 200 mm), dominating the 2 to 4 year age classes.

Saffron Cod spawn in February and March in nearshore habitat (2-10 m) under the sea ice in strong tidal currents and highly saline waters. Spawning substrate is clean sand and gravel/ pebble. After spawning, adults return to silty bottoms where they feed. Eggs are demersal and incubate in the gravel for 2-3 months, depending on temperature, and hatch in April-June. Although the eggs can survive in a wide range of temperatures (<-3.8° to 8°C), they cannot tolerate brackish water and perish when salinity falls below 23.2 ppt (Pokrovskaya 1960 as cited in (Wolotira Jr. 1985). Larvae are planktonic for 2-3 months and descend to the bottom by mid-summer, at around 5-6 cm (Wolotira Jr. 1985).

Young of the year and juvenile use the coastal habitat as nursery. Age-0 (35 to 130 mm) and to some extent later age-classes Saffron Cod have been found to be closely associated with eelgrass and shallow (< 3 m depth) habitat (Laurel et al. 2007; Laurel et al. 2009). Habitat use by juveniles shift ontogenetically from shallow-water eelgrass and macroalgae to deeper coarse-grained sediments (e.g. gravel, cobble; (Laurel et al. 2009).

Juveniles eventually disperse along the coast in shallow nearshore habitat, adopting a benthopelagic existence. Juvenile are not considered migratory and stay in shallow water through the year, whereas adults exhibit fairly restricted seasonal movements related to feeding, spawning and water temperature: inshore during winter for purposes of spawning and offshore during summer for feeding (Wolotira Jr. 1985; Cohen et al. 1990).

3.3.2 Habitat Classification

Habitat at the proposed cargo dock location was categorized similarly to what has been done for the Mary River Project (SEM 2011) based on an approach developed for coastal waters in Newfoundland and Labrador (Kelly et al. 2009) as cited in SEM (2011). Two habitat attributes have been retained for the assessment: substrate and depth. As the substrate only applies to the ocean floor, this attribute only relates to fish species/life stages using the demersal, benthic and epibenthic zones. Surveys in 2017 revealed that the sub-littoral habitat at the proposed cargo dock location was composed of three different substrate types:

1. Mud and Fines;
2. Sand and Gravel; and
3. Cobble and Larger Rocks.

Depth was divided into five habitat zones, which roughly correspond to different associations with substrate type, and also to different habitats used by marine life:

1. Intertidal (0 - 0.5 m);
2. Upper Sub-Tidal (0.5 - 3 m);
3. Shallow Sub-Tidal (3 - 15 m);
4. Moderate Sub-Tidal (15 - 25 m); and
5. Deep Sub-Tidal (>25 m).

Other habitat attributes were considered in the development of the HEP. Some life stages of Saffron Cod are influenced by vegetation and tidal action. Those two attributes were included in the final HSI model by multiplying the HSI ranks by a specific factor (Section 3.3.3). Other attributes such as distance from shore, salinity and water temperature were not included per se, but are correlated with water depth to some extent (correlation coefficient between distance from shore and water depth calculated at the proposed cargo dock site is -0.94). Their inclusion would have caused redundancy in the calculations. Other attributes such as exposure or wave/current energy were not relevant to the species selected though were considered qualitatively when assigning HSIs.

3.3.3 *HSI Models*

Because habitat requirements can differ greatly over the life cycle of a fish, different life stages were considered when assigning his values. For the present assessment, four life stages were considered:

1. Spawning/Incubation
2. Larvae/Young-of-the-year (YOY)
3. Juvenile
4. Adult

Arctic Char is anadromous and only uses Roberts Bay for part of its life-cycle as described above. Thus, for Arctic Char, only the Juvenile and the Adult stage were taken into consideration for HSI calculations.

Saffron Cod is considered a true marine species, completing its entire life stage in the marine environment. All four stages were thus considered for HSI.

The habitat suitability of each depth category and substrate type was evaluated qualitatively based on the habitat requirements found in the literature, and using four qualifiers: N = not utilized, L = low, M = medium and, H = high. Tables 3.3-1 and 3.3-2 present the results of this analysis for both Arctic Char and Saffron Cod respectively.

Ranks assigned above (Tables 3.3-1 and 3.3-2) were converted to numerical values to quantify habitat requirement for each habitat type on a scale of 0 to 1, as follow: N = 0, L = 0.33, M = 0.67 and H =1 (DFO 2016b) (Tables 3.3-3 and 3.3-4). At this step, weighing factors were used to take into account the specific requirements/habitat use of Arctic Char and Saffron Cod in Roberts Bay. Juvenile and adult Arctic Char only uses Roberts Bay one quarter of the year (3 months, mid-June to mid-September), thus values were weighted by a factor of 0.25 (Table 3.3-3). Saffron Cod spawning and larvae rearing are preferably associated with vegetated areas, strong tidal action and highly saline waters. Those conditions are not typical of Roberts Bay (Volume 5, Chapter 7.2.4), thus both spawning and rearing/YOY life stages were weighted by a factor of 0.50, to account for possible spawning in the area (Table 3.3-4).

Values were subsequently averaged over each life stage, and for each species (Table 3.3-5).

For each depth-substrate combination, the values were further averaged to create an HSI matrix for each species (Table 3.3-6). To be conservative, the highest value was subsequently carried over in the HEU calculation.

From the results presented in Table 3.3-6, it is observed that habitat values were consistently rated higher for Saffron Cod than for Arctic Char for each depth-substrate combination. Saffron Cod is thus driving the result of the analysis.

