REPORT

Evaluation of Underwater and In-air Acoustic Impacts on Marine Mammals from Small Arms Munitions in OPAREA WH

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Executive Summary

On behalf of Public Services and Procurement Canada (PSPC) and Department of National Defence (DND), Golder Associates Ltd. (Golder) has prepared this Evaluation of Underwater and In-air Acoustic Impacts on Marine Mammals from Small Arms Munitions in Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs) Whiskey Hotel (WH). The scope of work for this report was undertaken under the Public Works and Government Services Canada (PWGSC) Human Health Ecological RACS CTA No. EZ897-161534/002/VAN dated August 9 2019 and as outlined for Tasks 5 in Golder's work plan titled, "Work-Plan and Cost Estimate for Evaluation of Underwater Noise Effects from Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs)" and dated 28 September 2018 which was approved under Task Authorization TA 700420324 dated 3 October 2018. An additional work plan was developed to finalize the Task 5 report titled, "Updated Project Work Plan and Cost Estimate for Evaluation of Underwater and In-air Noise Effects from Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs)" dated 16 September 2019 which was approved under Task Authorization TA 700450079 dated 23 May 2019.

DND is committed to sustainable management of its operations within the Maritime Forces Pacific (MARPAC) Operating Areas (OPAREAs). Within the MARPAC OPAREAs, Department of National Defence (DND) undertakes a variety of testing, training and exercises to ensure that DND personnel, including crew and equipment operators, are proficient and equipped to do their job and fulfil their combat readiness requirements. DND's environmental policy is to ensure that these military testing, training, and exercises comply with all applicable environmental laws and standards.

A review of the potential adverse environmental effects associated with in-air and underwater noise was conducted for the small-arms military training exercises in MARPAC OPAREA WH (the Physical Activity). In-air and underwater noise generated by the small-arms military training activities in MARPAC OPAREA WH have the potential to result in the following adverse effects to marine mammals:

- In-air Acoustic Effects (hauled-out pinnipeds or pinnipeds located at the surface)
  - Injury and/or mortality
  - Disturbance (behavioural effects)
  - Masking
- Underwater Acoustic Effects (all marine mammal species)
  - Injury and/or mortality
  - Disturbance (behavioural effects)
  - Masking

Acoustic propagation modelling of in-air and underwater noise from small-arms military training exercises was undertaken by JASCO Applied Sciences to determine distances to the established injury and disturbance thresholds for marine mammals. Five weapons of various calibre were modelled individually, in addition to three aggregate scenarios that include two weapons each (M2/M240, M2/MK38 and the C8/Pt). Three sets of criteria were considered in the in-air propagation model and included permanent threshold shifts (PTS), temporary threshold shift (TTS) and behavioural disturbance thresholds for pinnipeds defined by Southall et al. (2007, 2019), for impulsive sounds. Two sets of criteria were considered in the underwater noise model and included those that define thresholds for injury (PTS and TTS) that incorporate frequency weighting for the five distinct marine mammal hearing groups (NOAA 2018), and the National Marine Fisheries Services (NMFS 2013) 160 dB re 1 μPa SPL threshold for behavioural response for impulsive sounds for all marine mammal species.

Modelling results for in-air noises in MARPAC OPAREA WH indicated that the largest distances (R_{max}) to existing marine mammal injury thresholds (based on non-weighted peak SPL (SPL_{peak}) injury thresholds from Southall et al. 2019) were associated with TTS for pinniped in-air, equivalent to 219 m for the MK38 during training. For underwater noise, modelling results indicated that the largest distances (R_{max}) to existing marine mammal injury thresholds (based on 24hr auditory weighted sound exposure level (SEL) injury thresholds) were associated with TTS for HFC, equivalent to 28 m for the M2 and MK38 aggregate scenario. Behavioural disturbance for in-air noise was estimated to occur at a maximum distance from the source (R_{max}) of 15.6 km for the M2 and MK38 aggregate scenario. The underwater noise threshold for behavioural disturbance was not reached by any of the small arm scenarios modelled.

With the application of operationally achievable mitigation measures (e.g., visual monitoring of the Mitigation Avoidance Zone (MAZ) etc.), residual effects were limited to behavioural disturbance and masking effects associated with in-air noise and masking in underwater animals. Species most likely to be affected by these activities include harbour seals and Steller sea lions at nearby haul-outs. Expected behavioural reactions include brief alerting and orienting response with no significant behavioural responses (Finneran et al. 2017). Masking effects related to underwater noise is most likely to affect Southern Resident Killer Whale (SRKW) who forage in the areas close to shore and whose critical habitat overlaps with the range, harbour porpoises who use coastal areas and potentially humpback whales and grey whales who forage and migrate through the area. Masking of underwater communications is expected to be limited due to the lack of overlap in frequency of small arms activities (dominant frequencies) and the vocalizations of SRKW and harbour porpoises and the expected low densities of humpback and grey whales in MARPAC OPAREA WH.

There is a general lack of information regarding the behavioural effects of in-air gunfire on marine mammal behaviour. Studies conducted during training activities would increase the knowledge around potential behavioural reactions of marine mammals in-air (hauled-out) and underwater to gunfire activity.

LIST OF ACRONYMS

μPa	micropascal(s)
$μPa^2·s$	micropascal(s) squared per second(s)
AEP	Auditory Evoked Potential
AOI	Area of Interest
BC	British Columbia
CAF	Canadian Armed Forces
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSL	California Sea Lion
C8	C8, C7, or MK16A1 automatic rifles
dB	Decibel
DFO	Fisheries and Oceans Canada
DND	Department of National Defence
DP	Dall's Porpoise
EED	Environmental Effects Determination
EIA	Environmental Impact Assessment
EMAs	Enhanced Management Areas
EN	Endangered
FM	Frequency Modulated
Ft	Feet
FW	Fin Whale
Golder	Golder Associates Ltd.
GW	Grey Whale
HADD	Harmful Alteration, Disruption or Destruction
HFC	High-frequency Cetaceans
HP	Harbour Porpoise
HS	Harbour Seal
HW	Humpback Whale
Hz	Hertz
IAW	In accordance with
KIs	Key Indicators

kHz	Kilohertz
Km	Kilometre(s)
km^2	Kilometre(s) Squared
KW	Killer Whale
LFC	Low-frequency Cetaceans
M2	Browning M2 heavy machine gun
M240	M240 machine gun (representative of C6 machine gun)
MK38	MK38 machine gun
MARPAC	Maritime Forces Pacific
MAZ	Mitigation Avoidance Zone
MFC	Mid-frequency Cetaceans
MMRM	Marine Mammal Risk Mitigation
MW	Minke Whale
MPA	Marine Protected Area
NATO	North Atlantic Treaty Organization
NBP	Navel Boarding Party
NITS	noise-induced threshold shift
NMCA	National Marine Conservation Areas
NMFS	National Marine Fisheries Services
NNAG	NATO Naval Armaments Group
NOAA	National Oceanic and Atmospheric Administration
NRKW	Northern Resident Killer Whale
NVG	Night Vision Goggles
NWA	National Wildlife Area
OCA	Other Marine Carnivores In-air
OCW	Other Marine Carnivores in Water
OPAREA	Operating Area
OPAREAs	Operating Areas
OP	Otariid Pinnipeds
OPB	Offshore Pacific Bioregion
PA	Pinnipeds In-air

PCA	Phocid Carnivores In-air
Phocids	Phocinid Seals
PTS	Permanent Threshold Shifts
Pt	General Service Pistol (9 mm Browning Hi-Power or Sig Sauer P225)
PP	Phocid Pinnipeds
PSPC	Public Services and Procurement Canada
PWGSC	Public Works and Government Services Canada
RCAF	Royal Canadian Air Force
RCN	Royal Canadian Navy
S	Seconds
SAR	Species at Risk
SC	Special Concern
Sc1	Schedule 1
SARA	*Species at Risk Act*
SEL	Sound Exposure Level
SEOSS	Stabilized Electro-Optical Sighting System
SRKW	Southern Resident Killer Whale
SPL	Sound Pressure Level
SPL_{peak}	Peak Sound Pressure Level
SPL_{rms}	Sound Pressure Level Root-mean-square
SW	Sei Whale
TH	Threatened
TTS	Temporary Threshold Shift
VECs	Valued Ecosystem Components
WH	Whiskey Hotel
WSD	White Sided Dolphin
WRAS	Whale Report Alert System

NOTICE TO READERS

On behalf of Public Services and Procurement Canada (PSPC) and Department of National Defence (DND), Golder Associates Ltd. (Golder) has prepared this Evaluation of Underwater and In-air Acoustic Impacts on Marine Mammals from Small Arms Munitions in Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs) Whiskey Hotel (WH). The scope of work for this report was undertaken under the Public Works and Government Services Canada (PWGSC) Human Health Ecological RACS CTA No. EZ897-161534/002/VAN dated August 9 2019 and as outlined for Tasks 5 in Golder's work plan titled, "Work-Plan and Cost Estimate for Evaluation of Underwater Noise Effects from Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs)" and dated 28 September 2018 which was approved under Task Authorization TA 700420324 dated 3 October 2018. An additional work plan was developed to finalize the Task 5 report titled, "Updated Project Work Plan and Cost Estimate for Evaluation of Underwater and In-air Noise Effects from Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs)" dated 16 September 2019 which was approved under Task Authorization TA 700450079 dated 23 May 2019.

The inferences concerning the Site conditions contained in this report are based on information obtained during the assessment conducted by Golder personnel, and are based solely on the condition of the property at the time of the Site reconnaissance, supplemented by historical and interview information obtained by Golder, as described in this report.

This report was prepared, based in part, on information obtained from historic information sources. In evaluating the subject Site, Golder has relied in good faith on information provided. We accept no responsibility for any deficiency or inaccuracy contained in this report as a result of our reliance on the aforementioned information.

The findings and conclusions documented in this report have been prepared for the specific application to this project and have been developed in a manner consistent with that level of care normally exercised by environmental professionals currently practicing under similar conditions in the jurisdiction.

With respect to regulatory compliance issues, regulatory statutes are subject to interpretation. These interpretations may change over time, these should be reviewed.

If new information is discovered during future work, the conclusions of this report should be re-evaluated, and the report amended, as required, prior to any reliance upon the information presented herein.

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1.0 PROJECT INFORMATION

1.1 Introduction

On behalf of Public Services and Procurement Canada (PSPC) and Department of National Defence (DND), Golder Associates Ltd. (Golder) has prepared this Evaluation of Underwater and In-air Acoustic Impacts on Marine Mammals from Small Arms Munitions in Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs) Whiskey Hotel (WH). The scope of work for this report was undertaken under the Public Works and Government Services Canada (PWGSC) Human Health Ecological RACS CTA No. EZ897-161534/002/VAN and as outlined for Tasks 5 in Golder's work plan titled, "Work-Plan and Cost Estimate for Evaluation of Underwater Noise Effects from Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs)" and dated 28 September 2018 which was approved under Task Authorization TA 700420324 dated 3 October 2018. An additional work plan was developed to finalize the Task 5 report titled, "Updated Project Work Plan and Cost Estimate for Evaluation of Underwater and In-air Noise Effects from Military Training Activities in Maritime Forces Pacific (MARPAC)'s Marine Operating Areas (OPAREAs)" dated 16 September 2019 which was approved under Task Authorization TA 700450079 dated 23 May 2019.

This evaluation focused solely on the acoustic effects to marine mammals associated with gunnery activities in OPAREA Whiskey Hotel (OPAREA WH). As such, the potential for physical impacts from gunfire striking marine mammals was not evaluated, nor were effects to other marine wildlife (e.g., birds, fish) and other ocean users (e.g., coastal communities, CRA fishing, tourism, etc.) as it pertains to physical strikes and/or contamination of the water column/sediments (from debris). Further studies would be required to evaluate those effects. However, the Royal Canadian Navy (RCN) and the United States Coast Guard (USCG) follow firing orders that identify specific areas (safety firing arcs/area clear requirements) that must be clear of all land, vessels, aircraft and marine mammals. These areas are specific to each weapon and are based on weapon hazard patterns that were developed from a worst-case scenario that includes deflection error, environmental factors, ricochets and round fragmentation.

1.2 Location of Proposed Physical Activity

MARPAC OPAREA WH is a 30 × 11 km military training area located in the Strait of Juan de Fuca. The northern boundary of OPAREA WH runs parallel to shore approximately 1 km south of the Vancouver Island coastline (Figure 1 - Annex A). OPAREA SJ5 surrounds OPAREA WH but does not include it and the two areas are controlled by different agencies. The shoreline of OPAREA WH includes residential properties and portions of the Juan de Fuca Marine Trail and is commonly frequented by recreational users along the shoreline. Because of this, the northern boundary of OPAREA WH is situated 1,000 yards (914.4 m) offshore.

OPAREA WH overlaps with critical habitat of the Southern Resident Killer Whale (SRKW) as well as key foraging areas and enhanced management areas (EMAs) for this species (Figure 2 – Annex A). OPAREA WH also overlaps with Fisheries and Oceans Canada (DFO) defined Important Areas (IAs) for harbour porpoise (Figure 3 – Annex A), grey whale (Figure 4 – Annex A) and is located offshore of known harbour seal haul-out areas (Figure 5– Annex A).

1.3 Physical Activity Summary

The OPAREA WH training area is used by several units including the USCG, the United States Navy (USN), the RCN, the Royal Canadian Air Force (RCAF) and the Canadian Armed Forces (CAF) for military exercises. Military training exercises can occur anytime of year; however, due to heavy weather conditions prevalent in the Pacific Northwest during winter months, which prevent a stable firing platform offshore, gunnery training activities primarily occur during the summer months. Training sessions can occur from either vessels, i.e., frigates (HALIFAX Class) or helicopters (i.e., Cyclones by RCAF and Griffons by the CAF). Due to the relatively infrequent usage of OPAREA WH by helicopters in comparison to surface vessels, this evaluation is focused on firing from surface vessels. Training activities at the range can include several different small arms weapons. A list of these weapons is provided in Table 1.

