

5.19 MARINE MAMMALS ASSESSMENT

This section presents the results of the assessment of potential and cumulative effects on marine mammal as a result of the proposed Woodfibre Liquefied Natural Gas Project (Project). The processes used to select marine mammals as a valued component (VC), assessment boundaries, and existing conditions relevant to marine birds are described. This section also presents assessment findings, including evaluation of Project-related interactions and likely adverse effects, proposed approaches to mitigation, identification of likely residual and cumulative adverse effects, and determination of adverse effects significance. Monitoring and follow-up programs to be conducted with respect to marine birds are described. The assessments in this section should be read in conjunction with **Appendix 5.10-1 Marine Resources Baseline Study**.

The information and analyses in this section are supported by the analyses in the following sections (see **Table 4.2 Component Linkages Matrix**):

- Section 5.4 Atmospheric Sound
- Section 5.10 Marine Water Quality
- Section 5.16 Marine Benthic Habitat
- Section 5.18 Forage Fish and Other Fish (Marine)
- Section 7.3 Marine Transport

This section supports the assessment in **Section 7.4 Land and Resource Use** and **Section 7.6 Current Use of Lands and Resources for Traditional Purposes**.

5.19.1 Marine Mammals Scoping and Rationale

This section provides an overview of the marine mammals VC and its regulatory setting, the rationale for its selection as a VC, the spatial and temporal boundaries for marine mammals with associated rationale, and the indicators that will be used to determine potential adverse effects to the VC.

5.19.1.1 Overview and Regulatory Setting

The west coast of Canada comprises a rich and diverse network of marine habitats, including sheltered coastal shores, deep fjords, outer continental shelves, and submarine canyons (Ford et al. 2010). These areas provide marine mammals with valuable habitat for foraging, mating, and rearing young. A documented 25 species of cetaceans (whales, dolphins, and porpoises), five species of pinnipeds (seals and sea lions), and one species of sea otter occur in British Columbia (BC), seasonally or year-round depending on their life history strategies (Heise et al. 2007). At least 11 species of marine mammals have been reported, or have the potential to occur, in the southern Strait of Georgia and the protected waters of Howe Sound for varying periods of time and at different seasons throughout the year (see **Table 5.19-1**) (Keple 2002, BCCSN 2013).

Table 5.19-1 Marine Mammal Species in Southern Strait of Georgia and Howe Sound

Common Name (Scientific Name)	SARA ^(a)	COSEWIC ^(a)	CDC ^(a)
Killer whale (<i>Orcinus orca</i>) – Southern Resident	END/Sc1	Endangered	Red
Killer whale (<i>Orcinus orca</i>) – Northern Resident	TH/Sc1	Threatened	Red
Killer whale (<i>Orcinus orca</i>) – Transient	TH/Sc1	Threatened	Red
Killer whale (<i>Orcinus orca</i>) – Offshore	SC/Sc1	Threatened	Red
Pacific white-sided dolphin (<i>Lagenorhynchus obliquidens</i>)	Not at Risk	Not at Risk	Yellow
False killer whale (<i>Pseudorca crassidens</i>)	No Status	Not at Risk	Yellow
Dall's porpoise (<i>Phocoenoides dalli</i>)	No Status	Not at Risk	Yellow
Harbour porpoise (<i>Phocoena phocoena</i>)	SC/Sc1	Special Concern	Blue
Humpback whale (<i>Megaptera novaeangliae</i>)	TH/Sc1 ^(b)	Special Concern	Blue
Grey whale (<i>Eschrichtius robustus</i>)	SC/Sc1	Special Concern	Blue
Minke whale (<i>Balaenoptera acutorostrata</i>)	No Status	Not at Risk	Yellow
Steller sea lion (<i>Eumetopias jubatus</i>)	SC/Sc1	Special Concern	Red
California sea lion (<i>Zalophus californicanus</i>)	No Status	Not at Risk	Yellow
Harbour seal (<i>Phoca vitulina</i>)	No Status	Not at Risk	Yellow

Notes:

- (a) SARA = *Species at Risk Act*; END = Endangered, TH = Threatened, SC = Special Concern, Sc1=Schedule 1 of SARA;
Red = Extirpated, Endangered or Threatened; Blue = Vulnerable; Yellow = Not at Risk;
COSEWIC=Committee on the Status of Endangered Wildlife in Canada;
CDC=BC Conservation Data Centre;
- (b) The Minister of the Environment, on the advice of the Minister of Fisheries and Oceans Canada, has recommended that the Governor in Council make a regulatory amendment to Schedule 1 of SARA in order to change the status of the species from Threatened to a species of Special Concern. A notice in April of 2014 was given that the Governor in Council, pursuant to subsection 27(1) of the SARA, proposes to make the annexed Order Amending Schedule 1 to the SARA (Government of Canada 2014).

The federal *Fisheries Act*, RSC 1985, c. F-14, offers protection of all fish^a that are part of a commercial, recreational, or Aboriginal (CRA) fishery, or to fish that support such a fishery, including marine mammals. Under section 35 of the *Fisheries Act*, no one may undertake activities that result in harm, permanent alteration, or destruction of fish or fish habitat that are part of a CRA fishery, or to fish that support such a fishery, unless authorized by the Minister of Fisheries and Oceans Canada (DFO). Under the *Fisheries Act*, the *Marine Mammal Regulations* were enacted in 1993 and state that it is an offence to kill, harm, disturb, or harass marine mammals, except when fishing for marine mammals under the authority of these regulations (Government of Canada 1993).

^a Under the *Fisheries Act*, 'fish' is defined as shellfish, crustaceans, marine animals, and any part of the life history of the animal, including eggs, sperm, spat, larvae, and juvenile stages.

In 2002, the *Species at Risk Act*, SC 2002, c. 29, (*SARA*) was proclaimed as legislation to protect and prevent those wildlife species considered at risk of becoming Extinct, by promoting and securing necessary actions for recovery through legal protection. Species designated under Schedule 1 of *SARA*, as well as and their critical habitats, are legally protected in Canada (Government of Canada 2012). Section 32 of this *Act* prohibits the killing, harming, harassing, capturing, or taking an individual of a species listed under *SARA* as Extirpated, Endangered, or Threatened. Section 33 of this *Act* prohibits damaging or destroying the residence of individuals belonging to a species listed under *SARA* as Extirpated, Endangered, or Threatened.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), established in 1977, is an independent scientific group that provides assessments of species potentially at risk and ranks them according to conservation concern (i.e., Extinct, Extirpated, Endangered, Threatened, Special Concern, Not at Risk, or Data Deficient) based on the best scientific evidence available. Although COSEWIC has no legislative or management role, it provides an independent recommendation on the status of at-risk species to the federal Minister of the Environment, who in turn makes recommendations to the Cabinet regarding potential legal protection of a species through provisions under *SARA*.

For the purpose of this assessment, species at risk include those species listed under the *SARA* or by COSEWIC, as well as those species that have been provincially Blue- or Red-listed by the BC Conservation Data Centre (CDC).

Federal recovery strategies for northern and southern resident killer whale, harbour porpoise, grey whale, humpback whale, and Steller sea lion cite a number of anthropogenic factors threatening these populations (DFO 2009a, 2010a, 2010b, 2011, 2013), including several features potentially associated with the Project such as underwater noise disturbances (from shipping and construction activities), environmental contaminants, reduced prey availability, and vessel–marine mammal collisions. For further consideration specific to marine mammal collisions, refer to **Section 11.0 Accidents and Malfunctions**. No critical habitat for marine mammals exists in Howe Sound; however, established critical habitat for southern resident killer whales is present south of the Project area near the mouth of the Fraser River (as shown in **Figure 5.19-1**) and extending into the Strait of Georgia and toward the Gulf Islands and South Vancouver Island (DFO 2011).

5.19.1.2 Selection of Valued Component

The selection of marine mammals as a VC followed a process as set out in **Section 4.3 Issues Scoping and Selection of Valued Components** and described in **Section 5.1 Environmental Background** for environmental intermediate components (ICs) and VCs. Marine mammals were selected as a VC based on the following criteria:

- biological measure for marine ecosystem health as top predators in the marine food chain
- social, cultural, and ecological importance in Project area
- potential presence of listed marine mammal species in Project area (e.g., humpback whales, killer whales, harbour porpoise, Steller sea lions)
- Project activities have the potential to result in injury or behavioural disturbance of marine mammals as a result of construction and operation activities

5.19.1.3 Indicators

Indicators are parameters that are measurable aspects of a VC's condition and are used to provide an estimation of the effects of Project activities on a VC. The indicators used to assess the potential effects of the Project on marine mammals are shown in **Table 5.19-2** and were identified using known anthropogenic threats identified in the management plans for SARA-listed species (DFO 2009a, 2010a, 2010b, 2011, 2013), scientific studies, and professional judgment.

Table 5.19-2 Key Indicators for Marine Mammals

Indicator	Rationale for Selection
Changes in habitat quality	Marine mammal habitat quality could be altered as a result of changes in available prey.
Changes in behaviour	Marine mammal behaviour may be altered due to the underwater noise from Project vessels, in-water construction, and blasting relative to recommended acoustic thresholds.
Harm (physical injury or mortality) to marine mammals	Harm to marine mammals has the potential to occur as a result of underwater noise injury. Refer to Section 11.0 Accidents and Malfunctions for further consideration of harm to marine mammals as a result of marine mammal–vessel collisions and accidental spills.

Section 5.10 Marine Water Quality concludes that, with the mitigation measures in place, Project-related changes to marine water quality are unlikely to exceed water quality guidelines. Accordingly, effects to marine mammals as a result of changes to water quality are not included in the assessment.

Potential effects from the introduction of invasive species are addressed in **Section 5.16 Marine Benthic Habitat**. Discharge of ballast water during commercial shipping operations has the potential to introduce exotic invasive species to the marine environment and disrupt natural marine benthic communities by altering the abundance, diversity, and distribution of native marine species. After the implementation of the mitigation measures, the overall significance of the effect is considered negligible. Accordingly, effects to marine mammals as a result of changes to marine benthic habitat are not included in the assessment.

5.19.1.4 Assessment Boundaries

This section describes the spatial and temporal boundaries of the assessment of marine mammals, as well as administrative or technical boundaries that may apply.

5.19.1.4.1 Spatial Boundaries

The local assessment area (LAA) and regional assessment area (RAA) for marine mammals are defined in **Table 5.19-3** and shown in **Figure 5.19-1**. The LAA was established to encompass the area within which there may be interactions between marine mammals and Project activities, which potentially have direct or indirect adverse effects on marine mammals. In determining LAA boundaries, consideration was

given to the nature and characteristics of marine mammals, their potential exposure to various influences of underwater noise and vessel strikes, pathways of effects, and the maximum extent of potential adverse effects.

The RAA was established to provide a larger regional context for the assessment of Project-related effects and also encompasses the LAA. The RAA was also established to encompass the area where the residual effects of the Project are likely to overlap with residual effects of other certain or reasonably foreseeable projects and activities and, as a result, is the area within which the cumulative effects assessment has been conducted.

Table 5.19-3 Spatial Boundary Definitions for Marine Mammals

Spatial Boundary	Description of Assessment Area
Local Assessment Area	The marine portion of the Project area and the marine corridor plus a 1 km area on either side of the proposed liquefied natural gas (LNG) carrier route (in Howe Sound) and on either side of the worker ferry route and water taxi route between the Project site and Darrell Bay / Squamish Harbour.
Regional Assessment Area	Howe Sound as shown in Figure 5.19-1
Cumulative Effects Assessment Area	Same as the RAA

5.19.1.4.2 Temporal Boundaries

Temporal characteristics of the Project's construction, operation, and decommissioning phases are defined in **Section 2.2 Description of the Proposed Project**. The construction phase of the Project is expected to span a period of 24 months. The operation life of the Project is anticipated to be at least 25 years. If, after that timeframe, the Project can continue to operate in an effective and environmentally sound manner, plans will be developed for continued operation. Decommissioning at the end of Project life will last approximately 24 months. The temporal boundaries established for the assessment of adverse Project-related effects on marine mammals encompass these Project phases.

The temporal characteristics of the marine mammals VC are described in the existing conditions for this VC and relate to seasonal occurrence (i.e., year-round, seasonal or occasional use). Temporal characteristics are also considered in the identification of the potential effects, and in the proposed mitigation measures.

5.19.1.4.3 Administrative Boundaries

No administrative boundaries exist for the marine mammals VC.

5.19.1.4.4 Technical Boundaries

Technical boundaries for the assessment of the Project on marine mammals include seasonal occurrence (presence or absence) and marine mammal habitat use in the LAA and RAA, based on existing scientific literature and information currently available in the public domain.

5.19.2 Existing Conditions

This section describes the existing conditions with respect to marine mammals, as well as the surrounding environment. This section also describes other physical factors with a potential to directly or indirectly influence marine mammals, such as existing ambient underwater noise levels and ship traffic levels in the Project area.

5.19.2.1 Introduction

The Project may result in effects to marine mammals in the Project area including species protected under the federal *Fisheries Act* (*Marine Mammal Regulations* (Government of Canada 1993)) and SARA. The objective of the **Marine Resources Baseline Study (Appendix 5.10-1)** was to identify marine mammals and sensitive marine mammal habitats present within the marine footprint areas of the proposed terminal development, including barges and associated infrastructure, landing wharf, marine water intake and outfall structures, areas proposed for in-water and shoreline works, and proposed shipping and worker ferry corridors. The baseline assessment focused on species at risk, and those species with sensitive life-cycle periods and habitat areas that overlap spatially or temporally with the Project. Baseline information was used to contrast and measure against potential Project-related effects to a level adequate to support the environmental assessment and associated management and mitigation planning.

This section presents an overview of marine mammals in the LAA and RAA, including details on species occurrence and distribution, seasonal residency, habitat use, and behaviour (e.g., foraging, mating). Additional details on marine mammals in the LAA and RAA are provided in **Appendix 5.10-1 Marine Resources Baseline Study**.

Since the interactions of the effects associated with past and existing projects are not expected to change over time, these projects are considered through the documentation of the existing conditions for this VC. A summary of the projects, the effects of which are included in the existing conditions, is presented in **Table 4-7 Existing Conditions – Past and Existing Projects**. Projects and activities that are considered in the existing conditions for this VC include the Britannia Mine Remediation Project, Furry Creek Hydro Project, Howe Sound Pulp and Paper Corporation, Upper and Lower Mamquam Hydro Projects, McNair Creek Hydro Project, Squamish Terminals, BC Ferries, recreational boating, forestry, fishing, and backcountry and outdoor recreation activities.