Table 3.3-1. Habitat Suitability Index (HSI) Ranking for Arctic Char

Habitat Type	Life Stage			
	Juvenile		Adult	
	Rank	Rationale	Rank	Rationale
Substrate				
Mud and Fines	-	Pelagic - no direct interaction with bottom type[1]	-	Pelagic - no direct interaction with bottom type[1]
Sand and Gravel	-	Pelagic - no direct interaction with bottom type[1]	-	Pelagic - no direct interaction with bottom type[1]
Cobble and Larger Rocks	-	Pelagic - no direct interaction with bottom type[1]	-	Pelagic - no direct interaction with bottom type[1]
Depth				
Intertidal	N	Not utilized by juvenile, no record in the literature	N	Not utilized by adults, no record in the literature
Upper Subtidal 0-3 m	H	Highly used for migration and feeding corridor[2,3,4]	H	Highly used for migration and feeding corridor[2,3,4]
Shallow Subtidal 3-15 m	H	Highly used for migration and feeding corridor[2,3,4]	H	Highly used for migration and feeding corridor[2,3,4]
Moderate Subtidal 15-25 m	L	Less used, maximum dive around 16 m[4], suggested protected area <20 m[2]	L	Less used, maximum dive around 16 m[4], suggested protected area <20 m[2]
Deep Subtidal >25 m	N	No significant record, maximum dive around 16 m[4], suggested protected area <20 m[2]	N	No significant record, maximum dive around 16 m[4], suggested protected area <20 m[2]

Notes:
Spawning/Egg Incubation and Larvae/YOY life stages are not considered for Arctic Char as those 2 stages occur in freshwater.
Juveniles and adults use Roberts Bay for approximately a three-month period, from mid-June to mid-September.
Dashes indicate that pelagic species had no direct habitat substrate requirements, thus no value given.
N = Not Utilized, L = Low, M = Medium, H = High
[1] Klemetsen et al. 2003; [2] DFO 2011; [3] McCart 1980; [4] Rikardsen et al. 2007

Table 3.3-2. Habitat Suitability Index (HSI) Ranking for Saffron Cod

Habitat Type	Life Stage							
	Spawning/Egg Incubation		Larvae/YOY		Juvenile		Adult	
	Rank	Rationale	Rank	Rationale	Rank	Rationale	Rank	Rationale
Substrate								
Mud and Fines	N	Not utilized	M	YOY associated with shallow structured habitat <3 m, mainly composed of eelgrass[4,5]	M	Age 1 associated with shallow structured habitat < 3 m, mainly composed of eelgrass[4,5] ; Large catches in trap nets near muddy bottom in Roberts Bay[6]	H	Demersal, feed on silty bottom[2,8] ; Large catches in trap nets near muddy bottom in Roberts Bay[6]
Sand and Gravel	H	Spawn in nearshore habitat on clean sand and gravel[1,2,3]	M	YOY associated with shallow structured habitat < 3 m, mainly composed of eelgrass[4,5]. Ontogenetic switch to gravel documented for Atlantic and Pacific Cod[4]	M	Age 1 associated with shallow structured habitat < 3 m, mainly composed of eelgrass[4,5] ; Ontogenetic switch to gravel documented for Atlantic and Pacific Cod[4]	M	No specific mention of sand and gravel for adult; Catches in trap net in Roberts Bay associated to some extent with sand and gravel[6]
Cobble and Larger Rocks	N	Not utilized	L	No specific mention of coarser substrate for YOY	L	Age 1 associated with shallow structured habitat < 3 m, mainly composed of eelgrass[4,5]	L	No specific mention of cobble and larger rock for adults
Depth								
Intertidal	N	Not utilized	N	Not utilized	N	Not utilized	N	Not utilized
Upper Subtidal 0-3 m	H	Spawning on nearshore habitat[1,2,3]; Eggs demersal, adhesive, on sand and gravel at depth 2-10 m[2,3]	H	YOY are associated with shallow structured habitat < 3m, mainly composed of eelgrass[4,5]	H	Age 1+ highly associated with nearshore, shallow habitat[4,5,6]	H	Highly associated with nearshore, shallow habitat[4,5,6,8]
Shallow Subtidal 3-15 m	H	Spawning on nearshore habitat[1,2,3];Eggs demersal, adhesive, on sand and gravel at depth 2-10 m[2,3]	M	Potentially utilized by larvae during their planktonic stage[5,8]; No specific depth mentioned in literature search. YOY may uses the shallower portion of this range	M	Juvenile highly associated with nearshore, shallow habitat <5 m[4]	H	Primarily inhabit brackish to marine waters at relatively shallow depths up to 60 m[8]

(continued)

Table 3.3-2. Habitat Suitability Index (HSI) Ranking for Saffron Cod (completed)

Habitat Type	Life Stage							
	Spawning/Egg Incubation		Larvae/YOY		Juvenile		Adult	
	Rank	Rationale	Rank	Rationale	Rank	Rationale	Rank	Rationale
Moderate Subtidal 15-25 m	N	Not utilized	L	Potentially utilized by larvae during their planktonic stage; No specific depth mentioned in literature search. YOY usually found in shallower area[4,5]	L	Less than <20% of the juvenile population seen at 13 m and 18 m[5]	H	Primarily inhabit brackish to marine waters at relatively shallow depths up to 60 m[8]
Deep Subtidal >25 m	N	Not utilized	L	Potentially utilized by larvae during their planktonic stage; No specific depth mentioned in literature search; YOY usually found in shallower area[4,5]	L	Juvenile disperse along the coast <25 m[1]	M	Primarily inhabit brackish to marine waters at relatively shallow depths up to 60 m[8]

Notes:
YOY = Young of the year
Larvae are planktonic (ref 3, 8) thus no direct habitat substrate requirements. For substrate type, ranks given only for YOY
N = Not Utilized, L = Low, M = Medium, H = High
[1] *Cohen et al. 1990;* [2] *FAO 2017;* [3] *Arctic Ocean Diversity 2017;* [4] *Laurel et al. 2009;* [5] *Laurel et al. 2007;* [6] *Baseline studies cited in Section 10.2.6 of Volume 5;* [7] *Muter et al. 2016;* [8] *Wolotira Jr 1985*

Table 3.3-3. Habitat Suitability Index (HSI) Numerical Values for Arctic Char in Roberts Bay

	Life Stage	
	Juvenile	Adult
Habitat Type	Value	
Substrate		
Mud and Fines	-	-
Sand and Gravel	-	-
Cobble and Larger Rocks	-	-
Depth		
Intertidal	0.00	0.00
Upper Subtidal 0-3 m	0.25	0.25
Shallow Subtidal 3-15 m	0.25	0.25
Moderate Subtidal 15-25 m	0.08	0.08
Deep Subtidal >25 m	0.00	0.00

Notes:
Values derived from Table 3.3-2 where N = 0 (Not Utilized), L = 0.33 (Low), M = 0.67 (Medium), H = 1 (High)
Juvenile and Adult Arctic Char only uses Roberts Bay for a three-month period (mid-June to mid-September). Values were thus weighted by a factor of 0.25.