Table 1: Weapons used during Training Activities in OPEAREA WH

Unit	Weapon
USCG	MK38 25 mm, .50 cal, M240 (C6 and M240 are the same weapon system)
RCN	57 mm, 20 mm, 5.56 mm, 7.62 mm, 9 mm, .50 cal, and chaff (Note that 57 mm, 20 mm or chaff are rarely, if ever, deployed in OPAREA WH and as such have not been considered in the evaluation).
RCAF (Cyclone and Griffon helicopters)	C6 machine guns using 7.62 mm rounds (This evaluation is focused on firing from surface vessels).

The US Coast Guard (USCG) use OPAREA WH an average of 30 days per year, or two to three times per month. USCG units typically train using two types of firing sequences: 1) warning shots and 2) disabling fire. This training is conducted using each of the three automatic weapons: the MK38, .50 caliber (cal), and M240. When conducting warning shots, a burst of three to five shots is used. For disabling fire, a burst of nine to 15 shots is used. During training events, disabling fire is typically conducted more regularly than warning shots. However, a 50/50 split between warning and disabling fire was assumed for acoustic modeling. The total rounds expended during a training event is based on training allowances, course of fire, and number of training cycles. For the .50 cal and M250, the course of fire calls out belts of 25 or 50 rounds to practice loading and misfire procedures. Each training run is allotted 200 rounds and the training event would run for 10 to 15 min to fully expend the rounds. The total number of rounds expended per day depends on the number of crews being trained.

RCN ships do not currently use OPAREA WH as often as it is used by the USCG. Limited information pertaining to RCN firing details has been provided by MARPAC. No details are available for the 7.62 mm, but some general ammo expenditure information was provided for .50 cal shoots from the HALIFAX Class frigates. It was identified that approximately 1,600 rounds would be expended per shoot and both watches would be given an opportunity to shoot, resulting in an estimated total of 3,200 rounds/day. A search of the MARPAC Ammunition Tracker yielded only a single tracked .50 cal expenditure in OPAREA WH for the HALIFAX Class frigates which was conducted on 23 Jan 2018 when 600 rounds were expended. Given limited use of OPAREA WH and lack of firing details, acoustic modeling of the .50 cal, 25 mm and M240 (7.62 mm) was conducted using the USCG firing details.

For the 9 mm general service pistol (9 mm Browning Hi-Power or Sig Sauer P225) and 5.56 mm weaponry (C8, C7, or MK16A1 automatic rifles), there are no recent records of ammunition expenditure by the HALIFAX Class or KINGSTON Class vessels in OPAREA WH (following a search of the MARPAC Ammunition Tracker database). However, as these weapons are authorized for firing in OPAREA WH, for acoustic modeling purposes it was assumed that these weapons would be fired for either Naval Boarding Party (NBP) shoots or Small Arms shoots (Force Protection [FP]). For Small Arms shoots (FP), the C8 has 10 rounds per magazine (mag) (typically two mags per person) and the 9 mm has 5 rounds per mag (typically two mags per person). Each person would fire off all rounds in a mag, switch mags, and then fire off all rounds again. The number of people firing varies per training session. Records of the last shoot undertaken by the HMCS Ottawa (HALIFAX Class vessel) indicated that 51 Sig Sauer P225 shooters and 21 C8 shooters were involved resulting in 510 expended rounds of 9 mm and 420 expended rounds of 5.56 mm (CP02 Mark Bateman, 2019 pers. comm.). For NBP shoots, in accordance with (IAW) Combat Readiness Requirements (CRR), each ship uses 1,800 rounds of 5.56 mm and 450 rounds of 9 mm per shoot (day) (Lt(N) Gillian Herlinger 2019, pers. comm.).

In accordance with (IAW) naval orders (MARPACORD 3350-1), surface vessel firings are restricted to parallel firing to the shore and operations must be conducted outside a three-mile radius of Point-No-Point. When conducting surface firing against a surface towed target, the tug/target is to be stationed no further east than a line drawn 180 degrees true from San Simon Point.

1.4 Regulatory Framework

In Canada, marine fish, marine wildlife (mammals and sea turtles) and their habitats are protected under federal legislation, including the federal *Fisheries Act*, RSC 1985, C. F-14 and the *Species at Risk Act*, SC 2002, c. 29 (SARA).

Recent amendments to the federal *Fisheries Act* came into force with bill C-68 on 28 August 2019. These amendments return to the pre-2012 fish and fish habitat protection provisions prohibiting: 1) works, undertakings or activities that result in the death of a fish by means, other than fishing, and 2) the harmful alteration, disruption or destruction (HADD) of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO 2019a). A HADD is defined as “any temporary or permanent change to fish habitat that directly or indirectly impairs the habitat’s capacity to support one or more life processes of fish” (DFO 2019a).

The fish and fish habitat protection provisions apply to all fish and fish habitat throughout Canada. The definition of fish has not been explicitly stated in the new guidance or policy documentation; however, it is assumed that it will follow the previous definition that includes “a) parts of fish, b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans, marine animals, and c) the eggs, sperm, spat, larvae and juvenile stages of fish, shellfish, crustaceans and marine animals”. Fish habitat means “water frequented by fish and any other areas on which fish depend directly or indirectly to carry out their life processes including, spawning grounds and nursery, rearing, food supply and migration areas”.

New provisions under the amendments include the prohibition of prescribed works, undertakings or activities in ecologically significant areas. Section 35.2 enables the statutory authority to establish an ecologically significant area and to establish prescribed works, undertakings or activities that may occur within that area. Works, undertakings or activities that are proposed to be carried out within these areas which are not prescribed, or prohibited, would remain subject to the prohibitions against the death of fish and the HADD of fish habitat. In order to proceed with non-prescribed or prohibited works, undertakings or activities in these areas, a Ministerial authorization would be required (DFO 2019a). To date (December 2019), there are no identified ecologically significant areas in Pacific waters.

The Marine Mammal Regulations, enacted in 1993 (amended in 2018) pursuant to the *Fisheries Act*, prohibit the disturbance of marine mammals by any person except when fishing for marine mammals under the authority of the Regulations (Government of Canada 1993). Additional prohibitions under the Regulations stipulate that "No person shall disturb a marine mammal" and set out closest approach distances for vessels and aircrafts to marine mammals (outlined in Table 20). Section 7.2 (1) of the regulations state that "*When an aircraft is being operated at an altitude of less than 304.8 m (1,000 ft.) within a radius of one-half nautical mile from a marine mammal, no person shall perform a flight manoeuvre — including taking off, landing or altering the course or altitude of the aircraft — for the purpose of bringing the aircraft closer to the marine mammal or otherwise disturbing it*". The Act exempts DND or members of the Canadian Forces and peace officers from the Regulations while they are performing their duties. However, the intention is for DND to comply with the Regulations during training activities as per Departmental policy (DAOD 4003-0, Environmental Protection and Stewardship). Additional restrictions on vessel approach distances to marine mammals were enacted under an Interim Order under the *Canada Shipping Act* (Government of Canada 2020) and are summarized below in Table 8.

On 31 May 2020, the Government of Canada issued an Interim Order, to protect whales from vessel disturbance under the *Canada Shipping Act* (Government of Canada 2020). The Interim Order sets out two mandatory measures for vessels operating in certain waters of southern British Columbia to reduce physical and acoustic disturbance to killer whales.

First, the Interim Order prohibits vessels and persons operating and navigating a vessel, subject to exemptions, from approaching any killer whale at a distance of less than 400 m while in SRKW critical habitat and British Columbia coastal waters east of Vancouver Island and south of Campbell River (Cape Mudge) and Malaspina Peninsula (Sarah Point). The 400-m approach distance is in place year-round to provide on-going protection for any SRKW occurring in coastal BC waters regardless of the season.

Second, the Interim Order creates three Interim Sanctuary Zones (Figure 2 – Annex A), where vessel traffic is prohibited, including fishing or recreational boating, from 1 June 2020 until 30 November 2020 with some exceptions. These three zones are located off the south-west coast of Pender Island and south-east end of Saturna Island, and at Swiftsure Bank. Interim Sanctuary Zones will be in place from 1 June 2020 through 30 November 2020. This period is based on the greater seasonal presence of SRKW in key critical habitat areas in the Salish Sea. The federal Species at Risk Act contains provisions to help prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, provides for the recovery of endangered or threatened species, and encourages the management of other species to prevent them from becoming at-risk. This is achieved by promoting and securing necessary actions for recovery through legal protection. To kill, harm, harass, capture or take an individual of a species listed as extirpated, endangered or threatened is prohibited under Section 32 of SARA. To damage or destroy the residence of individuals of a species listed as Extirpated, Endangered or Threatened is prohibited under Section 33 of SARA. Under SARA, critical habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species" and is legally protected from destruction within 180 days of being identified in a recovery strategy or action plan.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is a scientific advisory panel that assesses the national status of wild species, subspecies, varieties, or other designable units that are considered to be at risk in Canada. COSEWIC uses a scientific process whereby species are assessed and ranked according to conservation concern (i.e., Extinct, Extirpated, Endangered, Threatened, Special Concern, Not at Risk, or Data Deficient). COSEWIC has no legislative or management role, but rather provides an independent recommendation on the status of “at risk” species to the Federal Minister of Environment and Climate Change, who in turn makes recommendations to the Cabinet regarding potential legal protection of a species through provisions under SARA. The COSEWIC assessment is taken into consideration during a SARA listing process; however, only species and their critical habitats listed under SARA Schedule 1 are legally protected.

The recently enacted federal Impact Assessment Act (S.C. 2019, c. 28, s. 1; IAA) is the legal basis for the federal environmental assessment process in Canada and is intended to protect components of the environment under federal jurisdiction from significant adverse environmental effects. An environmental impact assessment is a decision-making tool used to predict environmental effects of projects on the environment and develop appropriate mitigation measures to avoid or minimize any identified adverse effects and determine if the project should proceed. Testing and/or training of military weapons in a training area, range or test establishment established before 7 October 1994 by or under the authority of the Minister of National Defence does not require an environmental impact assessment under the IAA as per the Physical Activities Regulations: SOR/2019-285 (Section 2(17)), nor does it trigger the requirement to conduct a determination of effects under Section 82 or 83 of the IAA. However, according to the DND Environmental Impact Assessment (EIA) Directive, a determination on the likelihood of adverse environmental effects is required as an exercise of due diligence. The North Atlantic Treaty Organization (NATO) has developed marine mammal risk mitigation measures applicable to NATO member nations. Under the NATO Naval Armaments Group (NNAG) a working group was organized to develop a marine mammal risk mitigation (MMRM) project. This working group, composed of scientific and military experts from 10 NATO member nations, developed risk-mitigation principles and guidelines applicable to NATO military maritime activities outlined in Ryan and Jespers (2012). These principles and guidelines have been applied in the development of the mitigation measures outlined in this evaluation.

2.0 IDENTIFICATION OF VALUED ECOSYSTEM COMPONENTS (VECS)

Valued Ecosystem Components (VECs) are defined as components of the environment (e.g., species, population, biological event or other environmental feature) considered to be important to the local ecology and/or human population. VECs are legally, politically and/or professionally recognized as important to a particular region or community, or have a national or international profile, and, if altered, would be of concern to regulators, First Nations, general public, and/or other stakeholders. The selection of marine mammal VECs was carried out in consideration of regulatory guidance and requirements, the nature and extent of the planned Physical Activity, the environmental conditions in OPAREA WH, and the potential interaction with either underwater noise or in-air noise.

Key indicators (KIs) are subsets of marine mammal VECs used to communicate information about the environmental effects of the Project. The use of indicators is a pragmatic approach to conducting an environmental effects assessment, where evaluating every potential effect on the receiving environment is impractical.

The potential for interactions between the Physical Activity and VECs was evaluated based on a review of the literature, information provided by the proponent including a detailed description of the Physical Activity; an appraisal of the environmental setting; temporal and/or spatial overlap between VECs and the Physical Activity; and professional judgment. Existing conditions for each VEC are described in Section 3.1. Project effects and associated mitigation measures are discussed in Section 4.0.

Table 2: Marine Mammal Valued Ecosystem Components and Key Indicators

VECs	Key Indicators	Rationale for Selection
Underwater Noise		
Low-Frequency Cetaceans (LFC)	▪ Humpback whale (*Megaptera novaeangliae*) – North Pacific population ▪ Grey whale - (*Eschrichtius robustus*) – Northern Pacific Migratory population, Western Pacific population, Pacific Coast Feeding Group population	▪ Potential to be affected by the Physical Activity through physical injury, behavioural disturbance and auditory masking ▪ Changes in this VEC has carry-over effects to other biological and social/cultural VECs ▪ Commercial, social, cultural and ecological importance ▪ Biological indicators for marine ecosystem health ▪ Includes listed or protected species
Mid-Frequency Cetaceans (MFC)	▪ Killer whale (*Orcinus orca*) – Southern Resident (SRKW), Transient (Bigg's)	
High-Frequency Cetaceans (HFC)	▪ Pacific harbour porpoise (*Phocoena phocoena vomerina*) Dall's porpoise (*Phocoenoides dalli*)	
Phocid Pinnipeds (PP) Underwater	▪ Pacific harbour seal (*Phoca vitulina richardsi*)	
Otariid Pinnipeds (OP) Underwater	▪ Steller sea lion (*Eumetopias jubatus*) – Eastern population	
In-air Noise		
Phocid Carnivores In-air	▪ Pacific harbour seal (Phoca vitulina richardsii) ▪ Northern elephant seal (Mirounga angustirostris)	▪ Potential to be affected by the Physical Activity through physical injury, behavioural disturbance and auditory masking ▪ Changes in this VEC has carry-over effects to other biological and social/cultural VECs ▪ Commercial, social, cultural and ecological importance ▪ Biological indicators for marine ecosystem health ▪ Includes listed or protected species
Other Carnivores In-air	▪ Steller sea lion (Eumetopias jubatus) – Eastern population	

3.0 EXISTING ENVIRONMENT

A literature review was conducted to characterize the existing biophysical environment and potential socio-economic factors in and adjacent to existing MARPAC OPAREAs, with a focus on identified marine mammal VECs. Information sources consisted of:

- Readily available scientific and grey literature
- Government and non-government reports
- Regional fisheries information available from DFO
- Provincial and federal environmental metadata records (environmental resource mapping databases and online marine special planning tools)
- Federal and provincial records of protected/ listed species, including the federal Species at Risk Registry and BC Species and Ecosystem Explorer online database
- Previous marine-focused EA reports conducted in the MARPAC OPAREAs (as available in the public domain)

A description of all MARPAC OPAREAs is provided in DND's Environmental Effects Determination (EED) of Military Activities in MARPAC OPAREAs (SLR 2019).