5.19.2.2 Background Information

A desktop review was completed to characterize the existing environment for marine mammals in the LAA and RAA. Sources of information included but were not limited to the following:

- marine mammal sightings collected opportunistically during other field programs in the Project area
- available grey literature and scientific publications
- governmental and non-governmental reports and environmental metadata records (environmental resource databases and online marine spatial planning tools) including CDC, BC Marine Conservation Atlas, Coastal Resource Information Management System
- BC Cetacean Sightings Network^b database
- previous marine-based investigations and research programs, environmental resource surveys, and environmental reports completed in the Project area (as available in the public domain) including, but not limited to DFO's Cetacean Research Program (population and distribution studies)
- a review of existing provincial and federal species-at-risk databases, including the provincial Species At Risk BC database, COSEWIC's Wildlife Species Search Registry, and the federal SARA Registry including any relevant species recovery plans, action plans, or species update reports
- feedback from the applicable regulatory agencies during the AIR review process

5.19.2.3 Desktop and Field Studies

In 2013, Woodfibre LNG Limited (WLNG) initiated environmental studies on marine mammals to address known data gaps in the LAA and RAA, assist with Project design, and support the environmental assessment, as well as environmental management objectives of the Project. Desktop and field studies conducted with respect to marine mammals are summarized in **Table 5.19-4**.

Table 5.19-4 Summary of Desktop and Field Studies Related to Marine Mammals

Study Name	Study Purpose
Marine Mammal Baseline Study	A comprehensive literature review (desktop study) was completed to characterize existing marine mammal baseline conditions in the Project area, with an emphasis on seasonal residency / abundance and habitat use patterns. Refer to Appendix 5.10-1 Marine Resources Baseline Study.
Ambient Underwater Noise Assessment	Underwater ambient noise levels were measured in the Project area to serve as a baseline for comparison to anticipated underwater noise levels from proposed Project activities (e.g., impact pile driving, vessel operations) in relation to established acoustic injury and behavioural threshold criteria for marine mammals Refer to Appendix 5.4-1 Atmospheric Sound Baseline Study.

^b Data obtained from the BC Cetaceans Sighting Network (2013) were collected opportunistically with limited knowledge of observer effort on a temporal or spatial scale. As a result, absence of sightings at any location does not necessarily demonstrate absence of marine mammals in this area.

5.19.2.4 Description of Existing Conditions

This section presents a description of existing conditions for marine mammals that inhabit the waters of Southern BC, which includes characterization of existing ambient underwater noise levels in Howe Sound, as well as existing marine traffic levels in the Howe Sound region.

5.19.2.4.1 Marine Mammals in Southern British Columbia Waters

The west coast of Canada is a rich and diverse network of marine habitats that feature sheltered coastal shores, deep fjords, outer continental shelves, and submarine canyons (Ford et al. 2010). These areas provide marine mammals with valuable habitat for foraging, mating, and rearing young. A documented 25 species of cetaceans (whales, dolphins, and porpoises), five species of pinnipeds (seals and sea lions), and one species of sea otter occur in BC seasonally or year-round, depending on their life history strategies (Heise et al. 2007).

At least 11 species of marine mammal have the potential to occur in the southern Strait of Georgia and in the protected waters of Howe Sound (Keple 2002, BCCSN 2013), as identified in **Table 5.19-5**. Marine mammals at the species level vary greatly in their seasonal occurrence and habitat use within the LAA and RAA (**Table 5.19-5** and **Table 5.19-6**). Harbour seals are year-round residents in Howe Sound, while sea lions (California and Steller) and porpoises (harbour and Dall's) are considered occasional visitors throughout the year (EPS 1976, MOE 1979, BCCSN 2013). Other cetacean species have generally been absent from Howe Sound over the last few decades (Environment Canada 1973, BCCSN 2013) until recently, when sightings of Pacific white-sided dolphins, killer whales, grey whales, and humpback whales have notably increased since 2009 (BCCSN 2013). The recent rise in cetacean sightings in Howe Sound has been linked with improved water quality in the area, and associated return in prey fish numbers, including herring and salmonids. Minke and false killer whales are historically rare in Howe Sound, and would be considered vagrant sightings in this area. A detailed overview of each species is provided in **Appendix 5.10-1 Marine Resources Baseline Study**.

A long-term record of opportunistic cetacean sightings data collected between 1990 and 2013 in Howe Sound is provided in **Appendix 5.10-1 Marine Resources Baseline Study**. The most common marine mammal species reported in the upper reaches of Howe Sound near the Project area (current to 2013) are harbour seals, Pacific white-sided dolphins, and killer whales (Peatt and Knight 1980, BCCSN 2013). Habitat designated as critical habitat for southern resident killer whales is located at the mouth of the Fraser River (DFO 2011); however, this federally protected area does not overlap with the LAA or RAA (**Figure 5.19-1**). No established pinniped haul-out sites or rookeries^c have been identified in the upper reaches of Howe Sound near the Project area (**Appendix 5.10-1 Marine Resources**

^c A land-based (coastal) breeding ground where large groups of sea lions congregate seasonally (spring) to pup and mate. Harbour seals do not congregate in rookeries but rather pup on land in late summer throughout their range either in small groups or individually.

Baseline Study). However, during baseline field investigations, several opportunistic sightings occurred of individual harbour seals and Steller sea lions hauled out (resting) on logs near Squamish Yacht Club approximately 6 km from the Project area (**Table 5.19-7**). In addition, several other harbour seal haul-out sites were identified at Pam Rocks near Anvil Island and at Popham Island (small islet immediately west of Pasley Island; **Figure 5.19-1**).

Table 5.19-5 Marine Mammal Species in Southern Strait of Georgia and Howe Sound

Common Name (Scientific Name)	Seasonal Occurrence / Habitat Use ^(a)	Preferred prey ^(a)	Estimated Population Size (Number of Individuals) ^(a)
Killer whale (<i>Orcinus orca</i>) – Southern Resident	Occur year-round (peak May to October) in the Strait of Georgia. Forage and breed in this area. Critical habitat identified in the Southern Strait of Georgia including at the mouth of Fraser River, Haro Strait, Boundary Pass, and the eastern portion of the Strait of Juan de Fuca. Occasional occurrence in Howe Sound (sightings have increased since 2009).	Fishes (primarily chinook, and other salmon species)	79
Killer whale (<i>Orcinus orca</i>) – Northern Resident	Rare visitor in the Strait of Georgia; do not forage or breed in Project area. Critical habitat identified in southeastern Queen Charlotte Strait and Johnstone Strait east of Port McNeill to north of Campbell River.	Fishes (primarily chinook, and other salmon species)	205
Killer whale (<i>Orcinus orca</i>) – Transient	Occur year-round in the Strait of Georgia. Forage in this area. Occasional occurrence in Howe Sound (sightings have increased since 2009 with evidence of hunting prey observed).	Seals, sea lions, dolphin, and porpoise	220
Killer whale (<i>Orcinus orca</i>) – Offshore	Occur on continental shelf off outer coast of BC; occasionally observed along inside waters. Rarely observed in Strait of Georgia or Howe Sound area.	Fishes (including elasmobranchs)	288
Pacific white-sided dolphin (<i>Lagenorhynchus obliquidens</i>)	Extirpated historically from Strait of Georgia – numbers have since increased. Occasionally occur in Howe Sound area (sightings have increased since 2010).	Fishes (e.g., Pacific herring, salmon, schooling fishes), shrimp, and cephalopods	Unknown but 26,860 in central North Pacific
False killer whale (<i>Pseudorca crassidens</i>)	Rarely occur in the Strait of Georgia or Howe Sound. Reported sightings likely represent multiple observations of a vagrant individual.	Fishes and cephalopods	Unknown
Dall's porpoise (<i>Phocoenoides dalli</i>)	Occur year-round in the Strait of Georgia and forage in this area. Occasionally occur in Howe Sound area.	Fishes (e.g., Pacific herring, schooling fishes)	Unknown but 83,400 in Alaska (AK), 75,915 in CA/OR/WA

Common Name (Scientific Name)	Seasonal Occurrence / Habitat Use ^(a)	Preferred prey ^(a)	Estimated Population Size (Number of Individuals) ^(a)
Harbour porpoise (<i>Phocoena phocoena</i>)	Occur year-round in the Strait of Georgia; common in shallow (<200 m) nearshore areas; higher density in northern Strait of Georgia and Johnstone Strait. Occasionally occur to Howe Sound area.	Fishes (e.g., Pacific herring) and cephalopods	Unknown but 28,967 in WA/OR, 37,450 in southeast AK
Humpback whale (<i>Megaptera novaeangliae</i>)	Extirpated from Strait of Georgia in early 1900s. Population has since recovered. Presently forage and migrate through area during the summer, winter, and fall.	Pelagic crustaceans (e.g., krill, mysids) and schooling fish	2,145 in BC; 6,500 in eastern North Pacific
Grey whale (<i>Eschrichtius robustus</i>)	Summer resident populations may forage in the Strait of Georgia in the spring and summer. Other individuals from the eastern Pacific population migrate through on their way to foraging grounds in Northern BC and Alaska. Rare visitor to Howe Sound, although sightings have increased in recent years.	Mysid and ghost shrimp, benthic crustaceans, herring eggs	20,000 individuals in the eastern Pacific A sub-population of summer residents exists in BC (referred to as the Pacific Coast Feeding Aggregation) numbering in the low 100s
Minke whale (<i>Balaenoptera acutorostrata</i>)	Likely year-round resident in the Strait of Georgia; most frequently found in nearshore waters. Rare visitor in Howe Sound.	Krill, copepods, schooling fishes and cephalopods	Unknown, but not abundant; <600 in CA/OR/WA
Steller sea lion (<i>Eumetopias jubatus</i>)	Occasional visitor to Howe Sound throughout the year. Foraging and migratory movements in RAA, but no breeding sites.	Fishes (e.g., rockfish, flatfish, salmon) and cephalopods	18,400 to 19,700 in BC
California sea lion (<i>Zalophus californianus</i>)	Occasional visitor to Howe Sound throughout the year. Foraging and migratory movements in RAA, but no breeding sites.	Fishes and cephalopods	1,500 to 3,000 in BC
Harbour seal (<i>Phoca vitulina</i>)	Year-round resident; forage, mate, and rear young in region.	Fishes	108,000 in BC

Notes: (a) Johannessen et al. 2005; Heise et al. 2007; Golder 2012; Keple 2002; COSEWIC 2004; Environment Canada 2014, DFO 2009a, 2009b, 2009c, 2011; BCMCA 2014, Ellis et al. 2011, CWR 2014; Rugh et al. 2008; Calambokidis et al. 2002.

Table 5.19-6 Marine Mammal Seasonal Occurrence by Species in Southern Strait of Georgia and Howe Sound

Common Name (Scientific Name)	Seasonal Occurrence ^(a)			
	Spring	Summer	Fall	Winter
Southern Resident killer whale (<i>O. orca</i>)*	X	X	X	X
Transient killer whale (<i>O. orca</i>)*	X	X	X	X
Pacific white-sided dolphin (<i>L. obliquidens</i>)	X	X	X	X
False killer whale (<i>P. crassidens</i>)	X	X	X	X
Dall's porpoise (<i>P. dalli</i>)	X	X	X	X
Harbour porpoise (<i>P. phocoena</i>)*	X	X	X	X

Common Name (Scientific Name)	Seasonal Occurrence ^(a)			
	Spring	Summer	Fall	Winter
Humpback whale (<i>M. novaeangliae</i>)*		X	X	
Grey whale (<i>E. robustus</i>) *	X	X		
Minke whale (<i>B. acutorostrata</i>)	X	X		
Steller sea lion (<i>E. jubatus</i>)*	X	X	X	X
California sea lion (<i>Z. californianus</i>)	X	X	X	X
Harbour seal (<i>P. vitulina</i>)	X	X	X	X

Notes: (a) Seasonal occurrence based on sighting data from BCCSN (2013), Keple (2002) and DFO (2009a) and does not indicate number of individuals per sighting nor number of sightings per season; species with asterisk (*) denotes Schedule 1 of SARA listed species.

Table 5.19-7 Opportunistic Marine Mammal Species Identified during Marine Biological Resources Field Work

Date	Species	Number of Individuals	Behaviour	Location
April 1, 2013	Stellar sea lion	1	Surfacing several times	In LAA; near WMB2 sampling station
April 2, 2013	Harbour seal	1	Surfacing	In Project area, near passenger dock
April 3, 2013	Porpoise (unknown species)	1	Swimming	In LAA; near station WMREF1
	Sea lion (unknown species)	1	Surfacing	In LAA; near WMREF1
	Harbour seal	3	Swimming	In Project Area
April 4, 2013	Harbour seal	1	Surfacing	In Project area; near passenger dock
June 19, 2013	Harbour seal	1	Unknown	In LAA; near Project area
June 21, 2013	Harbour seal	1	Unknown	In LAA; near Project area
July 3, 2013	Harbour seal	1	Surfacing	Offshore of the Squamish Yacht Club; outside LAA
July 4, 2013	Harbour seal	1	Hauled-out on logs	Offshore of the Squamish Yacht Club; outside LAA
	Sea lion (unknown species)	1	Hauled-out on logs	Offshore of the Squamish Yacht Club; outside LAA
September 5, 2013	Harbour seal	1	Unknown	In LAA; near Project area
September 27, 2013	Harbour seal	1	Unknown	In LAA; near Project area

5.19.2.4.2 Existing Ambient Underwater Noise Levels in Howe Sound

Ambient underwater noise levels were measured over a nine hour period (full tidal cycle) at a single recording station near the Project area in Howe Sound on July 5, 2013. This information served as a baseline for comparison to anticipated underwater noise levels from proposed Project activities (e.g., impact pile driving, vessel operations) in relation to established acoustic injury and behavioural threshold criteria for marine mammals. Broadband ambient noise levels ranged from 112.0 decibels (dB) to 126.8 dB re 1 μ Pa, or micropascal, an international system of units (SI) unit of pressure and stress equal to 10^{-6} pascals (using one-third octave percentile band levels of the 5th to 95th percentile, respectively), with a median (50th percentile) of 116 decibels (dB) re 1 μ Pa. A detailed summary of the ambient underwater noise assessment is provided in **Appendix 5.10-1 Marine Resources Baseline Study**.

5.19.2.4.3 Existing Vessel Traffic Levels in Howe Sound

Approximately 80 deep-sea vessels call at the Squamish Terminals per year using established shipping routes. An additional three BC Ferries routes from Horseshoe Bay provide daily large vessel activities in the RAA (**Figure 5.19-1**). Tugs and barges also transit the route, although tug and barge traffic density in Montagu Channel is 13% of that in Thornbrough Channel. Canadian Coast Guard data for 2013 shows on average 1 to 1.9 large vessel movements in Squamish Harbour per day. According to anecdotal reports, there are approximately 10 water taxi movements to the site per day (WFP 2014a, 2014b). Additional details regarding shipping in the LAA and RAA are presented in **Section 7.3 Marine Transport**.

5.19.2.4.4 Existing Conditions in the Local Assessment Area Based on the Field Study

This section presents a summary of water quality, phytoplankton zooplankton and forage fish baseline studies conducted in July and September 2013 and April to June 2014. The results are presented in greater detail in **Appendix 5.10-1 Marine Resources Baseline Study**.