Table 3.3-4. Habitat Suitability Index (HSI) Numerical Values for Saffron Cod in Roberts Bay

	Life Stage			
	Spawning/ Egg Incubation	Larvae/YOY	Juvenile	Adult
Habitat Type	Value			
Substrate				
Mud and Fines	0.00	0.34	0.67	1.00
Sand and Gravel	0.50	0.34	0.67	0.67
Cobble and Larger Rocks	0.00	0.17	0.33	0.33
Depth				
Intertidal	0.00	0.00	0.00	0.00
Upper Subtidal 0-3 m	0.50	0.50	1.00	1.00
Shallow Subtidal 3-15 m	0.50	0.34	0.67	1.00
Moderate Subtidal 15-25 m	0.00	0.17	0.33	1.00
Deep Subtidal >25 m	0.00	0.17	0.33	0.67

Notes:
Values derived from Table 3.3-2 where N = 0 (Not Utilized), L = 0.33 (Low), M = 0.67 (Medium), H = 1 (High)
Spawning/Egg Incubation and Rearing/YOY life stages are unlikely in the proposed development area due to the lack of strong tidal and current action and vegetation. Values were thus weighted by a factor of 0.50.

Table 3.3-5. Habitat Suitability Index (HSI) Numerical Values Averaged over Life Stages for Arctic Char and Saffron Cod in Roberts Bay

	Species	
	Arctic Char	Saffron Cod
Habitat Type	Average Value	
Substrate		
Mud and Fines	-	0.5
Sand and Gravel	-	0.54
Cobble and Larger Rocks	-	0.21
Depth		
Intertidal	0.00	0
Upper Subtidal 0-3 m	0.25	0.75
Shallow Subtidal 3-15 m	0.25	0.63
Moderate Subtidal 15-25 m	0.08	0.37
Deep Subtidal >25 m	0.00	0.29

3.3.4 HEU Calculation

Habitat Equivalent Units (HEU) are calculated in m^2 and represent the surface area to be offset. HEU are calculated by multiplying the surface area lost by the construction of the proposed infrastructure (the cargo dock footprint) by the HSI values provided in the analysis above. The surface area to be lost by the cargo dock was calculated with GIS software (ArcGis 10.4) using bathymetric data and substrate type derived from field surveys completed in 2017 (Appendix V5-10F). The three-dimensional cargo dock footprint was considered for those calculations, as the slope and depth at which the riprap/armour stone will be constructed influence the total area lost (two-dimensional surface area along seabed) and created (three-dimensional surface area with vertical consideration). The area lost and HEU calculations are presented in Table 3.3-7. Total area to be lost is estimated at 9,675 m^2 based on current design. Fines and Mud represent 75% of that total (7,234 m^2) being lost, while Cobble and Larger Rocks represent 20% (1,952 m^2); Sand and Gravel represent the remaining 5% (489 m^2). Based on the preliminary HEP analysis, the area to be offset in HEU is 4,766 m^2, equivalent to 49% of the 9,675 m^2 to be lost by the cargo dock footprint, though 75 % consists of non-limiting fines/mud habitat. The objective would be to maximize the self-offsetting potential provided by riprap/armour stone additions to the extent possible, as presented to DFO in November 2017 (refer to Appendix V5-6AB for further information).

3.4 Identification of Offsetting Options

Identification of offsetting options is an iterative process requiring knowledge of local Inuit fisheries and community interest/priorities, fish distribution, fish population abundance, and habitat quality within the Madrid-Boston Project area. It requires a combination of stakeholder engagement/consultation including DFO and local Inuit groups, desktop analysis of available data, field-based assessment and sound professional judgement.

Table 3.3-6. Habitat Suitability Index (HSI) Numerical Values Averaged over Each Depth-Substrate Combination for Arctic Char and Saffron Cod in Roberts Bay

Depth	Substrate								
	Fines (Mud/Clay)			Sand and Gravel			Cobble and Larger Rocks		
	Arctic Char	Saffron Cod	Highest	Arctic Char	Saffron Cod	Highest	Arctic Char	Saffron Cod	Highest
Intertidal	0.00	0.25	0.25	0.00	0.27	0.27	0.00	0.10	0.10
Upper Subtidal 0-3 m	0.25	0.63	0.63	0.25	0.65	0.65	0.25	0.48	0.48
Shallow Subtidal 3-15 m	0.25	0.56	0.56	0.25	0.59	0.59	0.25	0.42	0.42
Moderate Subtidal 15-25 m	0.08	0.44	0.44	0.08	0.46	0.46	0.08	0.29	0.29
Deep Subtidal >25 m	0.00	0.40	0.40	0.00	0.42	0.42	0.00	0.25	0.25

Table 3.3-7. Area Lost/Altered by the Proposed Cargo Dock Infrastructure and Associated HEU

Depth	Substrate										
	Fines/Mud			Sand and Gravel			Cobble and Larger Rocks			Total	
	HSI Value	Area Lost (m^2)	HEU (m^2)	HSI Value	Area Lost (m^2)	HEU (m^2)	HSI Value	Area Lost (m^2)	HEU (m^2)	Area Lost (m^2)	HEU (m^2)
Intertidal	0.25	0	0	0.27	0	0	0.1	164	16	164	16
Upper Subtidal 0-3 m	0.63	0	0	0.65	2	1	0.48	804	386	806	387
Shallow Subtidal 3-15 m	0.56	3,992	2,235	0.59	487	287	0.42	984	413	5,463	2,936
Moderate Subtidal 15-25 m	0.44	3,242	1,427	0.46	0	0	0.29	0	0	3,242	1,427
Deep Subtidal >25 m	0.40	0	0	0.42	0	0	0.25	0	0	0	0
Total		**7,234**	**3,662**		**489**	**289**		**1,952**	**816**	**9,675**	**4,766**

Note:
HEU = Habitat Equivalent Unit

Specifically, the following may be undertaken to support the identification of most suitable fisheries offsetting options:

- Engagement with DFO and local Inuit such as the KIA and TMAC's Inuit Environmental Advisory Committee;
- Review of scientific literature on species-specific habitat limiting factors for valued fish species that are known to use habitat in Roberts Bay based upon peer-reviewed document and professional knowledge;
- Consideration of existing habitat conditions and identification of factors potentially limiting fish productivity within and outside of Roberts Bay. For example, identification of species and life history stages present, identification of known key habitats (e.g., spawning areas); and
- Identification of previous fisheries offsetting options implemented in Roberts Bay provided in background literature (e.g., environmental consultant reports for the Hope Bay Project area) or other projects in similar marine environments (e.g., Mary River Project) and evaluate their effectiveness. Identification of other relevant projects with similar anticipated impacts and approved Fisheries Authorizations to provide precedence to Madrid-Boston.
- Field reconnaissance of the locations selected for preliminary offsetting options to determine potential value. This also provides an opportunity to identify additional offsetting options. Through an iterative process of elimination and refinement, one or more technically feasible offsetting options can typically be identified.