3.1 Marine Mammals

A description of existing conditions for marine mammals in OPAREA WH is provided in DND's EED of Military Activities in MARPAC OPAREAs (SLR 2019) and a brief summary of this information is provided in Table 3 for reference. At least 19 species of marine mammal (belonging to 24 populations) have the potential to occur in OPAREA WH at different times of the year (Table 3), including six species of toothed whale (i.e., odontocetes), seven species of baleen whale (i.e., mysticetes), five species of pinniped, and one species of mustelid (sea otter). Eleven of these populations are listed under Schedule 1 of SARA.

This section provides a summary of the seasonal occurrence, preferred habitat and population information for those marine mammal species likely to occur in OPAREA WH (Table 3) including information on species density where available OPAREA (Table 4). A summary of species-specific hearing capabilities and vocal behaviour is also presented (Section 3.1.1).

Table 3: Marine Mammal Species with Potential to Occur in OPAREA WH

Species	Seasonal Occurrence / Habitat Preference	Diet	Estimated Population Size	SARA Status
Low frequency Cetaceans (LFC)				
Humpback whale – North Pacific population	Potential to occur seasonally (spring through fall). Migrate annually from winter breeding grounds in central Pacific (e.g., Hawaii) to summer foraging areas in North Pacific. Some individuals observed year-round in North Pacific (likely juveniles and non-breeders).	Pelagic crustaceans (e.g., krill, mysids) and schooling fish	18,302 (18,000 to 21,000) excluding calves (Calambokidis et al. 2008)	Special Concern – Schedule 1
Grey whale - Northern Pacific Migratory population	Potential to occur seasonally (spring through fall). Migrate annually from winter calving grounds in Mexico to summer feeding areas in the Bering, Chukchi and Beaufort Seas. Northbound migrants stay in close proximity to shore and feed within this migration corridor. DFO Important Area in the Strait of Juan de Fuca (Figure 4 – Annex A).	Mysid and ghost shrimp, benthic crustaceans and, herring eggs	21,000* (COSEWIC 2019a)	No status
Grey whale - Western Pacific population	Potential to occur seasonally (spring through fall). Migrate annually from winter calving grounds in Mexico along the West Coast of Canada to summer feeding areas in Russia. DFO Important Area in the Strait of Juan de Fuca (Figure 4 – Annex A).	Mysid and ghost shrimp, benthic crustaceans and, herring eggs	174* excluding calves and juveniles (COSEWIC 2019b)	No status
Grey whale - Pacific Coast Feeding Group population	Potential to occur seasonally (spring/summer). Migrate annually from wintering grounds in Mexico to their summer feeding areas in Pacific Northwest waters, where they reside the entire summer. DFO Important Area in the Strait of Juan de Fuca (Figure 4 – Annex A).	Mysid and ghost shrimp, benthic crustaceans and, herring eggs	243* (COSEWIC 2019c, DFO 2010a)	No status
Fin whale - *Balaenoptera physalus*	Unlikely to occur in the Strait of Juan de Fuca. Prefer waters near and beyond continental shelf and deep-water coastal areas.	Krill, copepod, euphausiids and schooling fish	No estimates for BC. 9,029 (CV=0.12) in California, Oregon, Washington waters (Nadeem et al. 2016).	Threatened – Schedule 1
Common Minke whale - North Pacific subspecies - *Balaenoptera acutorostrata scammonii*	Year-round. Prefer shallow, coastal waters but can also be found offshore.	Krill, copepods, schooling fish and cephalopods	636 (CV=0.72) in California, Oregon, and Washington waters (Barlow 2016).	No status
Sei whale - *Balaenoptera borealis*	Unlikely to occur in the Strait of Juan de Fuca. Prefer deep-water offshore areas; seldom in coastal waters.	Krill, copepod, and schooling fish	No estimates for BC. 519 (CV=0.40) in California, Oregon, and Washington waters (Barlow 2016).	Endangered – Schedule 1

Notes:

Schedule 1 (Sc1) of *Species at Risk Act* (SARA). Sources: Heise et al. 2007; Keple 2002; Environment Canada 2019; DFO 2018a, 2013, 2010a and b, 2009, 2007; Ford et al. 2013; CRIMS 2014; Ford 2014; Gregr et al. 2000; Levesque and Jamieson 2015; COSEWIC 2019a, b and c; NOAA 2017, 2015a, b and c. * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation; SRKW – southern resident killer whale; * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation, LFC – Low-frequency cetacean, HFC – high-frequency cetacean; MFC – mid-frequency cetacean; SRKW – southern resident killer whale

Species	Seasonal Occurrence / Habitat Preference	Diet	Estimated Population Size	SARA Status
Blue whale - *Balaenoptera musculus*	Unlikely to occur in the Strait of Juan de Fuca. Prefer deep-water offshore areas along continental shelf.	Krill	1,647 (CV=0.07) ranging from California to the Gulf of Alaska (Calambokidis and Barlow 2013)	Endangered – Schedule 1
North Pacific right whale - *Eubalaena japonica*	Unlikely to occur in the Strait of Juan de Fuca. Rarely observed - only 2 confirmed sightings between 1950 and 2013 in Canadian Pacific waters, observed near continental shelf.	Copepods and euphasiids	No estimates for BC. 31 whales (CV = 0.226: Wade et al. 2011) in the eastern Bering Sea and Aleutian Islands.	Endangered – Schedule 1
Mid-frequency Cetaceans (MFC)				
Killer whale (SRKW)	Year-round. Critical Habitat Areas occur in the Strait of Juan de Fuca and Strait of Georgia and off Southwest Vancouver Island near Swiftsure Bank. Critical habitat in the Strait of Juan de Fuca is utilized regularly by all three Southern Resident pods during June through October. J pod appears to be present in the area throughout the year, K and L pods are typically absent during December through April. Critical habitat off Southwest Vancouver Island near Swiftsure Bank is used by members of both the Southern and Northern Resident Killer Whale populations throughout most of the year (DFO 2018a).	Fish (primarily chinook and chum salmon) and cephalopods	Currently, there are an estimated 73 individuals in the SRKW subpopulation with 22 individuals in J pod, 17 in K pod, and 34 in L pod (absolute value as of 1 July 2019; CWR unpublished data 2019).	Endangered – Schedule 1
Killer whale – Northern Resident (NRKW)	Year-round. Critical habitat area off Southwest Vancouver Island near Swiftsure Bank is used by members of both NRKW and SRKW populations throughout most of the year (DFO 2018a).	Fish (primarily chinook and chum salmon) and cephalopods	309* (DFO-CRP unpublished data in DFO 2018a)	Threatened – Schedule 1
Killer whale – Transient (Bigg's)	Year-round. Designation of critical habitat under review, would include marine waters within 6 km of shore. This area identified as important for hunting/feeding.	Marine mammals (particularly seals and porpoises)	521 (total population count; Ford et al. 2013)	Threatened – Schedule 1
Killer whale – Offshore	Unlikely to occur. Infrequently observed in nearshore waters. Spend majority of time in pelagic or shelf-edge waters. Lack of information on seasonal distribution in outer coast waters, but possible northward shift from California to BC during summer.	Sharks and fish	300 (95% HPDI = 257 to 373; Ford et al. 2014)	Threatened – Schedule 1

Notes:

Schedule 1 (Sc1) of *Species at Risk Act* (SARA). Sources: Heise et al. 2007; Keple 2002; Environment Canada 2019; DFO 2018a, 2013, 2010a and b, 2009, 2007; Ford et al. 2013; CRIMS 2014; Ford 2014; Gregr et al. 2000; Levesque and Jamieson 2015; COSEWIC 2019a, b and c; NOAA 2017, 2015a, b and c. * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation; SRKW – southern resident killer whale; * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation, LFC – Low-frequency cetacean, HFC – high-frequency cetacean; MFC – mid-frequency cetacean; SRKW – southern resident killer whale

Species	Seasonal Occurrence / Habitat Preference	Diet	Estimated Population Size	SARA Status
False killer whale - *Pseudorca crassidens*	Unlikely to occur. Rarely sighted north of 50°N.	Fish and cephalopods	Not available	No status
Sperm whale - *Physeter macrocephalus*	Unlikely to occur. Prefer deep-water areas. Historical whaling data suggests mating and calving occurs in BC offshore waters between April and August.	Pelagic squid and fish	No estimates for BC. 1,997 (CV=0.57) in California current (Moore and Barlow 2017)	No status
Pacific white-sided dolphin - *Lagenorhynchus obliquidens*	Year-round. Widespread along continental shelf and slope; increase usage of inland waters in past 30 years, presumably due to prey availability.	Fish (e.g., Pacific herring, salmon, schooling fishes), shrimp and cephalopods	No estimates for BC. 26,880* in Alaskan stock (NOAA 2015a) and 26,814 (CV=0.28) in California, Oregon and Washington stock (Barlow 2016).	No status
High-frequency Cetaceans (HFC)				
Pacific harbour porpoise	Year-round. Prefer shallow shelf-waters throughout BC year-round. Occupy areas within 20 km of shore in waters <150 m characterized by high rates of tidal mixing. DFO Important Area in the Strait of Juan de Fuca (Figure 3 – Annex A).	Fish and cephalopods	In BC, estimates range from approximately 9,120 (95% CI: 4,210 to 19,760; Williams and Thomas 2007) in BC inland waters to about 252 (95% CI 123 to 519; Hall 2004) in the Strait of Juan de Fuca.	Special Concern – Schedule 1
Dall's porpoise - *Phocoenoides dalli*	Year-round. Inshore waters, continental shelf, and beyond, particularly in areas of tidal mixing and over continental shelves and slopes. Follow prey availability.	Fish, squid and crustaceans	No estimates for BC. 25,750 (CV=0.45; Barlow 2016) in California, Oregon, and Washington waters and 417,000 (CV = 0.097; NOAA 2015b) in Alaska waters.	No status
Phocid Pinnipeds				
Pacific harbour seal	Year-round. Forage, mate and rear young throughout BC waters. Usually remain within 20 km of shore. DFO Important Area in the Strait of Juan de Fuca (Figure 5 – Annex A).	Fish (e.g., salmon, Pacific herring), cephalopods	105,000 in BC (95% CI 90,900 to 118,900; DFO 2010b).	No status

Notes:

Schedule 1 (Sc1) of *Species at Risk Act* (SARA). Sources: Heise et al. 2007; Keple 2002; Environment Canada 2019; DFO 2018a, 2013, 2010a and b, 2009, 2007; Ford et al. 2013; CRIMS 2014; Ford 2014; Gregr et al. 2000; Levesque and Jamieson 2015; COSEWIC 2019a, b and c; NOAA 2017, 2015a, b and c. * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation; SRKW – southern resident killer whale; * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation, LFC – Low-frequency cetacean, HFC – high-frequency cetacean; MFC – mid-frequency cetacean; SRKW – southern resident killer whale

Species	Seasonal Occurrence / Habitat Preference	Diet	Estimated Population Size	SARA Status
Northern elephant seal	Strongly migratory, 8 to 10 months spent at sea on and beyond the continental shelf and in protected deep channels and fjords. Deep-diving animals (up to 2,000 m). Undertake two annual visits to land, once during the breeding season and once to moult. Small year-round haul-out and rookery established at Race Rocks Provincial Ecological Reserve.	Squid, sharks, rays, ratfish and other fish	Conservative estimate of 81,368 (twice the observed pup count in Lowry et al. 2014)	No status
Otariid Pinnipeds				
Steller sea lion – Eastern population	Year-round. Feed within 60 km from shore in summer but may range as far offshore as 200 km in the winter. Display site fidelity to seasonal and year-round haul-outs and rookeries. Year-round established haul-out site at Race Rocks Provincial Ecological Reserve that is also considered a DFO Important Area (Figure 6 – Annex A).	Fish (e.g., rockfish, flatfish, salmon) and invertebrates (cephalopods)	28,600 (range 27,100 to 29,500; Olesiuk 2011). May be as many 32,000 Steller Sea Lions in summer (range 27,200 to 36,700) and as many as 48,000 in winter (95% CI 37,900 to 58,300; COSEWIC 2013).	Special Concern – Schedule 1
California sea lion - *Zalophus californicanus*	Year-round. Display site fidelity to terrestrial haul-outs and rookeries. Only winter haul-outs occur in BC. Animals migrate south of BC during the breeding season (May to August). Established haul-out site at Race Rocks Provincial Ecological Reserve.	Fish and cephalopods	Most recent population estimate is 296,750 (based on 68,740 pup counts: NOAA 2015c)	No status
Northern fur seal - *Callorhinus ursinus*	Unlikely to occur. Pelagic pinnipeds spending 90% of time in offshore waters. Individuals occasionally recorded hauled-out at Race Rocks Provincial Ecological Reserve.	Particularly herring in BC during the winter. Other schooling fish and cephalopods.	653,000* (Towell and Ream 2008; Allen and Angliss 2009)	No status
Other				
Sea otter - *Enhydra lutris*	Unlikely to occur in Strait of Juan de Fuca. Observations have been limited to solitary males (vagrants). Prefer shallow (<50 m) coastal waters associated with rocky reefs and kelp beds. Common along West Coast of Vancouver Island and in central / northern coastal BC waters.	Benthic invertebrates (crabs, urchins, clams, snails)	3,185* (Nichol et al. 2005)	No status

Notes:

Schedule 1 (Sc1) of *Species at Risk Act* (SARA). Sources: Heise et al. 2007; Keple 2002; Environment Canada 2019; DFO 2018a, 2013, 2010a and b, 2009, 2007; Ford et al. 2013; CRIMS 2014; Ford 2014; Gregr et al. 2000; Levesque and Jamieson 2015; COSEWIC 2019a, b and c; NOAA 2017, 2015a, b and c. * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation; SRKW – southern resident killer whale; * Confidence interval not identified in literature; CI – confidence interval; CV – coefficient of variation, LFC – Low-frequency cetacean, HFC – high-frequency cetacean; MFC – mid-frequency cetacean; SRKW – southern resident killer whale

Table 4: Seasonal Density Estimates of Marine Mammals in the Strait of Juan de Fuca

Species	Individuals/km^2			
	Winter	Spring	Summer	Fall
Humpback whale	0.00002	0.00014	0.0343429	N/A
Grey whale	0.0051	0.0051	0.00014	0.00014
Minke Whale	0.02	0.02	0.02	0.02
Killer whale (SRKW)	0.000482	0.00072	0.00146	0.00146
Killer whale (Transient/Bigg's)	0.014583	0.020794	0.014583	0.020794
Pacific white-sided dolphin	0.031778	0.031778	0.0317784	0.031778
Harbour porpoise	2.1123	2.1123	2.1123	2.1123
Dall's porpoise	0.55179	0.55179	0.55179	0.55179
Northern elephant seal	0.006	0.006	0.006	0.006
Harbour seal	3.1799	3.1799	3.1799	3.1799
Steller sea lion	0.935	0.935	0.935	0.935
California sea lion	0.676	0.676	0.676	0.676

Sources: Hanser et al. 2015, Koshure 2012

Notes: N/A - not available in any dataset.