Marine Water Quality

The water column was stratified during each sampling season, and stratification was influenced mostly by seasonal changes in freshwater input from the Squamish River and nearby creeks. Salinity gradient between the surface and depth was high during all sampling seasons, formed by a relatively freshwater surface layer from the Squamish River discharge overlaying high-salinity ocean water. Observed riverine influence was stronger during the summer and beginning of the fall, resulting in lower salinities, thicker surface layer, and greater depth of the halocline.

Temperature stratification was also stronger in the summer; however, the thermocline was weaker and deeper than the halocline. Water temperatures in April were practically uniform throughout the entire water column and lower than during the other sampling sessions. At some stations in April, water at the

surface was slightly colder (6.3 degrees Celsius (°C)) than at layers immediately below, possibly due to colder riverine discharge or a cooling effect from the colder air. The thermocline was strongest in June 2014 when the highest temperature was recorded (14.9°C), and the thermocline occurred between depths of -3 m and -10 m. The lowest temperature in June (8.6°C) was recorded at a depth of 30 m.

Freshwater discharge was greater in summer associated with the snowmelt and in fall associated with the onset of the rainy season. Freshwater discharge created density gradients with the pycnocline coinciding with the halocline, which resulted in strong vertical density stratification, particularly during the summer time.

Water in the upper 5 m was generally well saturated with dissolved oxygen, which indicates photosynthetic activity and net primary production by phytoplankton. Maximum dissolved oxygen concentrations were observed at or slightly below the depths of lower limits of the thermocline and halocline. Below those depths the dissolved oxygen concentrations declined rapidly.

Water clarity within the Project and reference areas varied seasonally in relation to levels of freshwater input. Turbidity and TSS were associated with the surface freshwater layer and were higher at the surface, particularly in summer, and decreased with depth. In summer, TSS concentrations at the surface were as high as 49 milligrams per litre (mg/L) (September 2013), while TSS concentrations at the mid-depth and near-bottom were at or below the laboratory detection limit of 2 mg/L in most samples. Total suspended solids in April 2014 were consistently low throughout the water column and below the detection limit in all but one sample. Turbidity levels were consistent with TSS and ranged from below 1 nephelometric turbidity unit (NTU) throughout the water column in April, to as high as 48 NTU at the surface in September.

Marine water pH was within the Canadian water quality guidelines and BC water quality guidelines range for marine water of 7.0 to 8.7. Exceptions were three samples with pH between 6.5 and 6.8 collected at the surface in summer. These low pH values were associated with freshwater input and are normal for freshwater, particularly generated from precipitation (rain and snow).

The analyses of the samples collected at the study area have shown that levels of inorganic nitrogen available for phytoplankton production were low, particularly at the surface layers of water, although in many samples availability of nitrogen was difficult to assess due to variable laboratory detection limits. Total nitrogen concentrations at the surface within the Project and reference areas corresponded to marine ecosystems with oligotrophic (nutrient-poor) status.

No extractable petroleum hydrocarbon concentrations were detected in any of the samples collected throughout the Project area or reference area in 2013 and 2014. Some PAHs were detected in the water samples collected from the Project or reference areas in April and June 2014; however, none of the detected PAHs exceeded Canadian water quality guidelines or BC water quality guidelines.

Concentrations of metals in the Project and reference areas were low. Many metals were below detection limits in all samples (e.g., antimony, arsenic, beryllium, bismuth, cesium, gallium, mercury, phosphorus, rhenium, selenium, silver, tellurium, thorium, tin, tungsten, yttrium, and dissolved chromium). Total and dissolved cadmium and lead, total chromium, and dissolved iron and titanium were detected in less than 50% of the samples. While most of the metals were present mostly in their dissolved form, some metals (e.g., cobalt, iron, titanium) were found in primarily particulate form.

The exceptions to the low concentrations of metals were copper, boron, and zinc. Copper was present predominantly in its particulate form associated with freshwater input, and exceeded BC short-term maximum water quality guidelines (0.003 mg/L) and BC long-term water quality guidelines (0.002 mg/L) in samples collected from the surface in summer. Boron was present mainly in the dissolved form and associated with oceanic water occurring in higher concentrations at the depth below the pycnocline, where boron concentrations exceeded BC water quality guideline (1.2 mg/L) in all samples. Zinc was present predominantly in its dissolved form and exceeded BC water quality guideline (0.01 mg/L) in four samples.

Phytoplankton

A total of thirty-five genera were collected in phytoplankton samples from the Project and reference areas in 2013 and 2014. Ten of these genera were identified as dominant taxonomic groups by their abundance or frequency of occurrence across different sampling locations. Diatoms were the most present group with genus *Pseudonitzschia* sp. identified in a total thirteen samples. Other diatoms genera, which were present in greater than 50% of the sampling stations included *Leptocylindrus* sp., *Chaetoceros* sp., and *Thalassiosira* sp.

Phytoplankton growth and distribution within the survey areas was determined by seasonal changes in freshwater discharge from Squamish River and smaller streams. Solar radiation and nutrient availability are main physical factors controlling marine phytoplankton production. Increased freshwater discharge in the summer time created strong vertical stratification that prevented exchange between the upper and lower parts of the water column, therefore confining available nutrients (inorganic nitrogen and phosphorus) below the depth of the pycnocline (3-10m). High amounts of suspended sediments brought with the increased discharge created high turbidity that significantly limited light penetration through the water column.

The seasonal changes in physical factors within the water column reflected in phytoplankton abundance. Phytoplankton cells were abundant in samples collected in April, while abundance was unusually low in many of the samples collected in July, September 2013, and June 2014. The likely cause of low phytoplankton abundance is from environmental effects associated with density stratification and limited light penetration during the summer time. Stratification was deepest in July, which corresponded with the

lowest phytoplankton abundance. In addition, nitrogen levels were low in July even at depths below pycnocline. During the summer time, phytoplankton abundance was found higher at depth in September when the pycnocline was shallower than during the other summer months.

Phytoplankton carbon biomass was estimated for samples collected in April and June 2014. Phytoplankton biomass was higher in April ranging between a high of 885 ± 290 micrograms per litre ($\mu\text{g/L}$) and a low of 429 ± 213 $\mu\text{g/L}$. Biomass in June was only significantly high at one station, where it reached 481 ± 89 $\mu\text{g/L}$ and was lowest at < 0.01 $\mu\text{g/L}$.

Chlorophyll a followed a similar pattern as phytoplankton abundance and carbon biomass during most sampling events. Chlorophyll a concentrations were low at all stations in July 2013, ranging between 0.55 ± 0.13 $\mu\text{g/L}$ and 0.17 ± 0.01 $\mu\text{g/L}$. Productivity was also low in September 2013 (oligotrophic) at all stations except one, where productivity reached 1.81 ± 0.14 $\mu\text{g/L}$ (mesotrophic). Biomass productivity in April was generally mesotrophic or oligotrophic ranging from 1.99 ± 0.09 $\mu\text{g/L}$ and 0.45 ± 0.09 $\mu\text{g/L}$. Productivity in June was high at the surface and low at depth, ranging between a high of 2.41 ± 0.28 $\mu\text{g/L}$ and 0.040 ± 0.08 $\mu\text{g/L}$.

Phytoplankton diversity was moderate at some stations in September and June and low at many stations in April. Phytoplankton communities in September and June, which had contained low phytoplankton abundance, generally contained a few specimens of several different species keeping diversity comparatively high despite such low abundance. An exception was one station in June where the sample consisted of only a single species. Diversity was also comparatively high (0.74 ± 0.04 and 0.77 ± 0.04) in September at the stations in which abundance was high, as several different species contributed to the total abundance at these stations. In contrast, diversity was lower in April ranging between 0.63 ± 0.01 and 0.28 ± 0.04 . Taxa Richness varied significantly between stations in September and June and was consistently high in April. Richness in April ranged between 13 ± 0.3 and 9 ± 1.5 .

Zooplankton

Zooplankton communities at most stations were primarily comprised of crustaceans of several different life stages from three major groups: Calanoida, Cyclopoida and Cirripedia. Communities were dominated by different groups of crustaceans during each sampling event with smaller copepods of the group Cyclopoida abundant in September, barnacle larvae of the genus *Balanus* abundant in April and larger calanoid copepods abundant in June. Planktonic larvae of bivalve molluscs of family Mytilidae were also abundant in September but not in April or June. Other commonly found groups included polychaetes, amphipods and gastropods which were ubiquitous throughout collected samples and cnidarians, amphipods and decapods which were present in $>50\%$ of samples. Several larval fish specimens were found in samples collected in June including one specimen of the genus *Sebastes*, one specimen of the species *Artedius harringtoni*, and 3 specimens of the species *Rhinogobiops nicholsii*.

Zooplankton abundance was generally higher in September and April than in June. Abundance ranged from $2,013 \pm 372$ organisms/m³ to $3,514 \pm 365$ organisms/m³ in September; from $1,561 \pm 101$ organisms/m³ to $3,697 \pm 231$ organisms/m³ in April; and from $1,135 \pm 93$ organisms/m³ to $1,404 \pm 150$ organisms/m³ in June. In April, zooplankton abundance was notably lower near the outflow of Mill Creek. This trend was similar but less apparent in July.

Zooplankton biomass did not follow the same trend as abundance as biomass was comparatively higher in June than in September and April. Zooplankton biomass ranged from 117.16 ± 3.86 milligrams per cubic metre (mg/m³) to 220.96 ± 20.49 mg/m³ in September, from 247.51 ± 54.36 mg/m³ to 402.46 ± 38.57 mg/m³ in April, and from 304.21 ± 54.02 mg/m³ to 555.53 ± 39.41 mg/m³ in June. Zooplankton biomass in June was likely high despite lower abundance due to the presence of larger calanoid copepod species which in general have a higher biomass than species which were abundant in September and April.

Species composition of zooplankton samples was notably different between samples collected from different sampling events. The majority of samples collected in September and April contained less than 50% of one single group while in June the dominant group represented >50% of zooplankton abundance in each sample. In September, zooplankton abundance was dominated by cyclopoid copepods at three stations and by mussel larvae of family Mytilidae at two stations. Samples collected in April were dominated by larvae of group Cirripedia (barnacles) at three stations. In June, zooplankton abundance was mostly comprised of calanoid copepods at three stations. The dominant individual taxa (genus or higher level depending on the achieved taxonomic resolution) comprised less of the total zooplankton abundance than did the major group in September and June as individual taxa represented a maximum of 32% in September and 33% in June. In April, the dominant taxon was larvae of genus Balanus which comprised all of the relative abundance represented by group Cirripedia.

Taxa richness and diversity of zooplankton were high in all collected samples within the Project and reference areas. Taxa richness ranged from 14 to 16 ± 0.50 in September, from 20 ± 0.33 to 23 ± 1.73 in April, and from 22 ± 0.33 to 23 in June. Diversity ranged from 0.78 ± 0.004 to 0.85 ± 0.011 in September, from 0.54 ± 0.047 to 0.80 ± 0.04 in April and from 0.84 ± 0.01 to 0.86 ± 0.002 in June. High zooplankton diversity indicates that zooplankton abundance was generally spread amongst a large group of species despite the high abundance of certain major groups.

Forage Fish and Other Fish

The following section is summarized from **Section 5.18 Forage Fish and Other Fish (Marine)** and **Section 5.15 Freshwater Fish and Fish Habitat**. **Appendix 5.10-1 Marine Resources Baseline Study** contains additional information on the sampling methodology and analysis for the 2013 and 2014 fish surveys.

Forage fish are an important component of marine ecosystems, providing a food source for a variety of groups of marine and terrestrial animals. Several species of forage fish inhabit the BC coast, including Pacific herring (*Clupea pallasii*), surf smelt (*Hypomesus pretiosus*), Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), eulachon (*Thaleichthys pacificus*), capelin (*Mallotus villosus*) and Pacific sardine (*Sardinops sagax*). Three of the forage fish species, Pacific herring, surf smelt and Pacific sand lance, are known to spawn on the beaches in the RAA. Eulachon have been known to use Squamish River, at the head of Howe Sound, as irregular spawning habitat (Moody 2008). The other forage fish species spawn in pelagic environments or on beaches outside of Howe Sound and have not been included in this assessment (Cox and Peatt 1979, Peatt and Knight 1980, Whelen and Associates 1999).

During fish surveys conducted in 2014, juvenile and adult Pacific herring were captured in the LAA; however, no eulachon, surf smelt, or Pacific sand lance was captured (refer to **Appendix 5.10-1 Marine Resources Baseline Study**). Specifically, juvenile Pacific herring were captured during summer surveys at site S5, a low grade cobble beach with some boulder, south of Woodfibre Creek. Adult Pacific herring were captured at five sampling locations within the LAA during summer sampling.

During fish surveys conducted in 2014, juvenile and adult Pacific herring were captured in the Project area (see **Appendix 5.10-1 Marine Resources Baseline Study**). Specifically, juvenile Pacific herring were captured during summer surveys at site S5, a low-grade cobble beach with some boulder, south of Woodfibre Creek. Adult Pacific herring were captured at five sampling locations within the Project area during summer sampling.

The Project area likely serves as a migratory and juvenile rearing habitat for anadromous salmonid species, such as chum (*Oncorhynchus keta*), coho (*O. kisutch*), chinook (*O. tshawytscha*), and pink salmon (*O. gorbuscha*), as well as steelhead (anadromous rainbow trout; *O. mykiss*), Dolly Varden (*Salvelinus malma*), and the provincially Blue-listed coastal cutthroat trout (*O. clarkii clarkii*). Juvenile chum, pink, and chinook salmon, as well as Dolly Varden were captured during beach seine and gill net surveys conducted in 2014.

The lower reach of Mill Creek below the anadromous barrier is known to support pink salmon, coho salmon, and rainbow trout. Refer to **Section 5.15 Freshwater Fish and Fish Habitat** for additional information on anadromous barriers. Rainbow trout and coastal cutthroat trout have also been observed in the lower 1.5-km section of Woodfibre Creek (Moon and Brierley 1988, CMN 2013, MOE 2013a, MOE 2013b). Several salmonid species were observed in Mill Creek and Woodfibre Creek during freshwater fish surveys. Adult pink salmon were observed on September 10, 2013, when 1,860 live and 219 dead fish were observed. Coho salmon juveniles were identified during the July 2014 sampling event when only two were captured. Juvenile rainbow trout were captured within lower Mill Creek during sampling events in September 2013, and in April and July 2014, respectively. Onsite surveys of the lower reach of Woodfibre Creek have confirmed the presence of pink salmon, rainbow trout, and chinook salmon. Adult

pink salmon were observed on September 10, 2013 within the lower 25 m of Woodfibre Creek, where one live and two dead fish were documented. Juvenile rainbow trout were captured in the lower reach during sampling events in September 2013, and in April and July 2014, respectively. A single juvenile chinook salmon was captured during the September 2013 freshwater fisheries sampling event.

5.19.3 Assessment of Project-Related Effects

This section describes the methods for characterizing potential effects, the potential interactions between the Project activities and marine mammals, mitigation measures to avoid and reduce potential adverse interactions, and characterization of residual effects and their significance.