4. PRELIMINARY OFFSETTING OPTIONS

In advance of the predicted effects on marine fish and fish habitat associated with the Madrid-Boston Project, a few options have been identified that could offset potential serious harm to fisheries, as defined by the Fisheries Act (1985). The following section presents two preliminary offsetting options in the vicinity of the Hope Bay Project (in-kind) which are consistent with DFO guidance to offsetting (DFO 2013a; Bradford et al. 2016), and then also discusses the potential for off-site offsetting (out-of-kind), which may be an option should DFO be open to combining potential offsetting needs associated with the construction of the cargo dock in Roberts Bay with those identified in the freshwater environment (refer to Volume 5, Chapter 6 and Appendices V5-6AA and V5-6AB).

4.1 Project Vicinity Options

The following two options are currently the leading candidates for offsetting habitat loss due to the construction of the cargo dock:

- incorporation of self-offsetting habitat through the consideration of additional riprap/ stone armouring around the perimeter at the proposed cargo dock (most likely scenario based on calculations provided in Section 3.3 and TMAC's preferred approach); and

- installation of artificial rock shoals (artificial rock reefs) in subtidal habitat should addition of rock armouring (i.e., riprap) as part of cargo design be considered insufficient to fully offset anticipated losses in fisheries productivity (unlikely scenario based on calculations provided in Section 3.3).

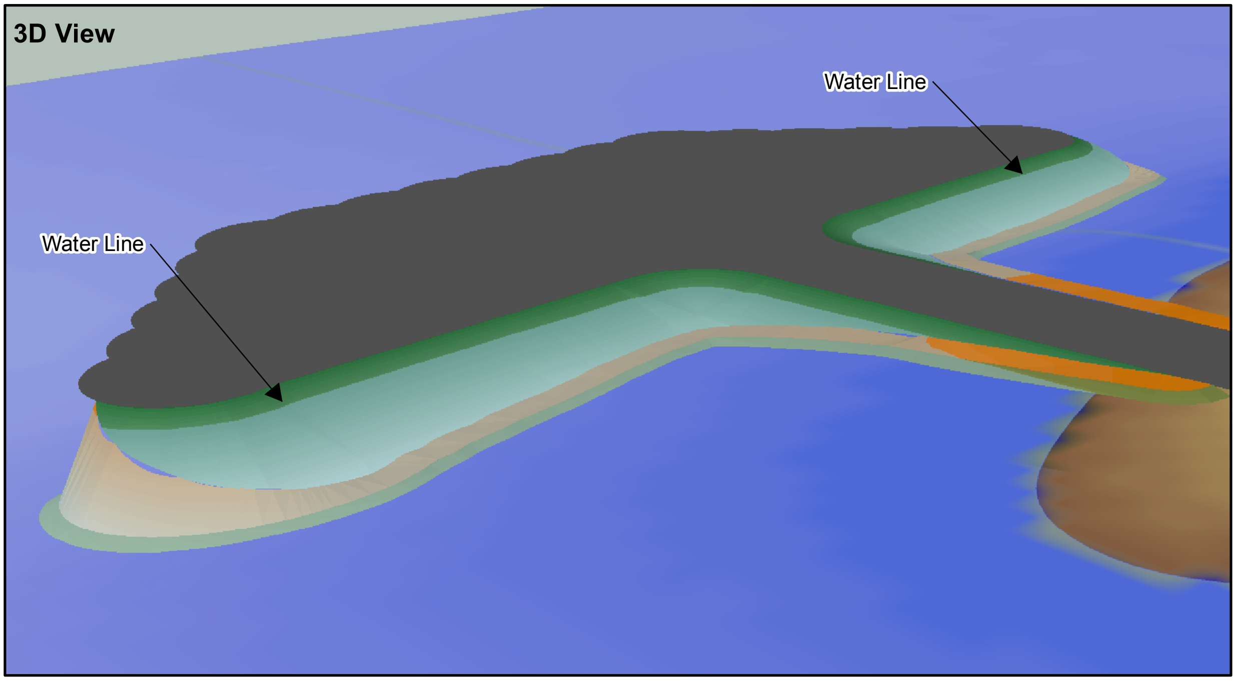
One of the main objectives during the final design stages of the cargo dock will be to minimize the in-water footprint and to incorporate self-offsetting to the extent possible, i.e., through the addition of a rock embankment (i.e., riprap/stone armouring around perimeter of the dock) designed to produce a balance or net increase in fish habitat through selection of rock particle size and slope.

Preliminary calculations based on the preferred cargo dock design (SRK 2017) yielded a submerged riprap/armour stone area of 2,663 m^2 (Figure 4.1-1). The actual surface area available for organism colonization and fish use that would be created by the addition of larger substrate will likely be higher if we consider the three-dimensional nature of the larger rock in comparison to the flat area provided by finer substrate (Bergey and Getty 2006). This most recent design assumes a 1:1.5 (33%) slope for the riprap armour stone, extending to a 4 m flat at the bottom of the ocean. Based on the HEP calculations presented above, the self-offsetting area created by the riprap/armour stone corresponds to 1,183 m^2 in HEU and represents 25% of the 4,767 m^2 HEU to be lost. However, this 1,183 m^2 of riprap/armour stone area, composed mainly of Cobble and Larger Rock, is 1.5 times the 816 m^2 HEU lost calculated for Cobble and Larger Rock (Tables 4.1-1 and 4.2-2). The remaining habitat to be offset is thus mainly composed of non-limiting Fines and Mud (3,662 m^2 HEU, Table 4.1-2). The need to offset these substrates is considered unnecessary given their dominance (i.e., they are non-limiting) throughout Roberts Bay.