3.1.1 Marine Mammal Hearing and Vocal Behaviour

Marine mammals emit a wide range of vocalizations and have distinct ear anatomies within species groups[1] allowing them to hear well at very different frequency ranges (Ketten 1991, Southall et al. 2007). An animal's sensitivity to sound varies with frequency. Response to sound depends on the level of sounds present in the frequency bands to which the animal is most sensitive (Richardson et al. 1995). The general trend is that larger species, such as baleen whales, hear better at lower frequency ranges than smaller species, such as porpoises and dolphins. Hearing abilities are generally better understood for smaller species where audiograms (plots of hearing threshold at different sound frequencies) have been developed based on captive behavioural response studies (reactions to sound) and electrophysiological experiments (measuring auditory evoked potentials [AEP]; Erbe 2012). AEPs have been measured in some toothed whale and pinniped species (Southall et al. 2007; Finneran 2015), while direct measurements of baleen whale hearing are lacking (Ridgway and Carder 2001). Baleen whale hearing sensitivities have therefore been estimated based on anatomy, modelling, vocalizations, taxonomy and behavioural responses (Houser et al. 2001; Parks et al. 2007; Ketten and Mountain 2011, 2014; Ketten 2014; Cranford and Krysl 2015; Richardson et al. 1995; Wartzok and Ketten 1999; Au and Hastings 2008; Dahlheim and Ljungblad 1990; Reichmuth 2007).

[1] Southall et al. 2007 grouped species of marine mammals with similar hearing ranges into 'functional hearing groups'. Species within these groups have anatomical features in common.

To better assess the potential effects of underwater noise and in-air noise on marine mammals, Southall et al. (2007) recommended that marine mammals be divided into functional hearing groups based on measured or estimated functional hearing ranges. These groupings were further modified in the National Marine Fisheries Service's (NMFS underwater threshold guidance document (NMFS 2018) and formalized into five functional hearing group categories as presented in Table 5. Further changes to the functional hearing groups have been proposed by Southall et al. (2019), however, they have not been formally incorporated into the NMFS threshold guidance. Southall et al. (2007) also included an additional functional hearing group for pinnipeds in-air. This was further refined in Southall et al. (2019) and included two phocid groups for in-air effects, Phocid Carnivores in Air (PCA) and Other Marine Carnivores in Water (OCW) (Table 6). The following sections presents information on hearing abilities and vocal behaviour for each functional hearing group with a focus on those species most likely to occur in OPAREA WH. Source levels and dominant frequencies for marine mammal vocalizations are presented in Table 19 in Section 4.1.3.5 (assessment of masking effects).

Table 5: Underwater Marine Mammal Functional Hearing Groups

Functional Hearing Groups	Taxonomic Group	Hearing Range
Low-Frequency Cetaceans (LFC)	Baleen whales	7 Hz to 35 kHz
Mid-Frequency Cetaceans (MFC)	Toothed whales, dolphins, beaked whales, bottlenose whales	150 Hz to 160 kHz
High-Frequency Cetaceans (HFC)	True porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*	275 Hz to 160 kHz
Phocid Pinnipeds (PP) Underwater	True seals	50 Hz to 86 kHz
Otariid Pinnipeds (OP) Underwater	Sea lions and fur seals	60 Hz to 39 kHz
Pinnipeds (PA) In-air	Phocid and otariid pinnipeds	75 Hz to 30 kHz

Source: NMFS (2018)

Table 6: In-air Marine Mammal Functional Hearing Groups

Functional Hearing Groups	Taxonomic Group	Hearing Range
Pinnipeds (PA) In-air[1]	Phocid and otariid pinnipeds	75 Hz to 30 kHz
Phocid Carnivores In-air (PCA) [2]	True seals	Not explicitly stated but expected that the upper frequency cut-off to be > 60 kHz
Other Marine Carnivores In-air (OCA) [2]	Odobenidae; Otariidae; Ursidae; Mustelidae	Not explicitly stated

Sources: 1) Southall et al. 2007; 2) Southall et al. 2019

3.1.1.1 Low-frequency Cetaceans (LFC)

Baleen whales that are most likely to occur in OPAREA WH include humpback whale, grey whale and minke whale. The occurrence of other baleen whale species in OPAREA WH such as sei whale, blue whale, fin whale and North Pacific right whale would be considered extremely rare. The auditory system of baleen whales does not appear to be as specialized as that of toothed whales (Ketten 1997). Audiograms are generally not available for baleen whales due to the difficulties of implementing controlled behavioural or electrophysiological hearing studies on large animals in captive experimental settings. Hearing thresholds and frequency sensitivities in baleen whales are thus inferred from anatomical ear structure, vocalizations, and behavioural studies in the wild (Richardson et al. 1995; JIP 2018). The estimated auditory bandwidth of low-frequency cetaceans is 0.007 to 35 kHz (NMFS 2018).

In general, most baleen whales produce low-frequency sounds and have been shown to be most sensitive to sounds in the low-frequency range (below 1 kHz). Dominant frequencies of baleen whale vocalizations are generally below 2 kHz with some song components cantered around 4 kHz (Richardson et al. 1995). Singing behaviour is an advanced form of vocalization in baleen whales and plays a role in mating (Clark 1991; Darling et al. 2006; Winn and Winn 1978; Herman 2016). Humpback whale may also use songs as long-range echolocation mechanisms to detect other whales and environmental features (Mercado 2018). Humpback whale songs are emitted within the range of 20 to 4,000 Hz with components extending to 8,000 Hz (Thompson et al. 1979; Payne and Payne 1985). Other baleen vocalizations include tonal moans, pulsive vocalizations, thumps, shrieks, grunts, clicks and calls that range from 20 Hz to 8,000 Hz. Less is known about the purpose and use of non-song vocalizations which are produced throughout the animal's range (Dunlop et al. 2008; Fournet et al. 2015; SMRU 2017). Tonal calls are thought to be related to foraging activities and may play a social role in the Pacific Northwest (Fournet et al. 2015). Some clicks recorded from grey whale calves can occur at 20,000 Hz although high-frequency clicks in baleen whales appear to be used infrequently (Stimpert et al. 2007; Richardson et al. 1995).

3.1.1.2 Mid-frequency Cetaceans (MFC)

Most toothed whales are classified as MFC, with this hearing group comprised globally of 32 species of dolphin, six species of larger toothed whale, and 19 species of beaked and bottlenose whale. MFC species most likely to occur in OPAREA WH include killer whale (primarily SRKW and transient ecotypes) and Pacific white-sided dolphin. MFC have a functional hearing range of 150 Hz to 160 kHz (Southall et al. 2007; NMFS 2018).

Hearing abilities in toothed whales has been studied since the late 1980s (Richardson et al. 1995; Au et al. 2000); however, little is known on the hearing abilities of the larger, deep-diving toothed whales such as the sperm whale and beaked whale species. Underwater behavioural audiograms of several toothed whale species show that they can hear sounds over a wide range of frequencies, as low as 40 to 75 Hz in the case of the beluga (*Delphinapterus leucas*) and bottlenose dolphin (*Tursiops truncatus*). However, their sensitivity at such low frequencies is likely poor (Richardson et al. 1995). Studies have also shown that the majority of small to medium-sized toothed whales hear well at higher frequencies with their best hearing sensitivity occurring at or near the frequency where echolocation signals are strongest (Southall et al. 2019). Based on audiometry data obtained from behavioural (BEH) and neurophysiological (AEP) studies, killer whale likely hear sounds as low as 200 Hz (BEH data) and as high as 90 kHz (AEP data) to 140 kHz (BEH; full review in Southall et al. 2019).

MFCs emit a wide range of sounds including tonal whistles, pulsed sounds, echolocation, cries, grunts and barks (Richardson et al. 1995). These sounds are used when foraging, navigating and for social interactions. Most echolocation clicks are produced at very high frequencies. Killer whales use a variety of vocalizations to communicate with each other, find prey and navigate through their environment (Ford 1989; Miller 2006; Heise et al. 2017). Pulsed calls are typically used to communicate between conspecifics over larger distances, up to 15 km, while whistles are typically used for short-range communication (Miller 2006). Pulsed calls and whistles (0.5 to 15 kHz) are important for maintaining group cohesion, communicating between cow-calf pairs, communicating information on the location of prey and potential threats, and maintaining social interactions (Heise et al. 2017). Killer whale use high frequency echolocation clicks (15 to 100 kHz) to find prey, avoid obstacles, and to navigate. Killer whale have been reported to use clicks to detect salmon up to at least 250 m away under favourable environmental conditions (Au et al. 2004, SMRU 2014a, b).

3.1.1.3 High-frequency Cetaceans (HFC)

HFC that may occur in OPAREA WH include Dall's porpoise and Pacific harbour porpoise. HFC hearing overlaps that of the MFC with a functional hearing range of 275 Hz to 160 kHz (Southall et al. 2007; NMFS 2018). Behavioural audiograms (BEH) are available for the harbour porpoise, Chinese river dolphin (*Lipotes vexillifer*) and the Amazon river dolphin (*Inia geoffrensis*; Andersen 1970; Kastelein et al. 2002a; Wang et al. 1992; Jacobs and Hall 1972). Audiograms using AEP methods have been obtained for three species: harbour porpoise (Popov et al. 1986, 2006; Beedholm and Miller 2007; Lucke et al. 2009), finless porpoise (*Neophocaena phocaenoides*; Popov et al. 2006), and Amazon river dolphin (Popov and Supin 1990). As with MFC, HFC hear well at higher frequencies with their optimal sensitivity occurring at or near the frequency where echolocation signals are strongest. Echolocation pulses generated by HFC occur at frequencies ranging from 110 to 150 kHz, with source levels ranging from 135 to 177 dB re 1 μPa at 1 m (Richardson et al. 1995). Within this group, harbour porpoise are considered one of the most sensitive mammal species to acoustic disturbance (Southall et al. 2007), with a hearing sensitivity of approximately 33 dB re 1 μPa between 100 and 140 kHz (Kastelein et al. 2002a).

3.1.1.4 Phocid Pinnipeds (PP)

Harbour seal and northern elephant seal are the only phocid pinniped species with potential to occur in OPAREA WH. Underwater hearing sensitivity in phocid pinnipeds falls between that of baleen and toothed whales, with a functional hearing range of 50 Hz to 86 kHz. Phocinid seals (phocids), such as the harbour seal, have underwater hearing thresholds between 60 and 85 dB re 1 μPa with flat audiograms between 1 kHz and 30 to 50 kHz (Møhl 1968; Terhune 1981; Terhune and Ronald 1972, 1975). Spotted seal (*Phoca largha*) and ringed seal (*Phoca hispida*) were shown to have hearing thresholds between 50 and 100 dB re 1 μPa with a flat audiogram between 1 and 50 kHz (JIP 2018). Some phocids, such as harbour seal, can detect high frequency sounds up to 180 kHz (Cunningham and Reichmuth 2016), although their sensitivity to sounds above 60 kHz is poor and frequencies cannot be discriminated (Møhl 1968). Phocids have an extended frequency range of hearing compared to otariids (sea lions), particularly at higher frequencies (Hemilä et al. 2006; Kastelein et al. 2002b). Some phocid species produce strong underwater sounds that may propagate over large distances while other emit weaker noises. Many of these sounds are produced during the mating season and associated with territoriality and reproduction. Detected sounds emitted by phocid seals range from 90 Hz to 16 kHz (Richardson et al. 1995).

3.1.1.5 Otariid Pinnipeds (OP)

Otariid pinnipeds that have the potential to occur in OPAREA WH include Steller sea lion and California sea lion. Otariid pinnipeds have a reduced functional hearing range compared to phocid seals, between 60 Hz to 39 kHz. Some otariids, such as the California sea lion, can detect high frequency sounds up to 180 kHz (Cunningham and Reichmuth 2016). Fur seal hearing is most sensitive between 4 kHz and 17 kHz, up to 28 kHz. Sea lions are most sensitive to frequencies between 2 kHz and 16 kHz (Richardson et al. 1995). Otariids have a lower high frequency cut-off than phocid seals (indicative of their lower upper limit to their functional hearing range) and do not hear as well as phocid seals at frequencies below 100 Hz (Cunningham and Reichmuth 2016).