5.19.3.1 Assessment Methodology

The potential residual effects of the Project are assessed using the methodology outlined in **Section 4.0 Environmental Assessment Methods**. Potential interactions between the Project activities and marine mammals are determined and described, mitigation is proposed to avoid or minimize potential adverse interactions, and the residual effects and their significance are described. Descriptions of residual effects characteristics and significance for marine mammals are provided in the following sections.

Definitions for ratings applied to residual effects criteria, developed with specific reference to marine mammals, are presented in **Table 5.19-8**.

Table 5.19-8 Criteria Used to Characterize Residual Effects on Marine Mammals

Criteria	Description	Definition of Rating
Magnitude	Expected size or severity of the residual effect	• Negligible – Project will have no measurable effect • Low – Project will result in changes in habitat quality that can be monitored and measured above background conditions, but are within the scope of natural variability, do not exceed established criteria or scientific threshold levels, and do not meet any of the medium or high magnitude definitions • Medium – Project will result in one or more of the following: ▪ localized contamination of habitat in excess of underwater noise behavioural or injury thresholds, water or sediment quality standards, guidelines, or baseline conditions – less than 10 times ▪ ≥1 death or injury of a VC species ▪ occasional or temporary disruption of critical activities (e.g., breeding, nursing); and/or localized damage to sensitive habitats • High – Project is likely to result in one or more of the following: ▪ widespread degradation of habitat in excess of underwater noise behavioural or injury thresholds, water or sediment quality standards, guidelines, or baseline conditions – more than 10 times ▪ ≥1 death or injury of a SARA, Blue or Red -listed species ▪ extensive disruption of critical activities (e.g., foraging, breeding or nursing grounds) or damage to sensitive or critical habitats

Criteria	Description	Definition of Rating
Geographic Extent	Spatial scale over which the residual effect is expected to occur	• None – no geographic extent • Site-specific – the incremental change in the indicator is confined to the Project area • Local – the incremental change in the indicator extends beyond the Project area into LAA • Regional – the incremental change in the indicator extends beyond the LAA into the RAA
Duration	Length of time over which the residual effect is expected to persist	• Short-term – the incremental change in the indicator continues to the end of the construction phase of the Project (1.5 years) • Long-term – the incremental change in the indicator continues to the end of the operation phase of the Project (25 years) • Permanent – the incremental change in the indicator is irreversible
Frequency	How often the residual effect is expected to occur	• Infrequent – the incremental change in the indicator is confined to a specific discrete event • Frequent – the incremental change in the indicator occurs intermittently over the life of the Project • Continuous – the incremental change in the indicator occurs continuously across the life of the Project
Reversibility	Whether or not the residual effect can be reversed once the physical work or activity causing the effect ceases	• Fully reversible – the incremental change in the indicator is reversible within a time period that can be identified when the Project no longer contributes to an adverse cumulative effect • Partially reversible – the incremental change in the indicator is partially reversible within a time period that can be identified when the Project no longer contributes to an adverse cumulative effect • Irreversible – the incremental change in the indicator is predicted to influence the VC indefinitely (duration is permanent or unknown)
Context	Refers primarily to the sensitivity and resilience of the VC to change caused by the Project	• High – the system has a high natural resilience to imposed stresses • Moderate – the system has a moderate natural resilience to imposed stresses • Low – the system is susceptible to potential changes caused by the Project

5.19.3.1.1 Definition of Significance

For VCs without legislated or regulated thresholds to define significance, the BC Environmental Assessment Office (EAO) (2013) recommends using VC-specific factors such as population integrity to define significance. Consequently, significant effects would be considered likely for this VC if the population or meta-population is likely to not be self-sustaining or ecologically effective in the RAA as a result of project effects within the LAA. A VC is considered to be no longer self-sustaining where residual effects within the LAA are expected to place the abundance of a VC in the RAA, whether an open or closed population, on a declining trajectory that is not likely to recover or stabilize. Effects that are not significant could result in no change, stabilization at lower abundance, stabilization at higher abundance, or a temporary decline followed by recovery. Significant effects could result from either a decline to zero

or apparent stabilization, but at a level that is sensitive to stochastic events, which could cause extirpation. In the case of species listed under SARA as Endangered or Threatened, the loss of any individuals is considered a significant residual adverse effect.

The level of each residual effect has been rated as negligible, not significant, or significant, as follows:

Negligible (N)	Negligible effect is defined, for the purposes of this assessment, as a residual effect with negligible consequences to the population or low probability of occurrence. The incremental change to the indicator (defined in Table 5.19-2) from an effect of negligible significance is not measureable. Negligible effects are not carried forward to the residual effects characterization, significance section, or the cumulative effects assessment.
Not significant (NS)	Residual effects are determined to be not significant are those that are greater than negligible and that do not meet the definition of significant. Not-significant effects are carried forward to the cumulative effects assessment.
Significant (S)	A significant effect is defined, for the purposes of this assessment, as a residual effect that is predicted to exceed the resilience and adaptability limits of the population and result in a population that is not self-sustaining or ecologically effective. Significant effects are carried forward to the cumulative effects assessment.

5.19.3.1.2 Likelihood

Likelihood refers to whether or not a residual effect is likely to occur (EAO 2013). The basis for likelihood will be assessed using appropriate qualitative or quantitative terms with applicable descriptions for how a conclusion was reached. Likelihood has been assessed in terms of a residual effect occurring being **likely** (residual effect is likely to occur) or **not likely** (residual effect is not likely to occur).

5.19.3.1.3 Confidence and risk

The level of confidence for each predicted effect is discussed to characterize the level of uncertainty associated with both the significance and likelihood determinations. Level of confidence is typically based on expert judgement and is characterized as follows:

- **Low** – prediction is based on incomplete understanding of cause-effect relationships and incomplete data pertinent to the proposed Project area
- **Moderate** – prediction is based on a good understanding of cause-effect relationships using data from outside the proposed Project area or incompletely understood cause-effect relationships using data pertinent to the proposed Project area
- **High** – prediction is based on a good understanding of cause-effect relationships and data pertinent to the proposed Project area

Confidence in the assessment of significance of residual effects is related to the following elements:

- adequacy of baseline data for understanding current conditions and future changes unrelated to the Project (e.g., extent of future developments, climate change, catastrophic events)
- model inputs (e.g., thermal outfall discharge modeling)
- understanding of Project-related effects on complex ecosystems that contain interactions across different scales of time and space
- knowledge of the effectiveness of the environmental design features and mitigation for reducing or removing impacts (e.g., vessel speed restrictions)

Ecosystems are complex and are characterized by interactions across multiple scales, nonlinearity, self-organization, and emergent properties (Boyce 1992, Holling 1992, Levin 1998, Wu and Marceau 2002). These characteristics can confound the collective understanding of ecosystem processes and limit the accuracy of predictions on the effects of development on wildlife populations. To be scientifically defensible, residual effects predictions must be tempered with uncertainty associated with the data and knowledge of the ecosystem. To reduce uncertainty associated with effects to marine mammals, conservative estimates of the Project area affected were applied to determine the extent of the effect as a result of Project activities.

It is understood that development activities may directly and indirectly affect marine mammal habitat, abundance, and movement. Long-term, comprehensive monitoring studies documenting the resilience of marine mammals to development, the effectiveness of mitigation, and the time required to reverse these impacts are lacking, particularly with respect to potential long-term impacts of behavioural changes due to elevations in underwater noise. Uncertainty remains surrounding the degree to which some effects may occur, and in the effectiveness of some marine mammal mitigative techniques.

5.19.3.2 Potential Interactions of the Project and Proposed Mitigation

Potential interactions between the Project activities and marine mammals, and mitigation measures proposed to avoid or minimize the interactions are presented in the following sections.

5.19.3.2.1 Potential Interactions

Potential interactions between Project activities and marine mammals during the construction, operation, and decommissioning are identified in **Table 5.19-9**. The following criteria have been used to indicate the degree of the effect from the interaction between marine mammals and each activity:

- No interaction is predicted.
- Minor interaction (i.e., an adverse effect may result from an interaction, but standard measures to avoid or minimize the potential effect are available and well understood to be effective, and any residual effects are negligible).

- Carried forward means that interactions may result in an adverse effect and have been carried forward to the cumulative effects assessment.

Effects to marine mammals from spills of toxic or hazardous materials (e.g., hydrocarbon fuels, lubricants, concrete) into environmentally sensitive habitat, loss of containment of LNG, and vessel strikes are noted in the interactions table; however, they are addressed in **Section 11.0 Accidents and Malfunctions**. The interaction is therefore identified as not applicable (n/a) in **Table 5.19-9**.

Table 5.19-9 Potential for Interactions between Project-related Activities and Marine Mammals

Project Activities and Physical Works	Marine Mammals Interaction	Nature of Interaction and Rationale for Interaction Rating
Construction Phase		
All Project construction activities and works	Not applicable	See below
Transportation of construction crews to the Project area via crew boat or ferry, transportation of materials and supplies to the Project area via barge, and emergency transportation via helicopter	(n/a)	• injury or death due to vessel strikes (see Section 11.0 Accidents and Malfunctions which determined that there are not likely to be significant adverse effects) • toxic effect from accidental release of deleterious substances (see Section 11.0 Accidents and Malfunctions which determined that there are not likely to be significant adverse effects)
	Minor interaction	• changes in food availability due to accidental release of deleterious substances¹ • underwater noise effects from Project vessels including deep-sea vessels
Site clearing	Minor interaction	changes in food availability from potential changes in forage fish habitat quality due to erosion and sediment release into the marine environment ¹
Blasting where required to accommodate Project infrastructure	Minor interaction	changes in food availability from potential changes in forage fish habitat quality due to dust and introduction of nitrogen compounds ¹ . In-air noise effects from blasting ¹ .
Demolition of infrastructure not required for the Project	Minor interaction	changes in food availability from potential changes in forage fish habitat quality due to erosion and sediment release into the marine environment ¹ . Changes in food availability from potential changes in forage fish habitat quality due to leaching of creosote during removal of old piles ¹ .
Upgrades to existing buildings and infrastructure, including site administration and safety facilities	No interaction predicted	no effect is likely; upgrades to existing buildings will be upland construction
Installation of stormwater and erosion and sediment control measures	No interaction predicted	no effect is likely. Installation of stormwater and erosion and sediment control measures are a mitigation measure and not likely to cause negative changes
Construction of Mill Creek water intake, pipeline, and water storage tank	No interaction predicted	no effect is likely. Construction of the Mill Creek water intake is upland construction only. Potential changes to surface water quality were determined to be within guidelines for aquatic health

Project Activities and Physical Works	Marine Mammals Interaction	Nature of Interaction and Rationale for Interaction Rating
Installation of batch plant	No interaction predicted	no effect is likely. The batch plant will be placed on land a minimum of 30 m from a waterbody, so “no interaction” is likely
Upgrading and construction of onsite roads	Minor interaction	changes in food availability from potential changes in forage fish habitat quality due to erosion and sediment release into the marine environment ¹ .
Construction and upgrading of small-craft floats	Minor interaction	- changes in food availability from potential changes in forage fish habitat quality due to siltation/re-suspended sediment¹ - changes in food availability from potential changes in forage fish habitat quality due to potential release of cementitious material during cast-in-place works¹. Changes in food availability from potential changes in forage fish habitat quality due to leaching of creosote during removal of old piles ¹
Waste material disposal at permitted offsite and onsite landfills	(n/a)	toxic effect from accidental release of deleterious substances ¹ (see Section 11.0 Accidents and Malfunctions which determined that there are not likely to be significant adverse effects)
	(n/a)	changes in food availability due to accidental release of deleterious substances (see Section 11.0 Accidents and Malfunctions)
Construction of electrical substations and transformers and cables and powerlines	No interaction predicted	upland activity; no effect is likely
Construction of land-based civil works, including foundation excavation, cast-in-place concrete, and structures	Minor interaction	changes in food availability from potential changes in forage fish habitat quality due to erosion and sediment release into the marine environment ¹ . Changes in food availability from potential changes in forage fish habitat quality due to potential release of cementitious material during cast-in-place works ¹
Construction of the foundation and uploading dock for land-based LNG facility, including natural gas piping; transfer of the LNG facility to its foundation	Minor interaction	- changes in food availability from potential changes in forage fish habitat quality due to erosion and sediment release into the marine environment¹ - changes in food availability from potential changes in forage fish habitat quality due to potential release of cementitious material during cast-in-place works¹. Changes in habitat quality and food availability due to accidental release of deleterious substances ¹ .

Project Activities and Physical Works	Marine Mammals Interaction	Nature of Interaction and Rationale for Interaction Rating
Construction of floating storage and offloading unit (FSO) jetty, including pile driving and shoreline modifications to accommodate structural infrastructure, including possible dredging and permanent mooring of FSO	Minor interaction	• changes in food availability from potential changes in forage fish habitat quality due to erosion and sediment release into the marine environment¹ • changes in food availability from potential changes in forage fish habitat quality due to potential release of cementitious material during cast-in-place works¹ • changes in habitat quality and food availability due to accidental release of deleterious substances¹ • changes in habitat quality and food availability due to mobilization of legacy contaminants from disturbance to the seafloor¹ • changes in food availability due to mortality of forage fish as a result of underwater noise from pile driving¹ • changes in food availability due to direct loss of forage fish habitat from construction of infrastructure¹. No dredging is currently anticipated; therefore, no potential effects on marine mammals has been assessed
	Carried forward	underwater noise effects from pile driving
Connection of utilities (e.g., electrical, controls, gas, water) to LNG facility and FSO	No interaction predicted	no effect is likely; upland activity with no land likely disturbance
Installation of seawater cooling system, including inlet and outlet structures	Minor interaction	changes in food availability due to direct loss of forage fish habitat from construction of infrastructure ¹
Re-vegetation of areas of the Green Zone	No interaction predicted	no effect is likely. Upland activity and subject to any sediment and erosion control measures
Operation Phase		
All Project operation activities and works	Not applicable	See below
Commissioning of equipment for startup	No interaction predicted	no effect is likely; no land or marine disturbance anticipated
Delivery of natural gas via piping from the FortisBC natural gas metering station to the LNG facility	No interaction predicted	no effect is likely; no land disturbance is likely
Pre-treatment and liquefaction of natural gas at the LNG facility	Minor interaction	• changes in food availability due to mortality of forage fish from impingement at water intake¹ • changes in food availability due to mortality of forage fish from thermal outfall discharge and residual chlorine¹ • changes in food availability due to indirect loss of forage fish habitat from avoidance of warm cooling water plume area¹ • changes in food availability due to potential change in forage fish habitat quality from effluent¹
Storage and offloading of LNG at the FSO	No interaction predicted	no effect is likely; no land disturbance is likely