The vast majority (i.e., 77%) of the habitat found at the proposed cargo dock location consists primarily of non-complex and non-limiting substrates (i.e., fines and mud) will not be replaced, though which overall provides low structural complexity and structure for colonization by algae, vegetation, benthic invertebrates and fish. The introduction of high quality (and therefore high value) and structurally complex (i.e., large three-dimensional substrates) structures, particularly in areas where such habitat heterogeneity is limited and/or already present should thus balance fisheries productivity losses, even though the amount of riprap/armour stone proposed does not fully replace the footprint that is dominated by fines and mud.

Substrate introductions as proposed have shown to be useful in sediment bottom areas where no other hard substrate exits (Sherman, Gilliam, and Speiler 2002). A greater surface area provides enhanced biomass potential because a greater area may support higher densities of algae and invertebrates. One main benefit of planned, man-made reefs (comparable to riprap/armour stone additions) is thus to attract local fish to a known location of suboptimal habitat. Artificial reefs can create an ‘oasis-like’ environment that provides shelter from predation, increased feeding efficiency and additional habitat (Smiley 2006).

Figure 4.1-1
Riprap Area/Armour Stone Available for Fish Habitat at the Cargo Dock in Roberts Bay



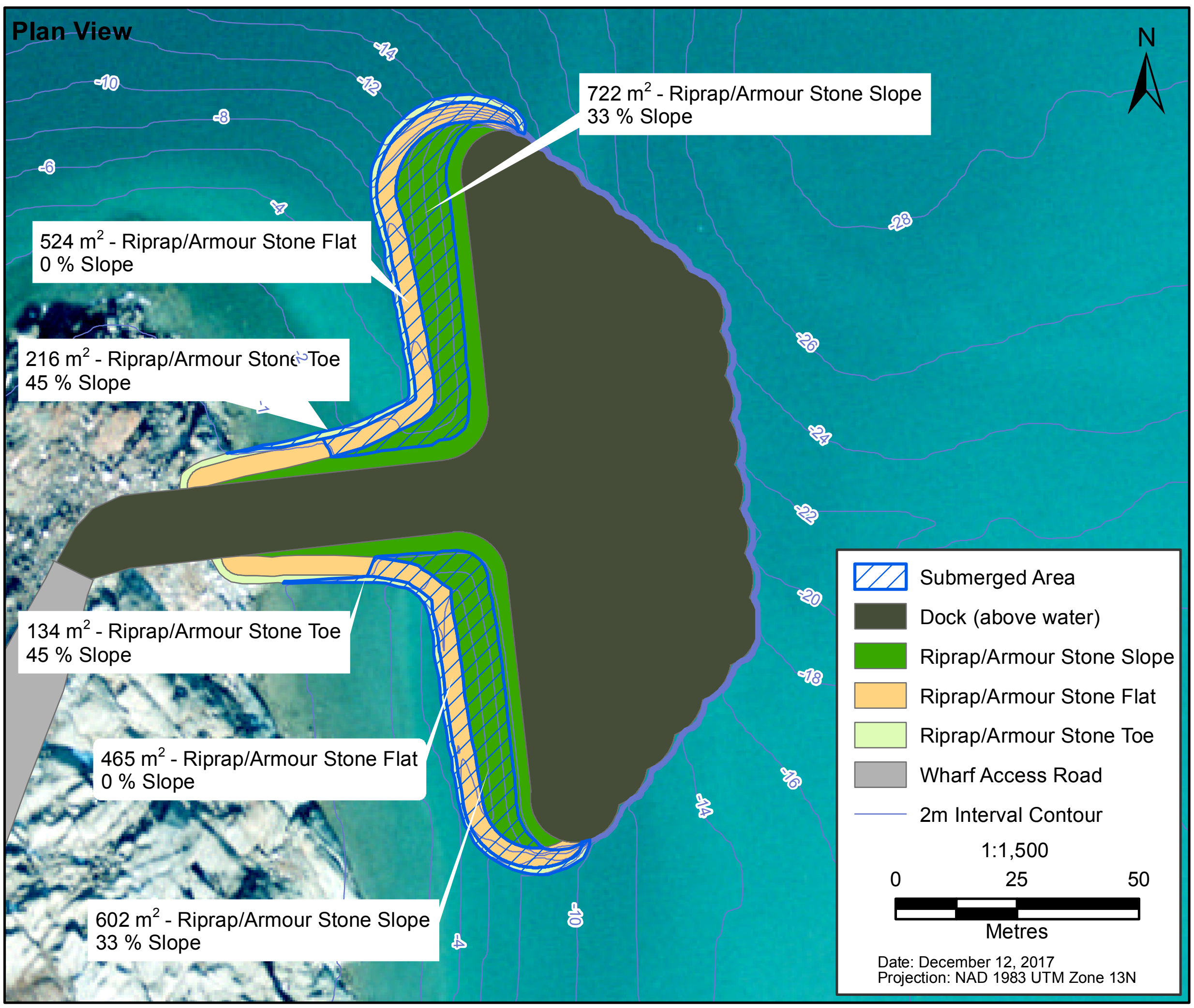


Table 4.1-1. Area Lost/Altered and Created and Associated HEU at the Proposed Cargo Dock Location

	Substrate																		
	Fines/Mud					Sand and Gravel					Cobble and Larger Rocks					Total			
Depth	HSI Value	Area Lost (m^2)	Area Created (m^2)	HEU Lost (m^2)	HEU Created (m^2)	HSI Value	Area Lost (m^2)	Area Created (m^2)	HEU Lost (m^2)	HEU Created (m^2)	HSI Value	Area Lost (m^2)	Area Created (m^2)	HEU Lost (m^2)	HEU Created (m^2)	Area Lost (m^2)	Area Created (m^2)	HEU Lost (m^2)	HEU Created (m^2)
Intertidal	0.25	0	0	0	0	0.27	0	0	0	0	0.1	164	0	16	0	164	0	16	0
Upper Subtidal 0-3 m	0.63	0	0	0	0	0.65	2	0	1	0	0.48	804	1,125	386	540	806	1,125	387	540
Shallow Subtidal 3-15 m	0.56	3,992	0	2,235	0	0.59	487	0	287	0	0.42	984	1,513	413	635	5,463	1,513	2,936	635
Moderate Subtidal 15-25 m	0.44	3,242	0	1,427	0	0.46	0	0	0	0	0.29	0	25	0	7	3,242	25	1,427	7
Deep Subtidal >25 m	0.40	0	0	0	0	0.42	0	0	0	0	0.25	0	0	0	0	0	0	0	0
Total		**7,234**	**0**	**3,662**	**0**		**489**	**0**	**289**	**0**		**1,952**	**2,663**	**816**	**1,183**	**9,675**	**2,663**	**4,766**	**1,183**