Sea lions and fur seals use in-air and underwater vocalizations to establish territories, during mating, and to maintain the mother-pup bond. Most studies of noises emitted by otariids has been conducted on the California sea lion (Richardson et al. 1995). When in the water with their heads above the surface, California sea lion mainly produce barks sounds but also emit whinny and buzzing sounds as well as clicks. Bark sounds are carried through the air as well as through the water with dominant frequencies of <2 kHz (Richardson et al. 1995).

3.1.2 Species at Risk

In the marine environment, species at risk (SAR) include those species listed under SARA or by COSEWIC. A review of the federal SARA registry was undertaken to determine if SAR were known to occur, or have the potential to occur, in or adjacent to OPAREA WH. The likelihood of occurrence of a SAR in the exercise areas was determined by assessing potential overlap between OPAREA WH and known SAR home ranges and habitat preferences. A list of species at risk potentially present in OPAREA WH is provided in Table 7.

Table 7: Listing Status of Marine Mammal VECs

Species	SARA Status and Schedule	COSEWIC Status	Designated Critical Habitat (Threatened and Endangered) or Important Areas (Special Concern)
Low-Frequency Cetaceans (LFC)			
Humpback whale	SC/Sc1	Special Concern	Previously protected critical habitat and Important Areas (IAs) are shown on Figure 4 – Annex A and do not overlap with OPAREA WH.
Grey whale – Pacific Coast Feeding Group population	No Status	Endangered1	IAs are shown on Figure 4– Annex A. IA for foraging overlaps with OPAREA WH.
Grey whale – Western Pacific population	No Status	Endangered1	IAs are shown on Figure 4– Annex A . IA for foraging overlaps with OPAREA WH.
Blue Whale	EN/Sc1	Endangered	Critical habitat has not been identified (Gregr et al. 2006). IAs do not overlap with OPAREA WH.
Fin Whale	TH/Sc1	Threatened	Critical habitat has not been identified (Gregr et al. 2006). IAs do not overlap with OPAREA WH.
Sei Whale	EN/Sc1	Endangered	Critical habitat has not been identified (Gregr et al. 2006). IAs do not overlap with OPAREA WH.
North Pacific Right Whale	EN/Sc1	Endangered	Critical habitat has not been identified (DFO 2011).
Mid-Frequency Cetaceans (MFC)			
Killer whale – SRKW	EN/Sc1	Endangered	Designated critical habitat is shown on Figure 2 – Annex A and overlaps with OPAREA WH.
Killer whale – NRKW	TH/Sc1	Threatened	Designated critical habitat is shown on Figure 2– Annex A and does not overlap with OPAREA WH.
Killer whale – Transient	TH/Sc1	Threatened	Designation of critical habitat is currently under review by DFO (DFO 2017).
Killer whale – Offshore	TH/Sc1	Threatened	Identification of critical habitat is not currently possible due to lack of information on habitat use (DFO 2018b).

Notes:

1) Currently in the DFO consultation phase. Committee on the Status of Endangered Wildlife in Canada (COSEWIC); Schedule 1 (Sc1) of *Species at Risk Act* (SARA); Note: EN=Endangered; TH=Threatened; SC=Special Concern. N/A = not available, recent changes to the grey whale designable units has not been incorporated by the province. 1. Currently in the DFO consultation phase. Source: Government of Canada 2019b.

Species	SARA Status and Schedule	COSEWIC Status	Designated Critical Habitat (Threatened and Endangered) or Important Areas (Special Concern)
High-Frequency Cetaceans (HFC)			
Pacific harbour porpoise	SC/Sc1	Special Concern	IAs are shown on Figure 3 – Annex A and overlap with OPAREA WH.
Otariid Pinnipeds (OP)			
Steller sea lion	SC/Sc1	Special Concern	IAs are shown on Figure 6 – Annex A and do not overlap with OPAREA WH.
Other			
Sea otter	SC/Sc1	Special Concern	IAs do not overlap with OPAREA WH.

Notes:

1) Currently in the DFO consultation phase. Committee on the Status of Endangered Wildlife in Canada (COSEWIC); Schedule 1 (Sc1) of *Species at Risk Act* (SARA); Note: EN=Endangered; TH=Threatened; SC=Special Concern. N/A = not available, recent changes to the grey whale designable units has not been incorporated by the province. 1. Currently in the DFO consultation phase. Source: Government of Canada 2019b.

3.1.3 Protected Areas

Several provincially and federally designated protected areas were identified within and adjacent to OPAREA WH. These areas are summarized in Table 8 and are presented in Figure 2 and Figure 7 (Annex A).

Table 8: Protected Areas Near OPAREA WH

Designations	Legislation
Federally Protected Areas	
NRKW and SRKW Designated Critical Habitat. Mandatory 400 m closest approach distances to killer whales within designated SRKW critical habitat and British Columbia coastal waters east of Vancouver Island and south of Campbell River (Cape Mudge) and Malaspina Peninsula (Sarah Point). The 400-m approach distance is in place year-round to provide on-going protection for any Southern Residents that are found in coastal BC waters, regardless of the season The Marine Mammal Regulations continue to remain in effect year-round, including maintaining a minimum 200 m approach distance from all killer whales in Canadian Pacific waters other than described above, and 100 m for other whales, porpoises and dolphins or 200 m when the animal is in resting position or with a calf.	*Species at Risk Act* and Interim Order, under the *Canada Shipping Act* (Government of Canada 2020). Marine Mammal Regulations (DFO 2018b; Government of Canada 2018)
Interim Sanctuary Zones (for SRKW) – prohibition of general vessel traffic (with exemptions). It is unclear if these Interim Sanctuary Zones will be made permanent under the Marine Mammal Regulations or Canadian Shipping Act. 1 June through 30 November 2020 (Figure 7– Annex A).	31 May 2020, the Government of Canada issued an Interim Order, under the *Canada Shipping Act* (Government of Canada 2020).

Designations	Legislation
National Wildlife Areas – Activities in a National Wildlife Area are authorized where notices have been posted at the entrance to or boundary of the area or published in local newspapers. Prohibited activities in all National Wildlife Areas include: hunting or fishing, possession of firearms or other hunting devices, possession of any wildlife or carcass, nest, or eggs, damaging, destroying or removing a plant, carrying on any agricultural activity, allowing any domestic animal to run at large, destroying or molesting any wildlife, carcasses, nests or eggs, cutting, picking, removing or wilfully damaging any vegetation, disturbing or removing soil, sand, gravel or other material, removing, defacing, damaging or destroying any artefact, natural object, building, fence, poster sign or other structure, recreational activities such as camping, swimming, picnicking or having campfires, using a boat, aircraft or other vehicle, any commercial or industrial activity, dumping or depositing any rubbish, waste material, or substance that would degrade or alter the quality of the environment, entry into any National Wildlife Area where notice prohibiting such entry has been given (ECCC 2019).	*Canada Wildlife Act*
National Park Reserves including two areas with marine components. Several prohibitions specific to each area under the regulations pursuant to the *Canada National Parks Act* (Parks Canada 2019).	*Canada National Parks Act*
DFO Rockfish Conservation Areas. Within RCAs, inshore rockfish are protected from all mortality associated with recreational and commercial fisheries (DFO 2019b)	*Fisheries Act*
Offshore Pacific Seamounts and Vents Closure - Prohibits all bottom-contact commercial and recreational fishing activities. Endeavour Hydrothermal Vents Marine Protected Area (MPA) also located within this area (DFO 2019c).	*Fisheries Act*
Strait of Georgia and Howe Sound Glass Sponge Reef (17 fisheries area closures) – Prohibits all bottom-contacting commercial, recreational, and Indigenous food, social and ceremonial fishing activities. Use of downrigger gear in recreational salmon trolling is also prohibited in certain areas due to the potential risk of damage to shallow reefs (DFO 2019c).	*Fisheries Act*
SGaan Kinghlas-Bowie Seamount MPA – Prohibition of activities that disturb, damage, destroy or remove from this area, living marine organisms or any part of their habitat, any part of the seabed or carry out any activity — including depositing, discharging or dumping any substance, or causing any substance to be deposited, discharged or dumped — that is likely to result in the disturbance, damage, destruction or removal of a living marine organism or any part of its habitat, unless listed as exceptions in the Regulations or approved by the Minister (DFO 2019d).	*Oceans Act*
Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA-Prohibition of activities that disturb, damage, destroy or remove from this area, living marine organisms or any part of their habitat, unless listed as exceptions in the Regulations or approved by the Minister (DFO 2019d).	*Oceans Act*
Endeavour Hydrothermal Vents MPA– Prohibition of activities that disturb, damage, destroy or remove from this area, living marine organisms or any part of their habitat, unless listed as exceptions in the Regulations or approved by the Minister (DFO 2019d).	*Oceans Act*

Designations	Legislation
Proposed Federally Protected Areas	
Proposed Southern Strait of Georgia NMCA Reserve (National Marine Conservation Areas; Government of BC 2012).	Will be protected under the *National Marine Conservation Areas Act*
Race Rocks Area of Interest (AOI) as a MPA (Figure 7– Annex A). In 1998, DFO identified the area as an AOI for MPA designation under Canada's *Oceans Act*. The date of designation of the Race Rocks MPA is pending. Race Rocks AOI is also a Provincial Ecological Reserve (DFO 2019e).	Will be protected under the *Oceans Act*.
On 24 May 2017, the Minister of Fisheries and Oceans Canada announced a portion of the Offshore Pacific Bioregion (OPB) as an Area of Interest (AOI) for consideration as a Marine Protected Area (MPA) under the *Oceans Act*. Legal designation of this area has not yet been announced (as of November 2019; DFO 2019f).	Will be protected under the *Oceans Act*
Provincially Protected Areas	
Race Rocks Provincial Ecological Reserve (Figure 7 – Annex A). Consumptive activities like hunting, freshwater fishing, camping, livestock grazing, removal of materials, plants or animals are prohibited by regulation in ecological reserves. Motorized vehicles are not allowed. Research and educational activities may be carried out but only under permit (BC Parks 2019).	*Park Act and Protected Areas of BC Act.*
Migratory Bird Sanctuaries (Figure 7– Annex A). Prohibitions regarding the taking, injuring, destruction or molestation of migratory birds or their nests or eggs in the sanctuaries. Hunting of listed species under the Act is not permitted in any Migratory Bird Sanctuary (Government of Canada 2019a).	*Migratory Birds Convention Act*
Other	
DFO Important Areas (Figures 3 to 6 – Annex A; Levesque and Jamieson 2015).	None
Under the 2020 SRKW Management Measures to Protect SRKWs, a voluntary slow down to less than 7 knots when within 1,000 m of killer whales is in place year-round and in all Canadian Pacific waters (Figure 2 – Annex A).	None

4.0 POTENTIAL EFFECTS AND ASSOCIATED MITIGATION MEASURES

This section provides an evaluation of the potential effects of the Physical Activity (small-arms military training exercises in OPAREA WH) on marine mammal VECs/KIs identified in Table 2. The evaluation was based on a review of the scientific literature relevant to known effects of in-air and underwater noise from impulsive noises on marine mammals, predictive acoustic modelling results, and animal exposure probabilities based on available species density estimates in the areas of predicted exposure. Operationally achievable mitigation measures are described and assessed for effectiveness in Section 4.1.4 (Table 21) with aim to eliminate/reduce any identified adverse effects. Residual effects, following the application of operationally achievable mitigation, are outlined in Section 4.1.5.

This evaluation focused solely on the acoustic effects to marine mammals associated with gunnery activities in OPAREA WH. As such, the potential for physical impacts from gunfire striking marine mammals was not evaluated. However, RCN and USCG Units follow firing orders that identify specific areas (safety firing arcs/area clear requirements) that must be clear of all land, vessels, aircraft and marine mammals. These areas are specific to each weapon and are based on weapon hazard patterns that were developed from a worst-case scenario that includes deflection error, environmental factors, ricochets, and round fragmentation.

4.1 Marine Mammals

In-air and underwater noise generated during small-arms military training exercises in OPAREA WH has the potential to result in the following adverse effects on marine mammals:

- Injury and/or mortality
- Disturbance (behavioural effects)
- Acoustic Masking

In support of this part of the assessment, background information is provided below on marine mammals and in-air and underwater noise, including a summary of existing acoustic thresholds for marine mammal injury and disturbance.

Both in-air and underwater sound can be described through a source-path-receiver model. An acoustic source emits sound energy that radiates outward and travels through the air or 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 (Richardson et al. 1995). The amount of transmission loss that occurs depends on the source receiver separation, the frequency of the sound, atmospheric conditions, for in-air sound, and the properties of the water column and seafloor layers, for underwater sound. Sound levels are expressed in decibels (dB) which is a logarithmic ratio relative to a fixed reference pressure of 20 μPa (equal to 2×10^{-5} Pa or 10^{-4} bar) in air and1 μPa (equal to 10^{-6} Pa or 10^{-11} bar) underwater.

The efficiency of underwater sound propagation allows marine mammals to use underwater sound as a primary method of communication, navigation, prey detection (i.e., foraging) and predator avoidance (OSPAR Commission 2009; Richardson et al. 1995; Southall et al. 2011). Though underwater sound is important to all marine mammals, amphibious marine mammals, including the pinnipeds (seals, sea lions and walruses), sea otter and polar bear, also use in-air sound (Douglas and Ketten 1999). The use of in-air sound in pinniped species occurs primarily in social functions, advertisements of dominance and female attendance behaviour (Kastak and Schusterman 1998). Compared to seals and sea lions, the underwater hearing sensitivity of sea otters is considerably reduced suggesting that sea otters are primarily adapted to hearing in-air sounds (Ghoul and Reichmuth 2014).