Project Activities and Physical Works	Marine Mammals Interaction	Nature of Interaction and Rationale for Interaction Rating
Mooring of LNG carriers at the FSO for LNG transfer	Carried forward	underwater noise effects from LNG carriers
	Minor interaction	- changes in food availability due to direct loss of forage fish habitat from shading of marine vegetation¹ - changes in food availability due to potential change in habitat quality resulting from remobilization of legacy contaminants from the sea bottom caused by ship propeller scour¹
Shipping within Howe Sound (approximately 40 LNG carriers per year) in established shipping lanes	Carried forward	underwater noise effects from LNG carriers and tugs
	(n/a)	- injury or death due to vessel strikes.(see Section 11.0 Accidents and Malfunctions) - toxic effect from accidental release of deleterious substances (see Section 11.0 Accidents and Malfunctions)
	Minor interaction	- changes in food availability due to accidental release of deleterious substances¹. - changes in food availability due introduction of exotic species from ballast water exchange¹.
Patrolling of Control Zone around LNG facility, FSO, and LNG carriers	Carried forward	underwater noise effects from Project vessels
	(n/a)	toxic effect from accidental release of deleterious substances. (see Section 11.0 Accidents and Malfunctions)
	(n/a)	- changes in food availability due to accidental release of deleterious substances¹. - injury or death due to vessel strikes.(see Section 11.0 Accidents and Malfunctions which determined that there are not likely to be significant adverse effects)
Extraction of water from Mill Creek	No interaction predicted	no effect is likely; no land disturbance is likely
Supporting infrastructure: transport of employees through private passenger ferry terminal, transport of supplies using barges, site administration, safety facilities, and emergency transportation via helicopter	Carried forward	underwater noise effects from LNG carriers and tugs
	(n/a)	toxic effect from accidental release of deleterious substances (see Section 11.0 Accidents and Malfunctions)
	(n/a)	changes in food availability due to accidental release of deleterious substances ¹
	(n/a)	injury or death due to vessel strikes (see Section 11.0 Accidents and Malfunctions which determined that there are not likely to be significant adverse effects)

Project Activities and Physical Works	Marine Mammals Interaction	Nature of Interaction and Rationale for Interaction Rating
Decommissioning Phase		
All Project decommissioning activities	Not applicable	See below
Dismantling of equipment and buildings that will not continue to serve a purpose	(n/a)	injury or death due to vessel strikes. (see Section 11.0 Accidents and Malfunctions)
	Minor interaction	changes in food availability from potential changes in forage fish habitat quality due to erosion and sediment release into the marine environment ¹
Removal of LNG facility and FSO from the Project area	(n/a)	toxic effect from accidental release of deleterious substances (see Section 11.0 Accidents and Malfunctions)
	(n/a)	changes in food availability due to accidental release of deleterious substances ¹
	(n/a)	injury or death due to vessel strikes.(see Section 11.0 Accidents and Malfunctions which determined that there are not likely to be significant adverse effects)

Notes: ¹ = rationale to support the minor interaction rating: As described in **Section 5.18 Forage Fish and Other Fish (Marine)**, it is unlikely that significant adverse effects will result from the Project effects related to forage and other fish habitat in terms erosion and sediment, cementitious material, legacy contaminant, mortality of forage fish and loss of forage fish habitat, all of which relate to key habitat factors important to marine mammals. Consequently these related interactions are considered minor and therefore are not carried forward for further assessment.

5.19.3.2.2 Potential Adverse Effects

Based on the interactions table (refer to **Table 5.19-9**), the potential adverse effects on marine mammals during construction, operation, and decommissioning of the Project are summarized below and discussed in the subsequent sections:

- indirect effects from changes in food availability from potential changes in forage fish habitat quality during construction, operation and decommissioning
- effects as a result of in-air noise during construction
- effects as a result of underwater noise during construction, operation, and decommissioning

5.19.3.2.2.1 Construction

Changes in Habitat Quality

Several Project activities described in **Table 5.19-9** may create changes to forage fish availability, resulting in changes in marine mammal habitat quality due to the following:

- changes in forage fish habitat due to erosion and sediment release into the marine environment
- changes in forage fish habitat due to release of cementitious material during cast-in-place works

- changes in forage fish habitat due to mobilization of legacy contaminants from disturbance to the seafloor
- changes in food availability due to mortality of forage fish as a result of underwater noise from pile driving
- direct loss of forage fish habitat from construction of infrastructure

The pathways of these effects on marine forage fish and other fish are discussed in the greater detail in **Section 5.18 Forage Fish and Other Fish (Marine)**. Indirect effects on marine mammals may include changes in the abundance and distribution of forage fish species. From the assessment in **Section 5.18 Forage Fish and Other Fish (Marine)** no significant effects on forage fish are likely as a result of the Project; therefore, any effect on marine mammals as a result of the availability of forage fish is considered negligible and is not assessed further.

In-air noise

Marine mammals that spend some of their time hauled-out on land (e.g., pinnipeds) could be affected by increases in in-air noise as a result of blasting activities during Project construction in the Project area. In general, pinniped in-air hearing sensitivity is poor, at frequencies below 2 kilohertz (kHz) (Richardson et al. 1995). For in-air noise, the National Marine Fisheries Service (NMFS) has adopted behavioural disturbance acoustic thresholds for both harbour seals (90 dB relative to 20 micro Pascals (μ Pa) at 1 metre (m) (re 20 μ Pa) (rms)) and other pinnipeds (100dB re 20 μ Pa (rms)). As there are no acoustic behavioural thresholds established under Canadian legislation for in-air noise, the NMFS thresholds have been applied for the present assessment. No acoustic thresholds presently exist under Canadian or US legislation (NMFS) for onset of auditory injury in pinnipeds with respect to in-air noise.

There is limited information regarding the potential effects of blasting noise on hauled-out pinnipeds. Most of the relevant literature is based on in-air noise effects from aircraft movements. Based on this information, we can infer that the potential effects of in-air blasting on pinnipeds range from temporary displacement from the haul-out areas to low levels of mortality (limited to pups) as a result of trampling by fleeing adults (Richardson et al. 1995). Blasting activities near an established Steller sea lion haul-out near Vancouver Island (Race Rocks) were reported to generate in-air noise levels above the pinniped acoustic disturbance threshold (i.e., >109dBF peak), but below levels of potential auditory injury (i.e., <149dBF peak) (Demarchi et al. 2012).

The response of pinnipeds to in-air blasting will depend on the distance between the animal and the blasting source, as well as the intensity of the sound. No established pinniped haul-out sites or rookeries have been identified in the upper reaches of Howe Sound near the Project area (refer to **Appendix 5.10-1 Marine Resources Baseline Study**). Haul-out behaviour has been observed, however, with individual or small groups of seals in the Project area outside the marine terminal footprint. Based on

available literature, in-air blasting may exceed behavioural acoustic thresholds for pinnipeds, resulting in temporary displacement of individuals hauled out in close proximity to the terminal footprint area; however, individuals will likely return to these areas once blasting activities have subsided (Richardson et al. 1995, Demarchi et al. 2012). Because there are no major haul-out sites close to the Project area, behavioural effects from blasting would likely be limited to a small number of individuals. Consequently, no effect at the population level is likely; therefore, the effect is likely to be negligible and is not considered further in the assessment.

Underwater Noise

The potential effects of underwater noise exposure to marine mammals are assessed in this section, which includes an overview of underwater sound terminology relevant to marine mammals and their receiving environment. A summary of recommended mitigation measures is provided in **Table 5.19-13**. The characteristics and significance of adverse residual effects related to underwater noise effects on marine mammals are provided in **Table 5.19-15**.

Underwater sound can be described through a source-path-receiver model. An acoustic source emits sound energy that radiates outward and travels through the water and the seafloor as pressure waves. The sound level decreases with increasing distance from the acoustic source as the sound pressure waves spread out under the influence of the surrounding environment. The amount by which the sound levels decrease between a source and receiver is called transmission loss. The amount of transmission loss that occurs depends on the source-receiver separation, the frequency of the sound, the properties of the water column, and the properties of the seafloor layers. An animal senses the sound at a level that is dependent on the amount of transmission loss between the source and the receiver (Richardson et al. 1995).

The efficiency of underwater sound propagation allows marine mammals to use underwater sound as a primary method of communication, navigation, and prey detection. Underwater anthropogenic noise has gained recognition as an important stressor for marine mammals because of their reliance on underwater hearing for maintenance of these critical biological functions (Richardson et al. 1995, Ketten 1998). The potential effects of underwater noise on marine mammals depends, to a degree, on the type of marine mammal involved as well as the characteristics of the sound emitted, including the received sound level and the frequency content of the received sound signal relative to the hearing abilities of the animal. The potential zone of effect of anthropogenic sound is also influenced strongly by the properties of natural background (ambient) sound present in the area of exposure (Richardson et al. 1995) and local sound transmission properties, which are determined by site-specific environmental factors such as seafloor bathymetry, substrate composition, and water column characteristics.

Effects of underwater sound on marine mammals are generally measured through observations of behavioural responses to sounds used as a surrogate measure for sensitivity or susceptibility (McCauley 1994, Richardson et al. 1995). Potential effects range from subtle changes in behaviour at low received levels to strong disturbance effects or temporary or permanent hearing impairment at high received levels. Several metrics are commonly used to characterize sound pressure levels (SPLs) from impulsive noise sources such as impact pile driving and non-pulsed (continuous) noise sources such as shipping. For the present assessment, all received sound levels presented and discussed in this assessment are quantified using the primary sound-level metrics of root-mean-square sound pressure level (rms SPL), which involves averaging the sound pressure level over a period of time to determine the energy produced by the sound pressure wave. Underwater sound levels are expressed in dB, which is a logarithmic ratio relative to a fixed reference pressure of $1\mu\text{Pa}$ (equal to 10^{-6} Pa or 10^{-11} bar).

Marine mammals are acoustically diverse, with wide variations in ear anatomy, frequency and hearing range, and amplitude sensitivity (Ketten 1991). Audible frequencies for toothed whales (e.g., killer whales, white-sided dolphins, and porpoises) range from 0.08 to 150 kHz, but they are most sensitive to sounds in the mid-frequency range of 8 kHz to 90 kHz (Richardson et al. 1995, Southall et al. 2007). Toothed whales also produce echolocation clicks in the 0.5 kHz to 25 kHz range (at dominant frequencies from 1 kHz to 6 kHz) to detect the presence and location of objects including prey (Richardson et al. 1995). Baleen whales (e.g., humpback whales) are most sensitive to sounds in the low-frequency range, with an estimated auditory bandwidth of 0.007 kHz to 22 kHz (Southall et al. 2007), overlapping with the low-frequency noise typically emitted by shipping (0.05 to 0.5 kHz) (Richardson et al. 1995). Underwater hearing sensitivity in harbour seals and sea lions falls in between that of baleen and toothed whales with an estimated auditory bandwidth (flat audiogram) of 1 to 50 kHz (Terhune 1981).

Assessment of the potential effects of underwater anthropogenic noise on marine mammals requires acoustic thresholds against which received sound levels can be compared. The injury and disturbance sound threshold criteria currently applied to most underwater noise assessments in Canada and the US are based on the rms SPL metric as adapted for pulsed and non-pulsed sound sources. The injury threshold for cetaceans is 180 dB re 1 micro-Pascal (μPa) (rms), and 190 dB re $1\mu\text{Pa}$ (rms) for pinnipeds for both pulsed and non-pulsed noise sources (NOAA 2014). Two types of auditory injury are considered in National Ocean and Air Administration's (NOAA) injury sound threshold criteria (NOAA 2014), referred to as temporary threshold shifts (TTS) and permanent threshold shifts (PTS). The term TTS refers to a relatively short-term reversible loss of hearing following noise exposure, often resulting from cellular fatigue and metabolic changes (Saunders et al. 1985, Yost 2000). The term PTS refers to an irreversible loss of hearing (permanent damage) following noise exposure that commonly results from inner ear hair cell loss or severe damage or other structural damage to auditory tissues (Saunders et al., 1985, Henderson et al. 2008). The behavioural threshold for all marine mammals is 160 dB re $1\mu\text{Pa}$ (rms) for pulsed noise (e.g., impact pile driving) and 120 dB re $1\mu\text{Pa}$ (rms) non-pulsed noise (e.g., shipping)

(NOAA 2014). Behavioural responses are not necessarily predictable from the sound-source level (loudness) and may vary depending on factors such as age and status of the animal, type of activity, and social context (McCauley et al. 2003).

Marine mammals may be affected by increased underwater noise generated in the Project area during construction of the proposed marine infrastructure including the floating storage and offloading unit (FSO) jetty and as a result of Project vessel and shipping activities. The main sources of underwater noise considered in this assessment include impact driving of steel^d piles during the construction phase and Project vessel activities during construction, operation, and decommissioning (e.g., deep-sea vessels, liquefied natural gas (LNG) carriers, worker ferries, tugs and other Project vessels).

Noise modeling was conducted using the Practical Spreading Loss Model, a two-dimensional noise model designed by NMFS specifically for pile driving and drilling activities (WSDOT 2009). Underwater noise levels were calculated on the basis of methods described in the Washington State Department of Transportation's (WSDOT's) Advanced Training Manual, *Biological Assessment Preparation for Transportation Projects*, Version 10-08 (WSDOT 2014).

The Practical Spreading Loss Model is based on the following formula for geometric spreading:

$$TL = 15 \times \log (R1/R2) + \alpha R$$

Where:

TL: is the transmission loss in dB.

R1: is range in meters of the sound pressure level.

R2: is the distance from the source of the initial measurement.

αR : linear absorption and scattering loss

Solving for transmission loss will provide the underwater SPL at a given distance. To determine at what distance or range a known SPL will occur, the equation must be solved for R1:

$$R1 = (10(TL/15)) \bullet R2$$

The NMFS model was used to calculate the noise attenuation in the Project area to determine at what distance from the source the sound level would be expected to reach injury and behavioural threshold values for marine mammals. The most conservative injury threshold for marine mammals was adopted in the assessment for determining the spatial limits of underwater noise effects and associated mitigation measures.

^d It is assumed for the purpose of this assessment that only **steel** piles (and not another material, e.g., wood or concrete) will be used during construction of Project infrastructure.

Prediction confidence in the underwater noise model was considered to be moderate based on the following factors:

- The activities associated with construction and operation of the marine facilities were modeled using conservation values and measured values from similar materials, equipment, and operations.
- The NMFS model is designed specifically for pile driving activities.
- There are no other significant noise sources in the Project area that would need to be modeled with the anticipated Project noise sources.
- The short duration of all noise sources minimizes potential adverse effects.
- Quality assurance was accomplished by implementing quality control checks on all model runs to ensure that model input parameters were correct, model output was plotted correctly, and any calculations were checked.
- There are limitations of using a two-dimensional model with respect to sound attenuation in a three-dimensional environment. The spreading loss model used for the underwater noise assessment only provides a rough approximation to the actual spreading loss in the marine environment. The model assumes that sound travels in a homogeneous environment. It does not take into account potential propagation effects related to absorption and reflection, which may occur as a result of sound interacting with local marine topographical features, nor effects related to refraction that may occur as a result of boundary layer effects and water column stratification. For example, physical aspects of the receiving environment (e.g., freshwater surface lens, in-field gradients in temperature, bottom topography) could cause sound levels to attenuate more rapidly than predicted by this geometric spreading-based model. Sophisticated sound field models do exist that take into account the actual sound speed field in the ocean, and the reflections from the sea surface and sea floor as the sound travels away from the source. However, these types of models require detailed, site-specific inputs for the model with respect to existing oceanographic, bathymetric, and substrate conditions, which are not available for the Project area. Nonetheless, when the data required for a more complex model are not available, the practical spreading loss model is commonly used to estimate sound levels around a source.