Note:
HEU = Habitat Equivalent Unit

Table 4.1-2. Budget of Area Lost/Altered and Created Based on HEU at the Proposed Cargo Dock Location

	HEU Lost (m^2)	Relative Loss (%)	HEU Created (m^2)	Relative Contribution (%)
Fines/Mud	3,662	77	0	0
Sand and Gravel	289	6	0	0
Cobble and Larger Rock	816	17	1,183	100
Total	**4,766**	**100**	**1,183**	**100**

Note:
HEU = Habitat Equivalent Unit

Recent precedence for suitable offsetting measures associated with marine docks/harbours at Milne Inlet through the Mary River Project (SEM 2011, 2017); Fisheries Authorization 14-HCAA-00525) and Pangnirtung (Fisheries Authorization HCAA-CA7-0033) include the addition of riprap skirting along the perimeter of dock/harbour to partially or fully self-offset habitat losses. It is thus TMAC's understanding that a similar approach will be deemed suitable by DFO for offsetting in Roberts Bay. TMAC will continue to engage with DFO to determine the most appropriate approach to offsetting.

Should TMAC's preferred self-offsetting approach not provide enough offset habitat because of other design/engineering limitations and/or considerations, then supplemental habitat additions may be considered through the creation of artificial rock structures (i.e., rock shoals or reefs) installed in Roberts Bay, as done previously for the Roberts Bay Jetty-related compensation works. These would be expected to function similarly to the riprap/ armour stone incorporated into the cargo dock design.

The creation of three-dimensional subtidal habitat as an offsetting measure can take many forms including artificial reefs, habitat skirting, articulating ballast mats and/or placement of other three-dimensional rock structure configurations. Regardless of the method for creating three-dimensional structures, the created habitat provides hard and rough surfaces where algae and invertebrates colonize and provide resources for fish populations, thereby increasing overall ecosystem productivity (Hueckel and Stayton 1982; Hueckel and Buckley 1987; Clynick, Chapman, and Underwood 2007) .

Generally artificial reefs are intended to create an ecosystem with a large diversity of organisms. Habitat complexity is directly related in an artificial reef to the diversity of species using the structure (Protocol/UNEP 2009). Structurally diverse and large reefs (e.g., structures with holes, overhangs, and shadows) provide more opportunity for animals and algae to colonize and thus may lead to a higher local biological diversity (Menge and Sutherland 1976). Cavities provided refuge from predators for a variety of species and life stages.

Particularly useful is the creation of ledges, crevices, and similar shelter sites within these artificial structures (Ebata et al. 2011). Gadids (cod) and Cottids (sculpins) are particularly attracted to complex hard substrates (Tupper and Boutilier 1995). In Roberts Bay, this would include four of the most common marine fishes: Saffron Cod (marine fish community VEC), Greenland Cod, Fourhorn Sculpin, and Shorthorn Sculpin. This process of colonization has been documented on the Roberts Bay jetty and compensation shoals (Rescan 2009, 2010c).

There is thus the precedent for the successful creation of artificial rock reefs to enhance overall fisheries productivity due to habitat loss/alteration in Roberts Bay. As part of the existing Doris Project infrastructure, a jetty was constructed in early July 2007 at the south end of Roberts Bay for barge loading and off-loading. The jetty was constructed perpendicular to shore and measured 95 m in length, varying in width from 5.3 to 35 m (Rescan 2009). At the time, construction of the jetty resulted in the alteration and/or loss of 0.176 ha of fish habitat. To compensate, four underwater rock reefs (or shoals), each measuring 31.25 m long by 12 m wide and spaced approximately 19 m apart, were constructed west of the jetty in 2008. The four shoals were equivalent to 0.150 ha of fish habitat. In combination with the below high-water side-slope area of the jetty, which provided habitat for fish and invertebrates, the net gain of fish habitat was 0.138 ha.

The rock reef monitoring program included four main components: (1) periphyton biomass (as chlorophyll *a*), cell density and taxonomic composition; (2) benthic invertebrate density and taxonomic composition; (3) fish community composition and catch-per-unit-effort; and (4) macroalgae community composition and percent cover (Rescan 2009, 2010c). Results of the first year of monitoring (Rescan 2010c) indicated that periphyton and benthic invertebrate communities had established themselves on the compensation shoals. Periphyton assemblages were numerically dominated by blue-green algae and diatoms. The benthic invertebrate community composition on both the jetty and compensation shoals was dominated by amphipods, followed by polychaetes.

Visual snorkel surveys indicated that various genera of algae, invertebrates and fish were inhabiting and/or using the compensation structures. Macroalgae were not visually plentiful on the shoals or the jetty in Year 1. This was expected given that the compensation structures in Roberts Bay were new habitat and the natural succession of the algal communities was expected to take several years. By Year-2 monitoring results confirmed that periphyton and benthic invertebrate communities had established themselves on the compensation shoals in Roberts Bay (Rescan 2010c). Periphyton assemblages were again numerically dominated by cyanobacteria and diatoms. The filamentous cyanobacterium, *Anabaena cylindrica*, was the most abundant species on Roberts Bay shoals. The benthic invertebrate community composition was dominated by amphipods. *Lagunogammarus setosus* and *Ischyrocerus anguipes* were the most abundant species on the compensation shoals. Euphausiids (krill, of the order Euphausiacea) were the most abundant invertebrate observed throughout the visual surveys conducted in Roberts Bay. This shrimp-like crustacean plays a key role in marine food webs as it is known to be a main prey item to many marine vertebrates, including anadromous Arctic Char (marine fish community VEC).

Overall, Saffron Cod and Fourhorn Sculpin were the dominant species by number during the first summer sampling of post-construction shoal habitat and side-slopes of the jetty in Roberts Bay (Rescan 2010c). Over the two years of sampling, various species of adult, juvenile and young-of-the-year fish were observed during snorkel surveys in Roberts Bay (Rescan 2009, 2010c). Young-of-the-year fish (probably gadids) were the most common fish observed on the shoals. Their abundance shows that the jetty and shoal structures provide shelter and/or a food source for fish, thereby supporting their use for enhancing fisheries productivity.