Anthropogenic (i.e., human introduced) noise has gained recognition as an important stressor for marine mammals especially because of their reliance on underwater hearing for maintenance of these critical biological functions (Richardson et al. 1995; Ketten 1998). In-air and underwater noise generated by human activities can often be detected by marine mammals many kilometres from the source. With increasing distance from a noise source, potential acoustic impacts can range from physiological injury, permanent or temporary hearing loss, behavioural changes, and acoustic masking (Figure 1). All the above impacts have the potential to induce stress on marine mammals (OSPAR 2009; Erbe 2013).

Figure 1: Acoustic impact zones around a noise source (Source: Erbe 2013)

Anthropogenic noise sources can be categorized generally as impulsive (e.g., impact pile driving, blasting and gunfire) or non-impulsive/continuous (e.g., shipping, military sonar). Impulsive noises are characterized by broad frequencies, fast rise-times, short durations and high peak sound pressures (Finneran 2016) whereas non-impulsive noise is better described as a steady-state noise source. Both impulsive and non-impulsive sounds can be transient in nature and variable in temporal scale. For example, sounds from moving sources such as ships are non-impulsive noise sources, although transient relative to the receivers. Transient sounds may rise and fall in amplitude as the source or receiver move towards and away from one another. For the purpose of the current assessment, underwater noise from small-arms military training exercises is treated as impulsive noise due to its brief, broadband and transient nature.

The potential for in-air and underwater noise to cause adverse impacts to an animal depends on the received sound level, the frequency content of the sound relative to the hearing ability of the animal, and the level of natural background noise. Potential effects range from subtle changes in behaviour at low received levels to strong disturbance effects or potential injury and/or mortality at high received levels.

Sound reaching the receiver with ample duration and sound pressure level (SPL, an indicator of acoustic wave strength) can result in a loss of hearing sensitivity in marine mammals termed a noise-induced threshold shift (NITS). This may consist of a temporary threshold shift (TTS) or permanent threshold shift (PTS). TTS is a relatively short-term reversible loss of hearing following noise exposure (Southall et al. 2007; Le Prell 2012), often resulting from cellular fatigue and metabolic changes (Saunders et al. 1985; Yost 2000). While experiencing TTS, the hearing threshold rises, and a sound must be louder to be detected. PTS is an irreversible loss of hearing (permanent damage) following noise exposure that commonly results from inner ear hair cell loss and/or severe damage or other structural damage to auditory tissues (Saunders et al. 1985; Henderson et al. 2008). While there is no direct evidence of PTS occurring in marine mammals, TTS has been demonstrated in MFC (dolphins, beaked whales), HFC (harbour porpoise), and pinnipeds (harbour seal, California sea lion, northern elephant seal) in response to exposure to impulsive and non-impulsive noise sources (a review is provided in Southall et al. 2007 and NMFS 2013). Prolonged or repeated exposure to sound levels sufficient to induce TTS without recovery time can lead to PTS (Southall et al. 2007).

Behavioural responses to anthropogenic sound sources can be categorized using a severity scale of low, moderate, or high (Southall et al. 2007; Finneran et al. 2017). Low severity responses are within an animal's range of typical (baseline) behaviours and are unlikely to disrupt an individual to a point where natural behaviour patterns are significantly altered or abandoned. Examples of low severity responses include:

- Orientation response
- Startle response
- Change in respiration
- Change in heart rate
- Change in group spacing or synchrony

Moderate severity responses could become significant if sustained over a longer duration. What constitutes a long-duration response is different for each situation and species, although it is likely dependent upon the magnitude of the response, the nature of the receptor (e.g., body size, experience), and the contextual situation such as the animal's behavioural state at the time of the exposure (e.g., foraging, diving, resting). In general, a response would be considered 'long-duration' if it lasted for a few tens of minutes to a few hours, or long enough to significantly disrupt an animal's daily routine. Examples of moderate severity responses include:

- Altering migration path, locomotion (speed, heading), dive profiles
- Stopping/altering nursing, breeding, feeding/foraging, sheltering/resting, vocal behaviour
- Avoiding area near sound source
- Displays of aggression or annoyance (e.g., tail slapping)

Moderate severity responses would not be considered significant behavioural responses if they lasted for a short duration and the animal immediately returned to its pre-response behaviour (Southall et al. 2007). Conversely, a moderate severity response sustained over an extended period that had potential implications on a critical life function (e.g., foraging efficiency, breeding success) would be considered significant. For the purpose of this assessment, a long duration behavioural response was defined as a response that lasted for the full duration of exposure or longer, as this would suggest that had the exposure continued, the behavioural response would have also persisted.

High severity responses are those with possible immediate consequences to growth, survivability, or reproduction, for example:

- Long-term or permanent abandonment of area
- Prolonged separation of females and dependent offspring
- Panic, flight, or stampede
- Stranding

High severity responses include those with immediate consequences (e.g., stranding) and those affecting animals in vulnerable life stages (i.e., calving, rearing). High severity responses are therefore considered to be a significant behavioural response (Southall et al. 2007; Finneran et al. 2017).

Auditory masking occurs when sound signals used by marine mammals overlap in time, space and frequency with another sound source (Richardson et al. 1995). Masking can reduce communication space, limit the detection of relevant biological cues and reduce echolocation effectiveness. Masking effects are not considered in the behavioural response severity scale previously mentioned (Southall et al. 2007). A growing body of literature is focused on improving the framework for assessing the potential for masking of animal communication by anthropogenic noise and understand the resulting effects. More research is needed to understand the process of masking, the risk of masking by anthropogenic activities such as small weapons training exercises, the ecological significance of masking, and what anti-masking strategies are used by marine animals and their degree of effectiveness before masking can be incorporated into regulation strategies or mitigation approaches (Erbe et al. 2016).

Noises are less likely to disturb or injure an animal if they are at frequencies at which the animal cannot hear well. The importance of sound components at particular frequencies can be scaled by frequency weighting relative to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998; Nedwell et al. 2007). Regulatory thresholds used for the purpose of predicting the extent of potential noise impacts on marine mammals and subsequent management of these impacts have recently been revised to account for the duration of exposure and the differences in hearing acuity amongst marine mammal hearing groups (Finneran 2016; NMFS 2018; Southall et al. 2019), as described further below.

4.1.1 Acoustic Criteria for Injury and Disturbance

Assessment of potential effects of in-air and underwater noise on marine mammals requires acoustic thresholds against which received sound levels can be compared. Auditory thresholds for in-air and underwater noise are expressed using two common metrics: SPL, measured in dB re 20 µPa (in air) or dB re 1 µPa (underwater), and SEL, a measure of energy in dB re 20 uPa^2s (in air) or dB re 1 μPa^2s (underwater). SPL is an instantaneous value represented as either root-mean-square (SPL_{rms}) or peak sound pressure level (SPL_{peak}), whereas SEL is the total noise energy to which an animal is exposed over a given time period, typically one second for pulse sources. As such, the SEL metric is appropriate when assessing effects to marine mammals from cumulative exposure to multiple pulses.

4.1.1.1 Criteria for In-air Noise

Southall et al. (2007) recognized the amphibious nature of pinnipeds and the potential for pinnipeds to be harmed by in-air noise as well as underwater noise. The 2007 report included PTS thresholds and behavioural disturbance thresholds for pinnipeds in-air (PA). Recently, Southall et al. (2019) re-evaluated the previous in-air threshold criteria and proposed revised exposure criteria to predict the onset of auditory injury impacts to phocid pinnipeds and other marine carnivores. The updated in-air criteria included thresholds for two marine mammal groups, phocid carnivores in-air (PCA) and other marine carnivores in-air (OCA). Other marine carnivores include non-phocid pinnipeds such as sea lions, fur seals, and sea otters. These two classifications aimed to account for the significant hearing differences between phocid pinniped and other pinnipeds such as otariids (e.g., sea lions), with phocid pinnipeds having a much broader hearing sensitivity than any other mammalian taxa (Southall et al. 2019).

Small arms training activities are considered impulsive sounds like impact pile driving and seismic activities. The impulsive thresholds applied to assessments of in-air noise from small-arms military training activities include:

- frequency-weighted sound exposure level (SEL; $L_{E,24h}$) for onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) for phocid carnivores in-air (PCA) and other marine carnivores in air (OCA), based on Southall et al. (2019, Table 9)
- PTS for pinnipeds in-air, based on Southall et al. (2007, Table 10)
- Behavioural thresholds for pinnipeds in-air, based on Southall et al. (2007, Table 11)

Table 9: Injury Thresholds for Phocid Carnivores In-air and Other Marine Carnivores In-air – Impulsive Noise

Functional Hearing Group	Peak Sound Pressure Level (dB re 20 µPa)		Weighted SEL_{24h} (dB re 20 µPa^2·s)	
	TTS Threshold	PTS Threshold	TTS Threshold	PTS Threshold
PCA	138	144	123	138
OCA	161	167	146	161

Source - Southall et al. 2019. OCA – Other Marine Carnivores in-air; PCA – Phocid Carnivores In-air; PTS – permanent threshold shift; TTS – temporary threshold shift

Table 10: Injury Thresholds for Pinnipeds In-air – Impulsive Noise

Sound Level	PTS Threshold
Peak sound pressure level	149 dB re 20 µPa
Sound exposure level	144 dB re 20 µPa^2·s

Source - Southall et al. 2007. PTS – permanent threshold shift

Table 11: Behavioural Disturbance Thresholds for Pinnipeds In-air – Impulsive Noise

Sound Level	Behavioural Threshold
Peak sound pressure level	109 dB re 20 μPa
Sound exposure level	100 dB re 20 $\mu Pa^2 \cdot s$

Source - Southall et al. 2007

4.1.1.2 Criteria for Underwater Noise

The most widely accepted thresholds for underwater noise are provided by the NMFS (2018) and have recently been updated in terms of injury thresholds (e.g., physical impacts). No recent guidance has been published by the NMFS on behavioural disturbance thresholds for marine mammals. Since 2016, the NMFS has, by default, used an unweighted SPL_{rms} of 160 dB re 1 μPa as a behavioural response threshold for impulsive noise sources for all cetacean species (NMFS and NOAA 2005; NMFS 2013). This threshold is based on limited reported behavioural responses observed in migrating mysticetes in response to seismic airgun sounds (as reported in (Southall et al. 2007).

Thresholds within these guidelines are presented for impulsive noise sources which have been applied in the assessment of underwater noise from small-arms military training. The thresholds considered in this assessment include:

- frequency-weighted sound exposure level (SEL; $L_{E,24h}$) for onset of TTS and PTS of marine mammals based on NMFS (2018)
- unweighted sound pressure level root mean squared (SPL_{rms}) behavioural response threshold for all marine mammal species using 160 dB re 1 μPa SPL from NMFS (2013)

The specific methods used to determine thresholds for injury are summarized in NMFS (2018). This document represents the best available information on acoustic injury thresholds for marine mammals. NMFS (2018) criteria are based on updated frequency weighting functions for five functional hearing groups for underwater noise (LFC, MFC, HFC, phocid pinnipeds, otariid pinnipeds) described by Finneran and Jenkins (2012). The onset of PTS and TTS considers both duration of exposure and species-dependent hearing acuity. Table 12 lists the applied marine mammal PTS and TTS onset thresholds for each hearing group for an impulsive source.

Table 12: Marine Mammal Injury (PTS/TTS) Thresholds – Impulsive Noise

Hearing Group	Weighted SEL_{24h} (dB re 1 $Pa^2 \cdot s$)	
	TTS	PTS
Low-frequency (LF) cetaceans	168	183
Mid-frequency (MF) cetaceans	170	185
High-frequency (HF) cetaceans	140	155
Phocid pinnipeds in water	170	185
Otariid pinnipeds in water	188	203

Source: NMFS 2018

4.1.2 Literature Review

A literature review was conducted to characterize the potential effects of small arms training activities on marine mammals in both in-air and underwater environments. Due to the limited availability of information, studies from other impulsive noise sources (e.g., aircraft and blasting for in-air and seismic and impact pile driving for underwater) were referenced and used to predict effects.

4.1.2.1 In-air Noise

It has been well demonstrated that terrestrial animals exhibit immediate behavioural responses, such as hiding or fleeing, in response to acute and intense acoustic events, such as those produced by gunshot, aircraft overflight, or chainsaws (National Academies of Science 2017). However, there is a general lack of published studies regarding the potential effects of in-air anthropogenic noise on amphibious marine mammal species (e.g., pinnipeds, sea otters, polar bears etc.). Information is available from a limited number of activities including aircraft overflight (fixed wing aircraft and helicopters), explosive and non-explosive ordnance, and missiles (Demarchi, et al. 2012; Finneran, et al. 2017; Holst et al. 2011; NRC 2003). There is a need for more studies on the potential effects of in-air noise on pinnipeds and other amphibious marine mammal species.

None of the literature reviewed for this report demonstrated that in-air noise generated from the aforementioned activities resulted in direct injury or mortality to marine mammals. Demarchi et al. (2012) measured in-air noise levels of military training operations between 1997 and 2010 near Race Rocks Provincial Ecological Reserve to assess short-term behavioural responses of Steller sea lions in their winter haul-out area. The results of this study showed that received sound levels from military explosions (demolitions and ordnance disposal) were well below the Southall et al. (2007) proposed 149 dB re 20 μPa (SPL_{peak}) injury threshold (PTS) for pinnipeds in-air.