Pile Driving

Woodfibre LNG Limited is proposing to install an FSO jetty and associated marine infrastructure to receive LNG carriers and other Project vessels at its proposed LNG terminal in Howe Sound. High levels of underwater noise are likely to result from pile-driving activities occurring intermittently over a 5- 6 month period during the construction phase. Underwater noise generated during pile driving is dependent on the type of pile being driven, the type of hammer, substrate type, and water depth (ICF Jones and Stokes and Illingworth and Rodkin Inc. 2009). Underwater noise related to pile driving will be temporary and limited to the construction phase. The size and number of piles that will be used for construction of the proposed marine infrastructure are outlined in **Table 5.19-10**.

Table 5.19-10 Number and Diameter of Piles to be Installed in Marine Environment

Construction Activity	Number of Steel Piles	Approximate Diameter of Piles (m)
Loading Platform	48	1.1
FSO Mooring System	8	2.0
	18 (assumes 2 pile-supported shore moorings may be required and that each shore mooring will comprise 9 vertical piles)	1.0
FSO Utility Ramp and Personnel Access Ramp	18	0.8

The California Department of Transportation (ICF Jones and Stokes and Illingworth and Rodkin Inc. 2009) and the WSDOT (2009) present a range of reference noise levels for various pile sizes and types; however, reference data are not available for the exact size of pile being considered by WLNG.

Table 5.19-11 presents the reference source-level data for impact pile driving from WSDOT (2009) and California Department of Transportation (ICF Jones and Stokes and Illingworth and Rodkin Inc. 2009) that have been used as the basis of this noise assessment. Peak pressure is representative of the maximum pressure and rms is representative of the average pressure. All sound pressure levels are referenced to re 1 µPa.

Table 5.19-11 Underwater Pile-driving Noise Reference Source Levels

Project Activity	Sound Levels (Single Strike)		
	Reference Distance from Pile (m)	Peak Pressure (dB)	rms SPL (dB)
1.5-m-diameter steel pile (single strike)	10	210	195
2.44-m-diameter steel pile (single strike)	25	213	197

Underwater noise modeling results are presented in **Table 5.19-12**. Using the more conservative pile size (2.44 m) as the reference source in the noise model, noise levels from pile installation using an impact hammer are predicted to attenuate to the most conservative injury threshold for marine mammals (180 dB) at a distance of 340 m from the source. The model also predicts that noise levels from this activity will attenuate to the behavioural threshold for marine mammals (160 dB) at a distance of 7,322 m from the source. Based on these results, potential hearing impairment effects are not likely unless a marine mammal is located <400 m from the source during active pile driving. Noise modeling results suggest that behavioural effects are likely to occur, although these will be limited to the upper reaches of Howe Sound near the Project area.

Table 5.19-12 Distances to Marine Mammal Acoustic Injury and Behavioural Thresholds from Unmitigated Impact Pile Driving and Vessel Noise

Project Activity	Predicted Noise (dB)	Injury Threshold (dB) (Pinnipeds / Cetaceans)	Distance to Injury Threshold (m)	Behavioural Threshold (dB)	Distance to Behavioural Threshold (m)
Impact Pile Driving	213 Peak/ 197 rms SPL @ 25 m	190/180	73/340	160	7322
Vessel Noise	175 rms @ 1m	190/180	0/0	120	4642

Note: Unless otherwise noted, all sound pressure levels are referenced to 1 micro Pascal (uPa)

Vessel Noise

Increased numbers of deep-sea vessels operating in the proposed LNG carrier route, as well as other Project vessels operating between Squamish Harbour and the Project area, will introduce underwater noise to the marine environment and may cause marine mammals to avoid affected areas. Support vessels will include tugboats, barges, and piling vessels to remove and install new marine infrastructure. During the construction phase, it is anticipated that the Project will generate the following estimated additional vessel traffic within the LAA:

- approximately six 500-passenger capacity ferry movements per day between the Project site and Darrell Bay
- approximately 20 water taxi movements per week between the Project site and the government dock in Squamish
- approximately two equipment barge movements per week between the Project site and North Vancouver
- approximately four fuel barge movements per month between the site and North Vancouver
- intermittent support vessels in Squamish Harbour
- approximately 24 deep-sea vessel movements through Howe Sound over the course of construction

In general, ship noise increases with ship size, power, load, and speed, with the majority of underwater noise generated by propeller cavitation (Mitson 1995, JASCO 2011).

Vessel noise was analyzed as a continuous noise source in the NMFS model. There are no data available for noise levels from the specific vessels anticipated for the Project. Predicted noise levels were therefore obtained using measured sound levels from an LNG carrier similar to the largest vessel proposed for the Project (JASCO 2006). The model assumed that vessels approaching or leaving the marine facilities would have a maximum SPL (rms) of 175 dB (rel 1 uPa at 1 m) (JASCO 2006). Vessels of this size typically emit underwater noise in the 0.010-kHz to 30-kHz bandwidth range (Richardson et al. 1995, Nowacek et al. 2007).

Underwater noise modeling results are presented in **Table 5.19-12**. The assumed maximum SPL of 175 dB (rms @ 1m) is below the injury threshold for both pinnipeds and cetaceans. Modeling results indicate that noise levels from the largest Project vessels will attenuate to the acoustic behavioural threshold for marine mammals (120 dB) at a distance of 4,642 m from the source (vessel location). Marine mammals that are located in proximity to the LAA likely have had prior experience with vessel presence and associated underwater noise from existing traffic, given the volume of shipping that presently occurs in the area and natural acoustic sources (e.g., surface agitation such as wind and waves; see **Section 5.19.2.4**). The individual and species-specific reactions to anthropogenic noise may include no reaction, subtle reaction (e.g., change in breathing rate), and obvious reaction (e.g., altering swim direction and avoidance). Underwater noise has the potential to cause an avoidance response or auditory masking (interference with communication space) in marine mammals. In the extreme case, these effects could lead to a change in migration patterns, reduced foraging efficiency, increased energy expenditure, and resulting reduced fecundity and population health.

Based on the available literature, it is unlikely that the deep-sea vessels, including LNG carriers and escort tugs, will emit underwater noise at levels sufficient to cause injury to pinnipeds or cetaceans in the LAA. Potential injury and mortality of marine mammals as a result of underwater noise exposure from Project vessels are therefore not considered further in the assessment (i.e., adverse effects are likely to be negligible). Vessel noise is likely to adversely affect the behaviour of marine mammals in close proximity (<5 km) of the proposed terminal and associated shipping routes (e.g., in the LAA). Likely adverse effects on marine mammal behaviour are therefore carried forward in the assessment (**Section 5.19.3.4**).

5.19.3.2.2.2 Operation

Underwater Noise

Similar to the construction phase, an increase in the number of vessels operating in the Project area will introduce underwater noise to the marine environment and may cause marine mammals to avoid affected areas. Marine mammals that enter the vicinity of the LAA will likely have prior experience of noise exposure from large vessels (e.g., deep-sea cargo and BC ferries) that contribute to existing background (ambient) noise levels.

On average, 40 LNG carriers are expected to call at the terminal per year (80 movements) with only one LNG carrier docked at the FSO at any one time, and loading occurring over a period of approximately 24 hours. Project activities during the operation phase will lead to a 1% increase in large vessel traffic in Howe Sound, and large vessel traffic specific to Montagu and Ramillies Channels will increase by 10%. The proportion of deep-sea vessel traffic within the LAA will increase on average by 47% (up to 40 arrivals per year) over the current low level of deep-sea vessel traffic using this route. The Project will lead to an increase in deep-sea vessel movements similar to levels when the former Woodfibre Pulp Mill was operational.

The worker ferry service and water taxis are anticipated to travel to the Project site from Darrell Bay during the early stages of operation, but WLNG plans to investigate potential alternatives to the Darrell Bay ferry terminal within Squamish Harbour for future operational use. Water taxis are expected to also make 20 movements per week, and fuel delivery barges are expected to make four movements per month. Additionally, there are expected to be two flat-top barge movements once every three weeks.

The increase in marine noise resulting from vessel traffic associated with Project activities is not expected to exceed injury thresholds for marine mammals **Table 5.19-12**); therefore this potential adverse effect is likely to be negligible for the Project and is not carried forward for further assessment. Vessel noise may produce a localized behavioural response, including avoidance of the area around vessels and the terminal in the LAA. Behavioural effects as a result of increased vessel traffic during operation are considered to be similar to those described for construction phase vessel noise and are therefore considered likely and are carried forward for further assessment (see **Section 5.19.3.2.2.1**).

5.19.3.2.2.3 Decommissioning

Underwater noise effects related to vessel activities during decommissioning are consistent with those described for the construction phase and those related to potential mammal behavioural changes are considered likely and therefore carried forward for further assessment.

5.19.3.2.3 Proposed Measures to Mitigate Project Effects

The following measures will be implemented to mitigate effects from Project activities on marine mammals and are summarized in **Table 5.19-13**.

M5.17-6 – Underwater Noise Management Plan

Woodfibre LNG Limited will prepare and implement an Underwater Noise Management Plan component of the Marine Works Management Plan to mitigate potential mortality and behavioural changes to birds, fish and marine mammals. The plan will reference *Best Management Practices for Pile Driving and Related Operations* (BCMPDCA and DFO 2003) and will contain the following measures:

Pile Driving and Related Activities:

- Multiple underwater noise-generating activities will be minimized when practicable (e.g., avoid multiple pile-driving activities at the same time). Where multiple underwater noise-generating activities are planned, they will be sequenced to minimize construction duration.
- Works in the marine environment will be conducted during the least-risk fisheries work window specified by DFO for the region unless otherwise agreed upon by DFO. The prescribed work window for Howe Sound is August 16 to January 31 (DFO 2014).
- Where possible, pile-driving activities will avoid impacting hard substrates to prevent disturbance to fish habitat.

- Vibrational pile driving will be used where practical and feasible as impact pile driving is associated with louder SPLs underwater. The use of 'vibro-hammers' for pile installation minimizes the effects on fish by decreasing the anticipated noise levels.
- A "ramp-up" or "soft-start" technique will be used. Where equipment allows, power will be built up slowly from a low energy startup to give adequate time for marine wildlife to leave the vicinity before exposure to the maximum SPL. There will be a soft start every time pile driving is resumed following an interval of no pile driving.
- Underwater noise from pile-driving activities will be monitored in accordance with the following:
 - Sound will not exceed 30 kPa at a distance of 1 m to 2 m from pilings.
 - If the sound exceeds 30 kPa at a distance of 1 m to 2 m from pilings, measures will be taken to reduce either the intensity of the sound generated or the level of sound propagation through the water column. The appropriate measures will be chosen based on practicality to the Project and effectiveness and may include:
 - silt curtains around pile driving activities
 - bubble curtains around pile driving activities
 - a vibratory hammer in place of an impact hammer for pile driving
- Prior to pile driving, the perimeter of the pile-driving area will be identified so that work occurs within the confines of the pile driving area.

Monitoring:

- The Environmental Monitor will be responsible for monitoring underwater noise and potential effects to wildlife, and implementing corrective mitigation measures if necessary. Underwater noise will be monitored in order to establish proper mitigation measures for the underwater noise outputs resulting from the Project (e.g., establishing safety zones in the event underwater noise levels exceed injury thresholds (180 and 190dB re 1 µPa)).

M5.19-1 – Avoidance of Pile Driving on Hard Substrates

In addition to the mitigation measures described in M5.17-6, WLNG will prevent pile-driving activities from impacting hard substrates, where possible. During impact pile-driving activities, a qualified specialist marine mammal observer will monitor for marine mammals and will communicate presence or absence to the contractor.

M5.19-2 – Marine Mammal Management Plan

Woodfibre LNG Limited will produce a Marine Mammal Management Plan for the Project. This plan will include vessel speed reductions and avoidance of marine mammals:

- LNG carriers and other deep-sea vessel speeds will be kept at a maximum of 8 to 10 knots when operating in the LAA.

- All Project vessels will follow established shipping lanes/navigational routes typically used in the area.
- All Project vessels will maintain a constant course and constant speed, to the extent practical, when operating in the RAA.
- Under no circumstances, other than in the case of an emergency, will vessels approach within 100 m of any marine mammal.
- If marine mammals approach within 100 m of a vessel, the vessel will reduce its speed and, if possible, cautiously move away from the animal. If it is not possible for a vessel to move away from or detour around a stationary marine mammal or group of marine mammals, the vessel will reduce its speed and wait until the animal(s) moves at least 100 m from the vessel prior to resuming speed.
- During impact pile driving activities, a qualified specialist marine mammal observer will monitor for marine mammals and will communicate presence/absence to the contractor.

Table 5.19-13 summarizes potential effects and mitigation measures identified for marine mammals during the construction and operation phases of the Project.

Table 5.19-13 Summary of Potential Effects and Mitigations for Marine Mammals

Summary of Potential Effect	Mitigation Measure	Mitigation Number
Construction Phase		
Underwater noise from pile driving	Underwater Noise Management Plan	M5.17-6
	Avoidance of pile driving on hard substrates	M5.19-1
Underwater noise from deep-sea vessels and other Project vessels	Underwater Noise Management Plan	M5.17-6
	Marine Mammal Management Plan	M5.19-2
Operation Phase		
Underwater noise from LNG carriers and other Project vessels	Underwater Noise Management Plan	M5.17-6
	Marine Mammal Management Plan	M5.19-2
Decommissioning Phase		
Underwater noise from deep-sea vessels and other Project vessels	Underwater Noise Management Plan	M5.17-6
	Marine Mammal Management Plan	M5.19-2

5.19.3.3 Residual Effects and their Significance

The potential residual effects of the Project and their significance are described in terms of the effects characteristics and the definitions for significance for marine mammals. Residual adverse effects are those effects remaining following the implementation of mitigation and include the following:

- potential injury as a result of Project-related underwater noise
- changes in behaviour due to underwater noise

5.19.3.3.1 Characterization of Potential Injury from Underwater Noise

This section presents a description of potential injury as a result of underwater noise produced during the Project's construction phase.

5.19.3.3.1.1 Construction

Pile Driving

After the implementation of known and effective mitigation measures (e.g., bubble curtains; refer **Section 5.18 Forage Fish and Other Fish (Marine)**), the Project-generated underwater noise as a result of impact pile-driving activities is not likely to exceed 180 dB re 1uPa at a distance of 340 m from the piles. With the implementation of mitigation measures (e.g., relevant provisions of the Underwater Noise Management Plan and Marine Mammals Management Plan) pile driving is not likely to result in death or injury to marine mammal species. In addition, habitat use by marine mammals in the Project terminal area appears to be minimal, with limited observations of cetaceans in Squamish Harbour reported by the BC Cetacean Sighting Network since 1990 and several harbour seals observed opportunistically by marine biologists during field studies conducted at the site (**Appendix 5.10-1 Marine Resources Baseline Study**).