In summary, the addition of rock reefs as compensation structures in Roberts Bay showed enhancement success as defined in the *Fisheries Authorization*. Successful establishment of primary and secondary producers on the rock shoals as well as the side-slopes of the jetty of Roberts Bay was observed. Furthermore, the monitoring program confirmed the use of the shoals and riprap slopes of the jetty by fish prey and fish of multiple age classes.

Overall, the successful results of the Roberts Bay Jetty Monitoring Program demonstrate the feasibility for considering the addition of structurally complex habitats to increase overall fisheries productivity, further supporting the use of riprap/armour stone within the cargo dock's design to self-offset habitat losses/alterations associated with the cargo dock.

4.2 Off-Site Offsetting Options

Should the addition of riprap/armour stone not be considered sufficient to balance habitat loss, off-site offsetting may be considered a suitable alternative where enhancements would be constructed in or around a community in Nunavut, rather than within the Hope Bay Project area. This may be an option should DFO be open to combining potential offsetting needs associated with the construction of the cargo dock in Roberts Bay with those identified in the freshwater environment (refer to Volume 5, Chapter 6 and Appendices V5-6AA and V5-6AB). TMAC is keen to investigating off-site options for offsetting potential Project-related effects related to the freshwater environment. TMAC suggested to DFO and the KIA that a project based in Cambridge Bay contributing to the local Arctic Char commercial (DFO 2014) and/or subsistence fishery on Freshwater Creek would be most preferred (see Appendix V6-5AB for further information).Benefits to off-site offsetting options include:

- potential to rehabilitate human-impacted sites such as over-fished populations;
- increased engagement with local community directly through employment and indirectly through increased activity in the community;
- transfer of knowledge by training community members in enhancement and monitoring methods; and
- potential to engage local educational institutions such as the Canadian High Arctic Research Station.

In addition to community consultations to identify options, biological, hydrological, topographical, and engineering investigations will be required to determine the technical feasibility of preliminary off-site offsetting options. Once select sites are agreed upon by DFO and relevant stakeholders, the following biological data will eventually need to be collected to support the development of the Offsetting Plan:

- habitat assessment and mapping;
- fish passage assessments at potential restrictions; and
- fisheries community, demography, and abundance sampling (e.g., gillnetting, electrofishing, fish stranding enumeration) at potential sites.

Hydrological, topographical, and engineering data requirements are site-specific and will be determined during a field investigation.

5. SUMMARY

A final fisheries Offsetting Plan, if deemed necessary by DFO, will be developed to identify and compensate for potential serious harm in accordance with the *Fisheries Act*, the *Fisheries Protection Policy Statement* and *the Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting*. TMAC will work with DFO's FPP and local Inuit groups TMAC to develop such a marine fisheries offsetting plan. Preliminary analysis with the latest cargo dock design yielded a habitat loss of 4,766 m^2 in HEU. The vast majority of this area lost (77% or 3,662 m^2) is composed of non-limiting substrates found abundantly throughout Roberts Bay (Fines and Mud) and the need to offset these substrates is considered unnecessary. The remaining area loss of 1,104 m^2 in HEU is mostly composed of Cobble and Larger Rocks and to a lesser extent of Sand and Gravel. These losses in limiting substrates will be offset by the addition of 1,183 m^2 in HEU of riprap/armour stone through incorporation into the cargo dock design. Final quantification of habitat and productivity losses, identification of offset requirements, and a quantification of habitat and productivity gains relative to losses will be further pursued in consultation with DFO and relevant local Inuit groups. This process will involve the alignment of offsetting goals with local and regional sustainability objectives throughout the FEIS and subsequent permitting requirements, and any required application for a *Fisheries Authorization*.

REFERENCES

1985. *Fisheries Act*, RS. C. F-14. s. 1.

Bergey, E. A. and G. M. Getty. 2006. A review of methods for measuring the surface area of stream substrates. *Hydrobiologia*, 556: 7-46.

Billiton, B. 2002. *EKATI Diamond Mine: Sable, Pigeon and Beartooth no net loss plan*. Prepared for BHP Billiton Diamonds Inc. by Dillon Consulting Ltd.

Bradford, M. J., K. E. Smokorowski, K. D. Clarke, B. E. Keatley, and M. C. Wong. 2016. *Equivalency metrics for the determination of offset requirements for the Fisheries Protection Program* Doc. 2016/046. Department of Fisheries and Oceans.

Clynick, B. G., M. G. Chapman, and A. J. Underwood. 2007. Effects of epibiota on assemblages of fish associated with urban structures. *Marine Ecology Progress Series*, 332: 201-10.

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.

Dempson, J. B. and A. H. Kristofferson. 1987. Spatial and temporal aspects of the ocean migration of anadromous Arctic char. In *Common strategies of anadromous and catadromous fishes*. Eds. M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson, and J. E. Cooper. 340–57. American Fisheries Society Symposium.

DFO. 1991. *Department of Fisheries and Oceans: Policy for the Management of Fish Habitat*. Department of Fisheries and Oceans: Ottawa, ON.

DFO. 2011. *Identification of conservation objectives and boundary delineation for the Darnley Bay Area of Interest (AOI)*. 2011/009.

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

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

DFO. 2014. *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. 2016a. *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).

DFO. 2016b. *Review of habitat evaluation procedure (HEP) input parameters and model results for the Meadowbank Gold Mine Project*. 2016/038. Canadian Science Advisory Secretariat Science Response.

Diavik. 1998. "*No Net Loss*" *Plan*. Diavik Diamond Mines Inc.

Ebata, K., A. Higashi, A. Shiomitsu, S. Saisho, and T. Ikeda. 2011. Development of a small and lightweight artificial reef for Fukutokobushi (*Haliotis diversicolor diversicolor*). In *Global Change: Mankind-Marine Environment Interactions*. Eds. H.-J. Ceccaldi, I. Dekeyse, M. Girault, and G. Stora.

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

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

Hueckel, G. J. and R. M. Buckley. 1987. The influence of prey communities on fish species assemblages on artificial reefs in Puget Sound, Washington. *Environmental Biology of Fishes*, 19: 195-214.