Though there is no evidence of direct injury or mortality of marine mammals as a result of in-air noise sources, it is predicted that the small arms training activities have the potential to result in injury to marine mammals as these will exceed established in-air PTS and TTS thresholds for pinnipeds and other marine carnivores (as discussed in Section 4.1.1.1). For example, when pinnipeds are hauled out on land, they are known to startle and often stampede into the water in reaction to in-air noise (Calkins 1979). During such stampedes, vulnerable individuals, such as mothers and pups, are at risk of being trampled resulting in injury or death. In Eastern Canada, walrus have been reported to stampede into the water in response to aircraft overflights and these events were later shown to result in the death of calves (National Academies of Science 2017). In addition to being injured or killed by trampling, walrus calves can get separated from their mother and subsequently die if a mother abandons the calf during a stampeding event. During helicopter flyovers, harbour seal were observed reacting to flyovers with mothers abandoning newborn pups when they retreated into the water (NRC 2003).

As demonstrated in the above examples, most literature discussing marine mammal reactions to in-air noise describe behavioural responses with no examples of direct injury or death. The behavioural responses reported in the literature include: no reaction at all, startle response, increased alertness, increased activity, fleeing, mothers abandoning pups when fleeing, and stampeding (United States Pacific Fleet 2019). Finneran et al. (2017) reported that the most likely behavioural response from naval gunnery exercises is a brief alerting and orienting response and, because the sounds are impulsive and there are typically no further sounds following the exercise, significant (e.g., high severity responses) behavioural responses were not expected to occur. Significant responses are those with possible immediate consequences to growth, survivability, or reproduction, and are rated as high severity in the Southall et al. (2007) behavioural response criteria (e.g., long-term or permanent abandonment of area, prolonged separation of females and dependent offspring, panic, flight, or stampede) (Southall et al. 2007; Finneran et al. 2017). Demarchi et al. (2012) reported on the behavioural responses of Steller sea lion at Race Rocks Provincial Ecological Reserve to in-air noise generated from military blasting activities. Received sound levels were measured and exceeded the behavioural disturbance threshold level of 109 dB (peak) from Southall et al. (2007). Steller sea lion were observed reacting to the noise source by raising their heads during the activity. However, within minutes of the activity ceasing, sea lion vigilance levels dropped sharply and continued to drop until their activities returned to normal.

Behavioural response of marine mammals to noise can be highly variable and depend on several factors such as hearing sensitivity, behavioural state, age and sex and noise source context (NRC 2003) and can vary widely by species (Holst et al. 2011). Holst et al. (2011) observed California sea lion, northern elephant seal and harbour seal on a beach during launches of Navy missiles in the direct vicinity of haul-out areas. Variable behavioural reactions were observed by these species. Northern elephant seal displayed minimal responses to the missile launches with most individuals only lifting their heads briefly during the exposure period. Harbour seal displayed the strongest reactions with the majority of hauled-out individuals entering the water during the exposure event and not returning for several hours. The reactions of California sea lion varied depending on life stage; adults exhibited a startle response with increased vigilance for a couple minutes following the launch, while juveniles and pups reacted more overtly by moving down the beach. Calkins (1979) reported that Steller sea lion bulls, which are dominant and territory-holding, and females with young, were less likely than juveniles and pregnant females to depart from their haul-out in response to aircraft overflight.

There is no readily available information regarding the potential behavioural reactions of pinnipeds to in-air noise while in the water (e.g., not hauled-out). Behavioural reactions discussed here are considered to approximate potential effects to pinnipeds in water. Many authors report that pinnipeds flee into the water in response to in-air noise suggesting that pinnipeds perceive the water to be safer.

4.1.2.2 Underwater Noise

Noise from weapons used for small arms exercises are treated as impulsive and these sound sources affect animals differently compared to non-impulsive sources. Studies assessing the impacts of impulsive noises on terrestrial mammals generally suggest that, at comparable sound levels, impulsive noise is more hazardous than non-impulsive sound with respect to hearing damage (Hastie et al. 2019). The increased risk to hearing damage from impulsive sound is reflected in the lower sound exposure level (SEL) values specified in the marine mammal exposure criteria for impulsive noise sources as outlined in Section 4.1.1 (NMFS 2018; Southall et al. 2007; Southall et al. 2019; Finneran et al. 2017).

No studies on the effects of underwater noise on marine mammals as a result of in-air gunfire were identified in the literature. The potential for injury was assessed based on underwater noise modelling undertaken for the small arms activities described in Section 4.1.3 and detailed in Annex B. Behavioural responses were inferred from studies conducted on other impulsive noise sources and anecdotal evidence from marine mammal studies conducted in the Arctic.

The best approximation for potential impacts on marine mammals from impulsive noise comes from behavioural response data available for other impulsive noise sources, such as seismic surveys and pile driving. Seismic surveys and pile driving activities emit underwater noise at frequencies ranging from 120 Hz to 500 Hz, which is comparable to that emitted by small arms activities (150 Hz to 500 Hz). Therefore, seismic and pile driving activities are considered appropriate proxies for assessing potential effects on marine mammals from small arms training activities.

The National Academies of Science's (2017) report on the cumulative effects of stressors to marine mammals provides an overview of responses by marine mammals from both seismic surveys and pile driving activities. For seismic surveys, responses included increases in stress hormones and dopamine in beluga, elevated stress hormones and decreased levels of white blood cells in bottlenose dolphin, no change in direction of travel, increased energy in swimming, reduced foraging and no responses at ranges greater than 20 km for sperm whales, avoidance responses by migrating grey whales and spatial displacement by fin whales. Studies from pile driving activities in Europe focussed on small cetaceans and pinnipeds with a lack of data available to report on the responses of large cetaceans. The main response reported in these studies was avoidance of areas of pile driving activity at distances of 20 km or more and up to three days.

Though there is little published data on the behavioural responses of marine mammals to gunfire, anecdotal data from a shore-based marine mammal monitoring program conducted on Baffin Island, Nunavut provides some insight into potential behavioural reactions of cetaceans to gunfire. During a marine mammal survey that focused on narwhal behaviour, researchers were able to observe behavioural reactions of narwhal in the presence of gunfire from shore-based and boat-based hunting activities. Behaviours observed included 'herding events' which involved large numbers of narwhals fleeing the area while staying very close to shore. According to local hunters, they often shoot their guns in the air when narwhals are in the area but far from shore as this elicits a 'herding behaviour' and causes the animals to come closer to shore where they are more accessible to hunters (Zottenberg, K. Pers. Comm.).

4.1.2.3 Acoustic Masking

All marine mammals produce sounds over a variety of frequencies. Sound production has been associated with rearing young, mating, social interactions, group cohesion, mother and calf cohesion and feeding. Auditory masking occurs when sound signals used by marine mammals overlaps in time, space and frequency with another sound source (Richardson et al. 1995). This overlap can reduce communication space, limit the detection of relevant biological cues and reduce echolocation effectiveness. Masking can lead to changes in vocal patterns such as increasing source level or changing repetition rate and frequency and behaviours such as avoiding areas where the masking persists. It can also limit the effectiveness of predator and prey detection, finding mates, socializing and may impact individual fitness. There are no available studies regarding the potential for masking effects of in-air gunfire on underwater or in-air marine mammal vocalizations. The potential for Project Activities to cause masking effects is considered based on the potential for the noise to cause overlap with the vocalizations made by marine mammal VECs. Table 19 outlines the overlap between marine mammal vocalizations and the Project Activities.

4.1.3 Modelling Results and Effects Assessment

Acoustic propagation modelling of in-air and underwater noise from small-arms military training exercises was undertaken by JASCO Applied Sciences (JASCO) to determine distances to the established injury and disturbance thresholds for marine mammals (Annex B). Three sets of criteria were considered in the in-air propagation model:

1) those that define PTS thresholds (both weighted and unweighted) for pinnipeds in-air defined by Southall et al. (2007) for impulsive sounds

2) those that define TTS and PTS thresholds (weighted) for phocid carnivores in-air (PCA) and other marine carnivores in-air (OCA) from Southall et al. (2019) for impulsive sounds

3) those that define behavioural disturbance thresholds (both weighted and unweighted) for pinnipeds in-air from Southall et al. (2007).

Two sets of criteria were considered in the underwater noise model:

1) those that define thresholds for injury (PTS and TTS) that incorporate frequency weighting for the five distinct marine mammal hearing groups (NOAA 2018)

2) the NMFS (2013) 160 dB re 1 μPa SPL threshold for behavioural response for impulsive sounds for all marine mammal species.

Five weapons of various calibre were modelled individually, in addition to three aggregate scenarios that include two weapons each (M2/M240, M2/MK38 and C8/Pt). Model inputs were selected to conservatively assess the extent of sound propagation, particularly with respect to terrain topography, terrain impedance, atmospheric profiles for in-air noise and seasonal water column sound speed profiles and source depths for underwater noise. The maximum number of shots per weapon expected per training session were also considered to allow for a conservative modelling approach as was the most conservative source height and declination angle.

Muzzle blast noise was the only noise source considered in the modelling and evaluation given that sound propagates in all directions from the gun barrel (i.e., 360 degrees from the source). Noise resulting from muzzle blast propagates from the gun barrel and radiates in a pattern that exhibits louder sounds along the line-of-fire and quieter sounds behind the gun. Compared to sounds measured in front of a weapon, noise levels are reduced approximately 14 dB behind the gun (Pater and Shea 1981). Spectral analysis from muzzle noise show dominant frequencies of 150 to 300 Hz (Quijano and Lucke 2019). Dominant frequencies reported for these weapons ranged from 150 to 500 Hz (Quijano, Pers. Comm.) with source levels ranging from 131 to 144 dB re 20 μPa^2·s in-air and 156 to 172 dB re 1 μPa^2·s underwater (lowest level from Pt, highest level from MK38 in both environments). A detailed description of the source levels used in the modelling are discussed in Annex B.

Modelling assumed that shooting would occur at a height of 12.5 to 12.6 m above water, with declination angles of 11 to 28° (i.e., aiming at targets at a 65 to 24 m range from the vessel). Modelling of the machine guns involved two types of firings: warning shots (bursts of 3 to 5 shots) and disabling fire (bursts of 9 to 15 shots). The exact combination of both types of firings in a given training session is dependant on the training objective of the military units. To allow for a conservative modelling approach, the maximum number of shots per weapon expected per training session was used to compute the acoustic field required for cumulative metrics. Modelling was conducted to estimate the acoustic footprint of each individual gun, as well as three, two-gun combinations: M2/M240, M2/MK38 and C8/Pt.

Distances to thresholds for TTS, PTS and behavioural disturbance were computed for in-air and underwater propagation. Sound propagation was strongly driven by the weapon directionality, with sound levels along the line-of-shot being approximately 14 dB higher than sound levels in the opposite direction. In-air sound propagation was generally larger compared to underwater propagation, due to the high transmission loss (approximately 30 dB) that occurs when sound travels from the air into water.

Based on modelling results and species-specific density estimates available for OPAREA WH, the total number of animals that could be exposed to noise levels exceeding established injury thresholds (PTS and TTS) were predicted and are presented in Annex B, Tables B-1 to B-5 for each of the different small arms munition training scenarios. To characterize marine species densities (in-water sightings), data was compiled from Hanser et al. (2015) and Koshure (2012). A full summary of all density data reviewed is provided in Table 4 (Section 3.1). When differing density numbers or a range of density values were provided for the same area in the literature, the highest density value was used to provide a conservative estimate. Seasonal density data, when available, was also complied. When no seasonal data was provided, a single density value was applied across all seasons.

The following assumptions were made during the quantitative assessment:

- density estimates were applied to in-air and underwater noise assessments
- movement of the animal in and out of the sound field was not considered (i.e., animal is assumed to remain in a single location)
- maximum areas were considered
- no mitigation has been implemented (e.g., application of marine mammal safety zones)
- the distribution of marine mammals in the model domain was uniform

The following sections provides a summary of the injury modelling results for each marine mammal hearing group and the predicted number of number of animals that could be exposed to noise levels exceeding established injury thresholds (PTS and TTS).

4.1.3.1 In-air Noise - Potential Injury (PTS and TTS)

The potential for auditory injury in marine mammals from exposure to in-air noise from small arms munitions training in OPAREA WH was assessed using functional hearing group designations and impact criteria from Southall et al. (2007, 2019). Southall et al. (2007) categorize all pinnipeds with similar hearing sensitivities for in-air noise. Southall et al. (2019) applied slightly different hearing ranges for phocid carnivores in-air (PCA) and other marine carnivores in-air each (OCA). Modelling results in OPAREA WH indicated that the largest distances (R_{max}) to existing marine mammal injury thresholds (based on unweighted SPL_{peak} injury thresholds from Southall et al. 2019) were associated with TTS for PCA, equivalent to 219 m for the MK38 during training (Table 15). A summary of injury radii (distance ranges) for in-air noise for each of the different small arms and aggregate scenarios is provided in Table 13, Table 14, and Table 15. Detailed modelling results for OPAREA WH are provided in Annex B.

Similarly, modelling results for in-air noise indicated that the largest injury zones (total area in m^2) for phocid carnivores in-air were associated with TTS for SPL_{peak} from Southall et al. (2019), equivalent to 48,305 m^2 for the MK38 small arms munition training activities (Table 15). As a result, it is estimated that approximately 0.0003 Northern elephant seal and 0.2 harbour seal would be exposed to in-air noise in excess of TTS SPL_{peak} thresholds from Southall et al. (2019). PTS impact areas were generally smaller than TTS areas with the largest PTS injury zones (total area in m^2) calculated at 12,868 m^2 for the MK38 scenario for phocid carnivores in-air. An estimated 0.00008 northern elephant seals and 0.04 harbour seals would potentially be exposed to in-air noise in excess of PTS SPL_{peak} thresholds from Southall et al. (2019). Further analysis of the number of individuals potentially exposed to in-air noises in excess of TTS and PTS thresholds for all small arms munition scenarios are provided in Tables C-1 through C-3 in Annex C.