The magnitude of the likely residual adverse effect would be low due to the adherence to levels of underwater noise below injury thresholds through the implementation of known and effective mitigation measures (e.g., marine mammal monitoring, underwater noise monitoring). The geographic extent is considered site-specific as the potential for pile driving to cause hearing impairment to marine mammal species is confined to the immediate area around the activity (e.g., within the Project area). The duration is considered short term as the potential for pile driving to occur is only during construction. The frequency is considered infrequent as the potential for auditory injury to marine mammals will be limited to pile-driving periods. Injury to marine mammals may be partially or fully reversible depending on the trauma incurred. The effect is considered fully reversible if the injury consists of a temporary threshold shift (TTS), as this type of auditory injury is temporary with the individual's hearing sensitivity returning to near normal (pre-exposure) levels over time. The effect is considered irreversible if the injury consists of a permanent threshold shift (PTS), as this type of auditory injury is lasting (hearing levels will not return to pre-exposure levels).

The context is considered moderate for listed marine mammal species and high for all other marine mammal species. No detectable changes are anticipated in marine mammal populations compared to baseline conditions as a result of injury due to pile driving.

With the proposed mitigation in place (e.g., underwater noise levels and marine mammal monitoring), an injury from underwater noise as a result of pile driving is not likely to occur. Given the availability of accepted mitigation measures, adverse residual effects on marine mammal populations are likely to be

negligible. There is a high level of confidence that the potential effect will not be greater than predicted; this is due to the implementation of known and effective mitigation measures for underwater noise and the localized area in which the potential effect could occur.

5.19.3.3.2 Characterization of Changes in Behaviour

This section presents a description of potential behavioural changes in marine mammals during all phases of the Project.

5.19.3.3.2.1 Underwater Noise – All Project Phases

Toothed whales are mostly sensitive to mid- and high-frequency sounds. Movement and presence of deep-sea vessels and LNG carriers emit low- to mid- frequency sound, and the movement and presence of water taxis and other smaller marine vessels emit higher-frequency sounds. These sounds can mask or limit audible communication between conspecifics (two or more individual organisms, populations, or taxa are conspecific if they belong to the same species) during foraging, breeding, and rearing young. An increase in underwater noise may lead to abandonment of forage areas or habituation to vessels. This is particularly problematic for southern resident killer whales that comprise a SARA-listed species and frequent waters in and around established vessel routes. However, the proposed LNG carrier routes do not overlap with the critical habitat of southern resident killer whales; therefore, behavioural disturbances due to underwater sounds on this population in their critical habitat are not expected. Consequently potential adverse effects to this population are likely to be negligible.

Baleen whales are most sensitive to sounds in the low frequency range and often react to low-frequency vessel and shipping noise (5 hertz (Hz) to 500 Hz) (Richardson et al. 1995). Observed behavioural responses to underwater noise include site avoidance and movement away from the sound source, interruption of feeding and foraging, and change in dive patterns (DFO 2013).

Underwater hearing sensitivity in seals and sea lions falls in between that of baleen and toothed whales, with an estimated auditory bandwidth between 75 Hz and 75 kHz. Phocid seals, such as the harbour seal, have underwater hearing thresholds between 60 and 85 dB re 1µPa, with flat audiograms between 1 kHz and 30 kHz to 50 kHz (Mohl 1968, Terhune and Ronald 1972, 1975; Terhune 1981). Some phocids are able to detect high-frequency sounds up to 180 kHz, although their sensitivity to sounds above 60 kHz is poor and frequencies cannot be discriminated (Mohl 1968).

Based on reports in the literature, it is conservative to assume that underwater noise associated with vessel operations may, in some cases, elicit behavioural response in individual marine mammals that are in close proximity to these vessels. Behavioural responses may include no reaction, subtle reaction (e.g., change in breathing rate), and obvious reaction (e.g., altering swim direction, avoidance) or auditory masking (e.g., interference with communication space). In the extreme case, these behavioural disturbances could lead to a change in migration patterns, and reduced foraging efficiency, increased energy expenditure, and could result in reduced fecundity and population health.

Vessel noise is transitory in nature and does not generally propagate at great distances from the vessel. Also important to the level of underwater noise generated by vessels are the operational aspects, such as speed and sudden alterations of course. Maintaining a constant speed and avoiding rapid changes in speed generates an even level of noise output, and avoids sudden spikes in underwater noise levels (Mitson 1995).

The magnitude of the effect of behavioural disturbance to marine mammals from underwater noise associated with Project vessels during all Project phases, and from pile driving during construction is considered medium as both impact pile driving and vessel noises are expected to exceed established behavioural criteria for marine mammals, but the effects will be localized to the Project area and the LAA. The geographic extent is considered local as potential behavioural effects associated with vessels will extend along the LNG carrier route in the LAA and site-specific for pile-driving activities as the effects will be limited to the Project area. The duration is considered to be long term over the course of all Project phases for potential behavioural effects associated with vessels, and short term over the course of the construction phase for potential behavioural effects associated pile driving. The frequency is considered frequent for vessel activities and infrequent for pile driving.

The effect is likely to be fully reversible as behavioural effects are likely to persist only for the duration of the vessel activities or pile-driving activities. Once these Project activities have been completed, marine mammals will likely return to the area to display behavioural activities that occurred in the LAA prior to the Project. The context of the effect is considered high for all marine mammal species. Marine mammals that occur in LAA likely have a high natural resilience to imposed stresses of underwater noise due to their prior experience with underwater noise from existing traffic, given the current volume of shipping that occurs in the area (**Section 5.19.2.4**), combined with natural acoustic sources (e.g., surface agitation, such as wind and waves; see **Section 5.19.2.4**).

The adverse residual effect is likely with a moderate degree of certainty that marine mammals will show changes in behaviour as a result of underwater noise from Project vessels and pile-driving activities. Based on available literature, marine mammals will either habituate to vessel sounds and remain in area, or leave temporarily and return once the noise has subsided; therefore, changes in behaviour are likely to be temporary and reversible, with no likely effects at the population level. Consequently any adverse residual effects on behaviour resulting from the Project are likely to be at the individual animal level and be negligible, therefore, no significant adverse residual effects of the Project on marine mammal behaviour are likely to result from the Project. The level of confidence that the effect will not be greater than predicted is considered moderate. This is due to lack of information regarding the long-term effects of increased shipping traffic on the behaviour of marine mammals combined with the application of conservative assumptions by the use of the NMFS behavioural thresholds.

5.19.3.4 Summary of Project-related Adverse Residual Effects and Significance

The potential adverse residual effects on marine mammals from the Project that remain following the implementation of mitigation include potential injury as a result of underwater noise from pile driving, and changes in behaviour due to underwater noise from pile driving and vessel activities.

Residual effects on marine mammals are likely to be negligible and not significant and are summarized in **Table 5.19-14** and **Table 5.19-15**.

Table 5.19-14 Summary of Determination of Significance of Adverse Residual Effects for Marine Mammals

Residual Effect	Significance (Significant / Not Significant)	Likelihood (Likely/Not Likely)	Level of Confidence (Low/Moderate/High)
Potential injury to as a result of underwater noise	Not significant	Likely – With the proposed mitigation measures in place (e.g., provisions from the Underwater Noise Management Plan and Marine Mammal Management Plan), a fatality or injury from underwater noise as a result of a pile-driving strike is not likely to be negligible.	The level of confidence that the effect will not be greater than predicted is high due to the implementation of known and effective mitigation measures for underwater noise and the localized area in which the potential effect will occur.
Changes in behaviour due to underwater noise	Not significant	Likely – Individual marine mammals will likely show temporary changes in behaviour as a result of underwater noise from Project vessels and pile-driving activities due to exceedances of NMFS behavioural thresholds	The level of confidence that the effect will not be greater than predicted and therefore is not likely to be significant is moderate due to the lack of information regarding the long-term effects of increased shipping traffic on the behaviour of marine mammals combined with the application of conservative assumptions by the use of the NMFS behavioural thresholds.

Table 5.19-15 Summary of Effects Characteristics and Significance for Marine Mammals

Potential Adverse Residual Effect	Contributing Project Activity or Physical Works	Mitigation #	Proposed Mitigation Measures	Residual Effects Characterization (see Notes for details)							
				Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Construction Phase											
Potential injury as a result of underwater noise due to pile-driving activities	Construction of FSO jetty, including pile driving and shoreline modifications to accommodate structural infrastructure, including possible dredging and permanent mooring of FSO	M5.17-6	Implement the Underwater Noise Management Plan	L	site	ST/IF	I	M	N	NL	H
		M5.19-1	Avoid pile driving on hard substrates								
		M5.19-2	Implement the Marine Mammal Management Plan								
Changes in behaviour due to underwater noise	Construction of FSO jetty, including pile driving and shoreline modifications to accommodate structural infrastructure, including possible dredging and permanent mooring of FSO	M5.17-6	Implement the Underwater Noise Management Plan	M	site	ST/IF	FR	H	NS	L	M
		M5.19-1	Avoid pile driving on hard substrates								
		M5.19-2	Implement the Marine Mammal Management Plan								
	Transportation of construction crews to the Project area via crew boat or ferry, transportation of materials and supplies to the Project area via barge	M5.17-6	Implement the Underwater Noise Management Plan	M	LAA	LT/FF	FR	H	NS	L	M
		M5.19-2	Implement the Marine Mammal Management Plan								

Potential Adverse Residual Effect	Contributing Project Activity or Physical Works	Mitigation #	Proposed Mitigation Measures	Residual Effects Characterization (see Notes for details)							
				Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Operation Phase											
Changes in behaviour due to underwater noise	- Mooring of LNG carriers at the FSO for LNG transfer - Shipping within Howe Sound (approximately 40 LNG carriers per year) in established shipping lanes - Patrolling of Control Zone around LNG facility, FSO, and LNG carriers	M5.17-6	Implement the Underwater Noise Management Plan	M	LAA	LT/FF	FR	H	NS	L	M
	Supporting infrastructure: transport of employees through private passenger ferry terminal, transport of supplies using barges, site administration, safety facilities, and emergency transportation via helicopter	M5.19-2	Implement the Marine Mammal Management Plan								

Potential Adverse Residual Effect	Contributing Project Activity or Physical Works	Mitigation #	Proposed Mitigation Measures	Residual Effects Characterization (see Notes for details)							
				Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Decommissioning											
Changes in behaviour due to underwater noise	- Project vessels associated with the dismantling of equipment and buildings that will not continue to serve a purpose - Project vessels associated with the removal of LNG facility and FSO from the Project area	M5.17-6	Implement the Underwater Noise Management Plan	M	LAA	LT/FF	FR	H	NS	L	M
		M5.19-2	Implement the Marine Mammal Management Plan								

Notes:

Magnitude: NM = negligible, LM = low magnitude, MM = medium magnitude, HM = high magnitude
 Geographic extent: No = none, site = site-specific, LAA = local, RAA = regional
 Duration: P = permanent, LT = long term, ST = short term,
 Frequency: CF = continuous, FF = frequent, IF = infrequent
 Reversibility: FR = fully reversible, PR = partially reversible, I = irreversible,
 Context: H = high, M = moderate, L = low
 Level of Effect: N = negligible, NS = not-significant, S = significant
 Likelihood: L = likely, NL = not likely
 Confidence: L = low, M = moderate, H = high

5.19.4 Marine Mammals Cumulative Effects Assessment

This section describes the assessment of potential cumulative effects associated with the marine mammals VC. Cumulative effects result from interactions between Project-related adverse residual effects and incremental effects of all other certain and reasonably foreseeable projects and activities. The effects of other Projects and activities that have been carried out (past and present Projects) are considered through the documentation of the existing conditions as reported in **Section 5.19.2.4**. The combination of the residual Project effects with the effects of all other certain and reasonably foreseeable projects and activities that will be carried out comprise the total future cumulative effects.

Cumulative effects assessment follows the same method for assessing residual adverse effects following the identification of interactions described in **Section 5.19.3.2.1**. Essentially, the only difference in the outcome of assessment criteria between cumulative and incremental effects from the Project is in the magnitude and geographic extent of adverse residual effects. Determining the magnitude of potential cumulative effects involves comparing changes from existing conditions to conditions with the future case, in terms of incremental adverse effects relative to baseline values (i.e. existing conditions). Cumulative effects from the Project in combination with all other certain and reasonably foreseeable projects and activities can influence a population throughout its entire annual range (including migratory movements, where applicable). In contrast, the geographic extent of incremental adverse residual effects from the Project alone may have a local or regional influence on marine mammal populations.

5.19.4.1 Residual Effects Included in Cumulative Effects Assessment

A list of Project-related residual adverse effects and rationales for their inclusion in or exclusion from the cumulative effects assessment is provided in **Table 5.19-16**. Residual effects that were assessed as negligible are not considered likely to interact cumulatively, and are not carried forward into the cumulative effects assessment.

Table 5.19-16 Residual Effects Included in Cumulative Effects Assessment

Residual Effect	Included in Cumulative Effects Assessment	Rationale
Changes in behaviour due to underwater noise	Yes	Potential for the effects to contribute incrementally and act in a cumulative fashion on marine mammal populations with other certain and reasonably foreseeable projects and activities

5.19.4.2 Spatial and Temporal Boundaries

As described in **Section 5.19.1.4.1**, the spatial boundary of the cumulative effects assessment for marine mammals is defined as the RAA (i.e. Howe Sound), as shown in **Figure 5.19-1**.

5.19.4.3 Potential Interactions with Other Reasonably Foreseeable Projects

Reasonably foreseeable projects and activities are those that: (a) have been publicly announced with a defined project schedule and with sufficient detail that they can be included in the assessment; (b) are currently undergoing an EA, or (c) are in a permitting process.

The cumulative effects assessment involves examination of only the potential for interactions between the adverse residual effects of the Project and the incremental effects of other projects and activities that are certain and reasonably foreseeable. The effects of other existing projects and activities that have already been implemented (construction and operation) are considered as part of the existing conditions for marine mammals, discussed in **Section 5.19.2.4**.

A list of certain and reasonably foreseeable projects and activities with potential effects that could interact with a Project-related residual effect on marine mammals, and result in a cumulative effect is provided in **Table 5.19-17**.