Hueckel, G. J. and R. L. Stayton. 1982. Fish foraging on an artificial reef in Puget Sound, Washington. *Marine Fisheries Review*, 44: 38-44.

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.

Kelly, J., R. Power, L. Noble, M. J., K. Reid, S. Kuehnemund, C. Carley, C. Grant, M. Roberge, E. Lee, and M. Teasdale. 2009. *(Draft). A system for characterizing and quantifying coastal marine habitat in Newfoundland and Labrador*. Fisheries and Ocean Canada: St. John's NL.

Klemetsen, A., P.-A. Amundsen, J. B. Dempson, B. Jonsson, N. Jonsson, M. F. O'Connell, and E. Mortensen. 2003. Atlantic salmon Salmo salar L., brown trout Salmo trutta L. and Arctic charr Salvelinus alpinus (L.): a review of aspects of their life histories. . *Ecology of Freshwater Fish*, 12: 1–59.

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.

Laurel, B. J., A. W. Stoner, C. H. Ryer, T. P. Hurst, and A. A. Abookire. 2007. Comparative habitat associations in juvenile Pacific cod and other gadids using seines, baited cameras and laboratory techniques. *Journal of Experimental Marine Biology and Ecology*, 351 (1–2): 42-55.

Lauria, V., M. Gristina, M. J. Attrill, F. Fiorentino, and G. Garagalo. 2015. Predictive habitat suitability models to aid conservation of elasmobranch diversity in the central Mediterranean Sea. *Scientific Reports*, 5: 13245.

Lauria, V., A. M. Power, C. Lordan, A. Weetman, and M. P. Johnson. 2015. Spatial Transferability of Habitat Suitability Models of Nephrops norvegius among Fished Areas in the Northeast Atlantic: Sufficiently Stable for Marine Resource Conservation? . *PLoS One*, 10(2): e0117006.

Lauria, V., S. Vaz, C. Martin, S. Mackinson, and S. Carpentier. 2011. What influences European plaice (*Pleuronectes platessa*) distribution in the English Channel? Using habitat modelling and GIS to predict habitat utilization. . *ICES Journal of Marine Science*, 68: 1500-10.

McCart, P. 1980. A review of the systematics and ecology of Arctic char Salvelinus alpinus in the western Arctic. *Canadian Technical Report of Fisheries and Aquatic Sciences*, 935: vii + 89p.

Menge, B. A. and J. P. Sutherland. 1976. Species diversity gradients: synthesis of the roles of predation, competition, and temporal heterogeneity. *American Naturalist*, 110: 351-69.

Moore, J.-S. 2012. Patterns and consequences of dispersal in Arctic Char (Pisces: *Salvelinus alpinus*) from the Canadian Arctic. Doctor of Philosophy diss., University of British Columbia.

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, J. Le Luyer, B. J. G. Sutherland, Q. Rougemont, R. F. Tallman, A. T. Fisk, and L. Bernatchez. 2017. Genomics and telemetry suggest a role for migration harshness in determining overwintering habitat choice, but not gene flow, in anadromous Arctic Char. *Molecular Ecology.*

Mueter, F. J., J. Nahrgang, R. J. Nelson, and J. Berge. 2016. The ecology of gadid fishes in the circumpolar Arctic with a special emphasis on the polar cod (*Boreogadus saida*). *Polar Biol (2016) 39:961–967*, 39: 961–67.

Protocol/UNEP, L. C. a. 2009. *London Convention and Protocol/UNEP Guidelines for the Placement of Artificial Reefs*. London, UK.

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. 2005. *Twin Lakes Diversion Project Conceptual No Net Loss Fish Habitat Compensation Plan*. BHP Billiton Base Metals.

Rescan. 2007. *Galore Creek Project: Fish habitat compensation plan*. Prepared for Novagold Canada Inc. by Rescan Environmental Services Ltd: Vancouver, BC.

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

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

Rescan Environmental Services Ltd. 2012. *KSM Project: HADD Fish Habitat Compensation Plan*. Seabridge Gold Inc.: Vancouver, BC.

Rikardsen, A. H., H. O. H. Diserud, J. M. Elliott, J. B. Dempson, J. Sturlaugsson, and A. J. Jensen. 2007. The marine temperature and depth preferences of Arctic charr (*Salvelinus alpinus*) and sea trout (*Salmo trutta*), as recorded by data storage tags. . *Fisheries Oceanography*, 16 (5): 437 – 47.

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

RL&L/Golder. 2003b. *Doris North Project No Net Loss Plan*. Miramar Hope Bay Ltd.

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.

SEM, S. E. M. L. 2011. *Mary River Project Environmental Impact Statement: Determination of Harmful Alteration, Disruption or Destruction (HADD) of Fish Habitat in the Marine Environment Associated with the Mary River Project*. Prepared for Baffinland Iron Mines Corporation by Sikumiut Environmental Management Ltd.: St John's. Newfounland.

SEM, S. E. M. L. 2017. *2016 Milne Ore Dock Fish Offsetting Monitoring*. Prepared by Sikumiut Environmental Management Limited for Baffinland Iron Mines Corporation: St. John's, Newfounland.

Sherman, R. L., D. S. Gilliam, and R. E. Speiler. 2002. Artificial reef design: void space, complexity, and attractants. *ICES Journal of Marine Science*, 59: S196-S200.

Smiley, B. D. 2006. *The intentional scuttling of surplus and derelict vessels: Some effects on marine biota and their habitats in British Columbia waters, 2002*. 2006/059. Canadian Science Advisory Secretariat, Research Document.

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.

SRK. 2017. *Hope Bay Project: Roberts Bay Cargo Dock Preliminary Design.* . 1CT022.013. Prepared for TMAC Resources Inc. by SRK Consulting.

Tupper, M. and R. G. Boutilier. 1995. Effects of habitat on settlement, growth and post-settlement survival of Atlantic cod (*Gadus morhua*). . *Canadian Journal of Fisheries and Aquatic Sciences*, 52: 1834-41.

USFWS. 1980. *Habitat Evaluation Procedures*. ESM 102. US Fish and Wildlife Service, Department of the Interior.

USFWS. 1981. *Standards for the Development of Habitat Suitability Index Models for Use in the Habitat Evaluation Procedure*. United States Fish and Wildlife Service, Division of Ecological Services Report ESM 103. United States Fish and Wildlife Service: Washington, DC.

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.