Table 5.19-17 Potential Incremental Effects of Other Projects and Activities on Marine Mammals

Project / Activity	Description	Potential to Interact	Rationale
Project			
Aquilini Waste-to-Energy Facility	Aquilini Developments proposes a waste-to-energy facility for the incineration of approximately 370,000 tonnes of Metro Vancouver waste per year. The proposed waste-to-energy facility will be located approximately 22 km west-southwest of the Project.	Unknown	- insufficient project information currently available to assess potential effects - there is no indication of how waste will be transported to the proposed facility - if shipping is considered there is no indication of vessel routes, types, or volume, and therefore interactions with the Project cannot be identified
Box Canyon Hydro project	The Box Canyon Hydro project is a 16-megawatt (MW) hydro project in the McNab watershed on Howe Sound, approximately 10 km south of the Project. It is currently under construction.	No	no marine shipping component is identified. No marine terminal construction component is identified
South Britannia	A 200-ha development located on the Makin lands at Britannia Beach, proposing a mix of 3,000 residences, retail, and light industrial land uses. South Britannia is 6.5 km southeast of the Project, on the east side of Howe Sound.	No	- no marine shipping component is identified - potentially some in-water works are identified (waterfront and pier); however, insufficient project information is currently available to assess these potential effects
Britannia Beach MacDonald Development	Zoning is in place for a new commercial and retail development incorporating many renovated historic buildings. The development is located approximately 6 km southeast of the Project.	No	- no marine shipping component is identified - no marine construction component is identified
BURNCO Aggregate project	BURNCO Rock Products has proposed a 1 to 1.6 million tonnes per annum sand and gravel extraction project in the McNab watershed on Howe Sound. The development will include a marine barge-loading facility; it is located approximately 10 km south of the Project. This project is currently in the EA process.	Yes	potential for cumulative increases in vessel traffic in RAA to act in a cumulative fashion with respect to potential injury of marine mammals as a result pile-driving activities and changes in behaviour of marine mammals due to underwater noise. Carried forward into the assessment
Culliton Creek Hydro project	The Culliton Creek Hydro project is a 15-MW hydroelectric project located on Culliton Creek, approximately 27 km north of the Project. Site preparation work began in May 2014.	No	- no marine shipping component is identified - no marine construction component is identified

Project / Activity	Description	Potential to Interact	Rationale
Eagle Mountain – Woodfibre Gas Pipeline project	FortisBC has proposed an approximately 52-km-long, 24 inch diameter natural gas pipeline from the area north of the Coquitlam Watershed; additional compression at existing compressor stations at Eagle Mountain in Coquitlam and Port Mellon north of Gibsons; a new compressor station in Squamish; and metering facilities at the receipt and delivery points. The pipeline will deliver natural gas to the Project. This project is currently in the EA process.	No	- no marine shipping component is identified - no marine construction component is identified
Eaglewind Community Development	Eaglewind is a new 25-acre master-planned community in downtown Squamish. The development is currently under construction, with some areas completed and future phases planned. The development is located approximately 7 km northeast of the Project.	No	- no marine shipping component is identified - no marine construction component is identified
Garibaldi at Squamish	A proposed all-season destination ski resort proposed for Brohm Ridge in the Cheakamus River watershed, approximately 22 km north of the Project. This resort will include 1,675 hotel units, 1,850 hectares (ha) of ski area, commercial and recreational developments, two 18-hole golf courses, and a recreational trail network.	No	- no marine shipping component is identified - no marine construction component is identified
Porteau Cove	Under a partnership between Squamish Nation and Concord Pacific, this residential development proposes 1,400 homes, lots, and commercial space, located on the east side of Howe Sound, 12.3 km south of the Project.	No	- no marine shipping component is identified - no marine construction component is identified
Raffuse Creek Hydro	The Raffuse Creek Hydro project is a 10-MW hydro project located on Raffuse Creek, approximately 19 km from the Project.	No	- no marine shipping component is identified - no marine construction component is identified
Rainy River Hydro project	The Rainy River Hydroelectric project is a 15-MW hydro project on the Rainy River, approximately 26 km southwest of the Project.	No	- no marine shipping component is identified - no marine construction component is identified
Site B	The project comprises 158 acres of industrial/commercial land owned by the Province of BC and Squamish Nation in the Squamish River estuary west of Stawamus.	No	- no marine shipping component is identified - the management plan discusses the potential for the development of a new marine terminal; however, there is insufficient project information currently available to assess these potential effects

Project / Activity	Description	Potential to Interact	Rationale
Skookum Creek Power	The Skookum Creek Hydro project is a 25-MW hydro project on Skookum Creek, approximately 20 km east-northeast of the Project.	No	- no marine shipping component identified - no marine construction component identified
Squamish Oceanfront Development Plan	This City of Squamish-proposed oceanfront development plan incorporates residential, recreational, and commercial opportunities. The development is located approximately 6 km northeast of the Project.	No	- no marine shipping component identified - likely marine construction component associated with this development plan; however, there is insufficient project information currently available to assess these potential effects
Woodfibre Substation	BC Hydro is constructing a new substation and connection to the electrical grid. The purpose of the new substation will be to deliver electricity to the Project.	No	- no marine shipping component identified; and - no marine construction component identified
Activity			
Forestry Activities	The Lower Squamish Landscape Unit (Sea-to-Sky Land and Resource Management Plan) contains several forms of forest tenures, including woodlots and forest and timber licences.	No	- the activity has been assessed against current forestry operations that contribute to commercial traffic - there is insufficient activity information currently available to assess effects of future forestry activities. There is no indication of vessel routes, types, or volume of vessels to undertake a cumulative assessment - no marine construction component identified
Mineral Activities	There are approximately 10 mineral tenures within the Howe Landscape Unit mostly adjacent to the foreshore.	No	- no marine shipping component is identified - there is insufficient information currently available to assess effects of future mineral activities in the marine environment

5.19.4.4 *Potential Interactions with Other Projects*

This section identifies the potential interactions between Project-related adverse residual effects and the incremental effects of other certain and reasonably foreseeable projects and activities, as listed in **Table 5.19-18**. The potential for interaction between a Project activity and a Project-related residual adverse effect that could result in an adverse cumulative effect to marine mammals is also summarized in **Table 5.19-18**. The potential cumulative effects resulting from these interactions are described in the following sections.

Table 5.19-18 Other Projects or Activities and Potential Cumulative Interactions and Effects for Marine Mammals

Other Project / Activity	Potential Incremental Effect	Potential for Interaction Resulting in Cumulative Effect	Rationale for Potential Cumulative Effect
Changes in behaviour due to underwater noise			
BURNCO Aggregate project	Changes in behaviour of marine mammal populations in the RAA as a result of impact pile driving and vessels	Y	The BURNCO project shipping (tug, barges, and crew transport vessels) and pile-driving activities have the potential to interact in a cumulative fashion with respect to changes in behaviour to marine mammal populations as the vessel routes and terminal locations for this project overlaps with the Project's RAA and is therefore likely to interact with the same marine mammal populations that are potentially affected by the Project.

Note: Y – Yes, potential cumulative effect.

5.19.4.4.1 Characterization of Cumulative Changes in Behaviour due to Underwater Noise

The BURNCO project shipping (tug, barges, and crew transport vessels) and pile-driving activities have the potential to interact in a cumulative fashion with respect to changes in marine mammal population behaviour because BURNCO vessel routes and terminal locations overlap with the Project's RAA and will therefore likely interact with the same marine mammal populations that are potentially affected by the Project. Similar behavioural effects are anticipated as a result of both projects. As described above for the Project, based on available literature, marine mammals will either habituate to underwater sounds and remain in the area, or leave temporarily and return once the noises subside.

The amount of marine mammal habitat and number of marine mammal individuals potentially affected by underwater noise from vessel traffic may increase as a result of the cumulative increase in shipping due to both projects. Changes in behaviour as a result of cumulative increases in underwater noise from pile-driving activities will likely be limited to the area directly around each terminal area and confined to the construction phase. Consequently changes in behaviour as a result of cumulative increases in underwater noise from both Project activities are considered to be temporary in nature and fully reversible with no effects at the population level anticipated.

5.19.4.4.2 Proposed Measures to Mitigate Cumulative Effects

Barge shipping activities connected to the BURNCO project will be subject to the same regulatory *Canada Shipping Act* requirements and control from the CCG Marine Communications and Traffic Services as Project-related vessel traffic. In order to reduce or prevent cumulative effects, the following measure has been identified:

M5.19-3 – Planning for Future Marine Traffic

Woodfibre LNG Limited will undertake additional passage planning concerning the interaction of future traffic in studies as part of the Technical Review Process under TERMPOL Code of Recommended Standards for the safety and Prevention of Pollution for Marine Transportation Systems and Related Assessment Procedures).

In addition to mitigation measures described in **Section 5.19.3.2.3** to reduce or otherwise mitigate the potential adverse cumulative effect of underwater noise on marine mammals (i.e. implementing relevant provisions of the Underwater Noise Management Plan (M5.17-6) and Marine Mammal Management Plan (M5.19-2)) are also considered relevant to the mitigation of cumulative effects.

5.19.4.5 Residual Cumulative Effects and Their Significance

The magnitude of the residual adverse effect of behavioural disturbance to marine mammals from cumulative underwater noise is considered to be the same as the incremental effect (medium) as activities are expected to exceed established behavioural criteria for marine mammals. The geographic extent is considered regional as potential behavioural effects associated with the BURNCO project will extend into the Project's RAA. The duration is considered to be long term over the course of all phases of the Project for potential behavioural effects associated with vessels, and short term over the course of the construction phase for potential behavioural effects associated pile driving. The frequency is considered frequent for vessel activities and infrequent for pile driving. The reversibility of the effect is considered fully reversible as marine mammals will either habituate to underwater sounds and remain in area, or leave temporarily and return once the noise has subsided. The context of the effect is considered high for all marine mammal species as those that occur in LAA likely have a high natural resilience to imposed stresses of underwater noise due to their prior experience with underwater noise from existing traffic, given the current volume of shipping that occurs in the area and natural acoustic sources (e.g., surface agitation, such as wind and waves see **Section 5.19.2.4**). In addition, there is no designated critical marine mammal habitat in the RAA.

Behavioural disturbance from cumulative project vessel noise is considered likely to occur as a result of Project residual effects in combination with the incremental effects of the other reasonable and foreseeable project which is BURNCO. No effects at the population level are likely; therefore, the cumulative adverse effect is not likely to be significant. The level of confidence that the effect will not be greater than predicted is medium. This is due to the lack of information regarding the long-term effects of increased shipping traffic on the behaviour of marine mammals in combination with the application of conservative assumptions using NMFS behavioural thresholds.

Potential residual cumulative effects and their significance are summarized in **Table 5.19-19** and **Table 5.19-20**.

Table 5.19-19 Summary of Determination of Significance of Adverse Residual Cumulative Effects for Marine Mammals

Residual Cumulative Effect	Significance (significant / not significant)	Likelihood (likely/unlikely)	Level of Confidence (low/medium/high)
Changes in behaviour due to underwater noise from vessels [during operation]	Not significant	Likely	Medium

Table 5.19-20 Summary of Residual Cumulative Effects Characterization for Marine Mammals

Potential Adverse Residual Effect	Project Phase	Contributing Projects or Activities	Mitigation #	Proposed Mitigation Measures	Cumulative Residual Effects Characterization							
					Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Construction Phase												
Changes in behaviour due to underwater noise	C	Construction of FSO jetty, including pile driving and shoreline modifications, to accommodate structural infrastructure, including possible dredging and permanent mooring of FSO	All	All Project-related mitigation measures for changes in marine mammal behaviour due to underwater noise	M	RAA	ST/IF	FR	H	NS	L	M
	C	• Transportation of construction crews to the Project area via crew boat or ferry • Transportation of materials and supplies to the Project area via barge	All	All Project-related mitigation measures for changes in marine mammal behaviour due to underwater noise	M	RAA	LT/FF	FR	H	NS	L	M

Potential Adverse Residual Effect	Project Phase	Contributing Projects or Activities	Mitigation #	Proposed Mitigation Measures	Cumulative Residual Effects Characterization							
					Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Operation Phase												
Changes in behaviour due to underwater noise	O	- Mooring of LNG carriers at the FSO for LNG transfer - Shipping within Howe Sound (approximately 40 LNG carriers per year) in established shipping lanes - Patrolling of Control Zone around LNG facility, FSO, and LNG carriers	All	All Project-related mitigation measures for changes in marine mammal behaviour due to underwater noise	M	RAA	LT/FF	FR	H	NS	L	M
		M5.19-3	Plan for future marine traffic									

Potential Adverse Residual Effect	Project Phase	Contributing Projects or Activities	Mitigation #	Proposed Mitigation Measures	Cumulative Residual Effects Characterization							
					Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Decommissioning Phase												
Changes in behaviour due to underwater noise	D	- Project vessels associated with the dismantling of equipment and buildings that will not continue to serve a purpose - Project vessels associated with the removal of LNG facility and FSO from the Project area	All	All Project-related mitigation measures for changes in marine mammal behaviour due to underwater noise	M	RAA	LT/FF	FR	H	NS	L	M

Notes:

Magnitude: NM = negligible, LM = low magnitude, MM = medium magnitude, HM = high magnitude
 Geographic extent: No = none, site = site-specific, LAA = local, RAA = regional
 Duration: P = permanent, LT = long term, ST = short term,
 Frequency: CF = continuous, FF = frequent, IF = infrequent
 Reversibility: FR = fully reversible, PR = partially reversible, I = irreversible
 Context: H = high, M = moderate, L = low
 Likelihood: likely = L, not likely = NL
 Level of Effect: N = negligible, NS = not-significant, S = significant
 Confidence: L = low, M = medium, H = high

5.19.5 Summary of Residual Project-Related Effects and Residual Cumulative Environmental Effects

This section summarizes the potential residual effects of the Project and potential residual cumulative adverse effects due to interactions with other certain and reasonably foreseeable projects and activities. In summary, the residual effects remaining following the implementation of mitigation for the Project are potential injury as a result of underwater noise from pile driving activities; and changes in behaviour due to underwater noise from pile-driving activities and vessels.

All Project-related residual effects were considered likely to be either negligible (potential injury from pile driving during construction) or not significant (behavioural disturbance from pile-driving noise and Project vessel noise throughout all Project phases). Potential auditory injuries to marine mammals from pile-driving noise are likely to be fully reversible in the case of a TTS injury, and irreversible in the case of a PTS injury; however, given that mortality is unlikely to occur as a result of auditory injury, no population effects are likely. Changes in behaviour as a result of increases in underwater noise from Project activities are likely to be temporary in nature and fully reversible, with no effects at the population level anticipated.

One cumulative residual effect was assessed for marine mammals: changes in behaviour due to underwater noise from pile-driving activities and vessels.

Changes in behaviour as a result of cumulative increases in underwater noise from the Project and certain and reasonably foreseeable projects and activities are considered to be temporary in nature and fully reversible with no effects at the population level anticipated.

5.19.6 Monitoring and Follow-up Programs

The implementation of the Underwater Noise Management Plan and Marine Mammal Management Plan will outline set out mitigations, including monitoring, to address adverse effects from noise during pile-driving activities. Any marine mammal incidents (e.g., ship strikes, strandings, deaths, distinct behavioural disturbances) as a result of the Project will be recorded.

This includes marine mammal monitoring to be undertaken by shipping contractors during all shipping activities to avoid interactions with marine mammals. Refer to **Section 11.0 Accidents and Malfunctions** for further information related to recording of potential incidents of vessel strikes with marine mammals. In addition, the scope of follow-up monitoring pertaining to accidental spills into marine mammal habitat is presented in **Section 11.0 Accidents and Malfunctions**.

5.19.7 References

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