Table 13: Pinnipeds In-air - Distances (R_{Max}) and Areas (m^2) from the Source for PTS_{Peak} and SEL_{24h} Thresholds (Southall et al. 2007)

Source	PTS Threshold SPL_{peak}: 149 dB re 20 µPa		PTS Threshold SEL_{24h}: 144 dB re 20 µPa²·s	
	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)
Pt	<10	<314	<10	<314
C8	<10	<314	<10	<314
M240	<10	<314	9	380
M2	11	154	49	2,642
MK38	64	4,072	43	1,257
M2 and M240	N/A	N/A	53	3,019
M2 and MK38	N/A	N/A	69	4,778
C8 and Pt	N/A	N/A	<10	<314

Notes:

a dash indicates that the threshold was not reached. Sources: Pt = general service pistol (9 mm Browning Hi-Power or Sig Sauer P225), C8 = C8, C7, or MK16A1 automatic rifles, M240 = M240 and C6 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios.

Table 14: PCA and OCA In-air - Distances (R_{Max}) and Areas (m^2) from the Source for TTS and PTS SEL_{24h} Threshold (Southall et al. 2019)

Source	PCA				OCA			
	PTS Threshold SEL_{24h} = 138 dB re 20 µPa²·s		TTS Threshold SEL_{24h} = 123 dB re 20 µPa²·s		PTS Threshold SEL_{24h} = 161 dB re 20 µPa²·s		TTS Threshold SEL_{24h} = 146 dB re 20 µPa²·s	
	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)
Pt	<10	<314	<10	<314	-	-	-	-
C8	<10	<314	<10	<314	-	-	-	-
M240	16	314	72	6,648	-	-	-	-
M2	36	1,257	147	27,759	-	-	<10	<314
MK38	<10	<314	169	30,791	-	-	<10	<314
M2 and M240	39	1,521	154	30,791	-	-	11	154
M2 and MK38	42	1,662	207	53,093	-	-	<10	<314
C8 and Pt	<10	<314	96	5542	-	-	-	-

Notes:

a dash indicates that the threshold was not reached. Sources: Pt = general service pistol (9 mm Browning Hi-Power or Sig Sauer P225), C8 = automatic rifle, M240 = M240 and C6 machine gun, M2 = Browning M2 heavy machine gun, MK38= MK38 machine gun, Marine mammals: PCA = Phocid carnivores in air, OCA = Other carnivores in-air.

Table 15: PCA and OCA In-air - Distances (R_{Max}) and Areas (m^2) from the Source for TTS and PTS Peak Thresholds (Southall et al. 2019)

Source	PCA				OCA			
	PTS threshold L_{pk} = 144 dB re 20 µPa		TTS threshold L_{pk} = 138 dB re 20 µPa		Peak threshold L_{pk} = 167 dB re 20 µPa		Peak threshold L_{pk} = 161 dB re 20 µPa	
	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)
Pt	<10	79	13	<314	-	0	-	0
C8	16	314	31	1,018	-	<314	<10	<314
M240	19	380	37	1,385	<10	<314	<10	<314
M2	20	452	39	1,521	<10	<314	<10	<314
MK38	113	12,868	219	48,305	<10	<314	16	314
M2 and M240	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M2 and MK38	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C8 and Pt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

a dash indicates that the threshold was not reached. Sources: Pt = general service pistol (9 mm Browning Hi-Power or Sig Sauer P225), C8 = C8, C7, or MK16A1 automatic rifles, M240 = M240 and C6 machine gun, M2 = Browning M2 heavy machine gun, MK38= MK38 machine gun, Marine mammals: PCA = Phocid carnivores in air, OCA = Other carnivores in air. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios.

4.1.3.2 In-air Noise – Potential Disturbance

The potential for disturbance in pinnipeds from exposure to in-air noise from small arms munitions training in OPAREA WH was assessed using functional hearing group designations and impact criteria described in Southall et al. (2007). Southall et al. (2007) categorize all pinnipeds as having similar hearing sensitivities to in-air noise. Modelling results in OPAREA WH indicated that the largest distances (R_{max}) to existing marine mammal disturbance thresholds were associated with SEL_{24h} threshold (from Southall et al. 2007), equivalent to approximately 15.6 km for the M2 and MK38 aggregate scenario during training (Table 16). Detailed modelling results for OPAREA WH are provided in Annex B.

Similarly, modelling results for in-air noise indicated that the largest behavioural disturbance zones (total area in km^2) for pinnipeds in-air were associated with the SEL_{24h} threshold (from Southall et al. 2007) equivalent to 104 km^2 for the M2 and MK38 aggregate scenario (Table 16). From this, it was estimated that approximately 0.6 Northern elephant seal, 330 harbour seal, 97 Steller sea lion, and 70 California sea lion (Annex C) would be exposed to in-air noise in excess of the behavioural disturbance thresholds from Southall et al. (2007). Further analysis of the number of individuals potentially exposed to in-air noises in excess of behavioural disturbance thresholds from Southall et al. (2007) for all small arms munition scenarios are provided in Table C-4 in Annex C.

Table 16: Pinnipeds In-air - Distances (R_{Max}) and Impact Areas (m^2) from the Source for Behavioural Disturbance Thresholds (Southall et al. 2007)

Source	SPL_{peak} Threshold: 109 dB re 20 µPa		SEL_{24h} Threshold: 100 dB re 20 µPa^2·s	
	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)
Pt	357	130,741	1,319	2,300,000
C8	734	572,803	1,161	1,800,000
M240	854	779,128	1,826	4,100,000
M2	887	846,223	9,071	33,300,000
MK38	3,045	1,170,000	9,340	69,800,000
M2 and M240	N/A	N/A	9,091	42,100,000
M2 and MK38	N/A	N/A	15,642	104,000,000
C8 and Pt	N/A	N/A	1,588	3,400,000

Notes:

Sources: Pt = general service pistol (9 mm Browning Hi-Power or Sig Sauer P225), C8 = C8, C7, or MK16A1 automatic rifles, M240 = M240 and C6 machine gun, M2 = Browning M2 heavy machine gun, MK38= MK38 machine gun, Marine mammals: PCA = Phocid carnivores in air, OCA = Other carnivores in air. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios.

4.1.3.3 Underwater Noise - Potential Injury (PTS and TTS)

The potential for auditory injury in marine mammals from exposure to small arms munition training in OPAREA WH was assessed using functional hearing group designations and impact criteria from NMFS (NOAA 2018). These criteria categorize species with similar hearing sensitivities into hearing groups but apply slightly different hearing ranges for each group and different noise weighting across the hearing frequency ranges among different groups. Modelling results in OPAREA WH indicated that the largest distances (R_{max}) to existing marine mammal injury thresholds (based on 24-h auditory weighted SEL injury thresholds) were associated with TTS for HFC, equivalent to 28 m for M2 and MK38 aggregate scenario. A summary of injury radii (distance ranges) for each of the different hearing groups is provided in Table 17 and Table 18. Detailed modelling results for OPAREA WH are provided in Annex B.

Similarly, modelling results for underwater noise indicated that the largest injury zones (total area in m^2) were associated with TTS for HFC, equivalent to 1,134 m^2 for the M2 and MK38 aggregate scenario (Table 17). This resulted in a total of approximately 0.002 harbour porpoise and 0.0006 Dall's porpoise estimated to be potentially exposed to underwater sound levels greater than TTS SEL_{24h} thresholds from NMFS (2018). PTS impact areas were generally smaller than TTS areas with the largest PTS injury zone (total area in m^2) calculated to be <314 m^2 for the M2, M2 and M240 aggregate and the M2 and MK38 aggregate scenarios for the HFC hearing group. Approximately 0.0007 harbour porpoise and 0.0002 Dall's porpoise were estimated to be potentially exposed to underwater noise greater than PTS SEL_{24h} thresholds from NMFS (2018). PTS thresholds were not reached for any of the other marine mammal functional hearing groups for any scenario. A full analysis of the number of individuals potentially exposed to underwater noise greater than TTS and PTS thresholds for all small arms munition scenarios is provided in Table C-5 in Annex C.

Table 17: Cetaceans Underwater - Distances (R_{Max}) and Areas (m^2) from the Source for PTS and TTS Thresholds (NMFS 2018)

Source	LFC				MFC				HFC			
	PTS Threshold = 183 dB re 1 µPa²·s		TTS Threshold = 168 dB re 1 µPa²·s		PTS Threshold = 185 dB re 1 µPa²·s		TTS Threshold = 170 dB re 1 µPa²·s		PTS Threshold = 155 dB re 1 µPa²·s		TTS Threshold = 140 dB re 1 µPa²·s	
	R_{max}(m)	Area (m^2)	R_{max}(m)	Area (m^2)	R_{max}(m)	Area (m^2)	R_{max}(m)	Area (m^2)	R_{max}(m)	Area (m^2)	R_{max}(m)	Area (m^2)
Pt	-	-	-	-	-	-	-	-	-	-	< 10	< 314
C8	-	-	-	-	-	-	-	-	-	-	< 10	< 314
M240	-	-	< 10	< 314	-	-	-	-	-	-	< 10	< 314
M2	-	-	< 10	< 314	-	-	-	-	< 10	< 314	20	616
MK38	-	-	< 10	< 314	-	-	-	-	-	-	15	380
M2 and M240	-	-	< 10	< 314	-	-	-	-	< 10	< 314	22	707
M2 and MK38	-	-	11	314	-	-	-	-	< 10	< 314	28	1134
C8 and Pt	-	-	< 10	< 314	-	-	-	-	-	-	< 10	< 314

Notes:

a dash indicates that the threshold was not reached. Sources: Pt = general service pistol (9 mm Browning Hi-Power or Sig Sauer P225), C8 = C8, C7, or MK16A1 automatic rifles, M240 = M240 and C6 machine gun, M2 = Browning M2 heavy machine gun, MK38= MK38 machine gun, Marine mammals: PCA = Phocid carnivores in air, OCA = Other carnivores in air. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios.

Table 18: Pinnipeds Underwater - Distances (R_{Max}) and Areas (m^2) from the Source for PTS and TTS Thresholds (NMFS 2018)

Source	PP				OP			
	PTS Threshold = 185 dB re 1 µPa²·s		TTS Threshold = 170 dB re 1 µPa²·s		PTS Threshold = 203 dB re 1 µPa²·s		TTS Threshold = 188 dB re 1 µPa²·s	
	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max}(m)	Area (m^2)	R_{max} (m)	Area (m^2)
Pt	-	-	-	-	-	-	-	-
C8	-	-	-	-	-	-	-	-
M240	-	-	-	-	-	-	-	-
M2	-	-	< 10	< 314	-	-	-	-
MK38	-	-	< 10	< 314	-	-	-	-
M2 and M240	-	-	< 10	< 314	-	-	-	-
M2 and MK38	-	-	< 10	< 314	-	-	-	-
C8 and Pt	-	-	-	-	-	-	-	-

Notes:

a dash indicates that the threshold was not reached. Sources: Pt = general service pistol (9 mm Browning Hi-Power or Sig Sauer P225), C8 = C8, C7, or MK16A1 automatic rifles, M240 = M240 and C6 machine gun, M2 = Browning M2 heavy machine gun, MK38= MK38 machine gun, Marine Mammals: LFC = low-frequency cetaceans, MFC = mid-frequency cetaceans, HFC = high-frequency cetaceans, PP=phocid pinnipeds underwater, OT=otariid pinnipeds underwater.

4.1.3.4 Underwater Noise – Potential Disturbance

The underwater noise threshold for behavioural disturbance for impulsive noise sources (e.g., 160 dB SPL_{rms}; NMFS 2013) was not reached by any of the small arm scenarios modelled. This effect is therefore not considered further in the present evaluation.

4.1.3.5 Masking

For the purposes of this assessment, acoustic masking was assumed to be possible if the frequencies of the small arms munition were shown to overlap with the primary communication frequencies used by marine mammals (Table 19). The potential extent of masking from the small arms munition sources is not able to be quantified with any degree of certainty due to the lack of masking thresholds and the limited information known. The duty cycle of gunfire was also considered when evaluating the potential for masking. Higher duty gunfire is more likely to mask marine mammal communication as the sound transmits more frequently with fewer pauses or breaks between fires. If training activities in OPAREA WH resulted in the masking of biologically important sounds (such as foraging or mother calf contact calls) over extended periods of time and within areas important to marine mammals, this could result in adverse effects at the individual and population level.

The short-term consequences of masking range from temporary changes in vocal behaviour and temporary avoidance of areas. Longer-term consequences include permanent changes to vocal behaviour, reductions in fitness, survivorship and recruitment, loss in foraging opportunities and abandonment of important habitat areas.

Most marine mammal species use a range of frequencies to communicate as summarized in Table 19. The small arms munition modelled emit broadband noise with frequencies spanning over 7 Hz to 20 kHz. The impulsive nature of the gunfire has a lower potential to mask communications than other continuous anthropogenic sources such as high duty sonar sources. As noted above, some marine mammal species may alter their vocal patterns in the presence of the small arms munitions further reducing the potential for masking effects. However, changes in vocal patterns may have adverse effects on the fitness of animal as described above.

Table 19: Frequency Overlap between Marine Mammal Vocalizations and Project Activities

Source	Type of Vocalization	Dominant Frequency	Sound Pressure Level (dB re 1µ Pa at 1 m)	Small Arms Munitions Dominant Frequency 7 Hz to 20 kHz*
Low-frequency Cetaceans (LFC)				
HW	Song	71 Hz to 708 Hz	170	X
		20 Hz to 4 kHz with components up to 8 kHz	144 to174	X
	Moans and grunts	20 Hz to 1.9 kHz	175 to 190	X
	Low-frequency pulse train	25 Hz to 80 Hz	162 to 171	X
	Blowhole shriek	555 Hz to 2 kHz	179 to 181	X
	Trumpet-like horn blast	414 Hz	181 to 185	X
FW	Moans	20 Hz	160 to 186	X
	Calls	20 Hz to 40 Hz	189	X
	Whistles, chirps	1.5 Hz to 2.5 kHz	Not available	X
BW	Moans	16 Hz to 25 Hz	188	X
	Calls	9 Hz to 200 Hz	189	X
	Clicks	6 kHz to 8 kHz and 25 kHz	130 and 159	X
SW	FM sweeps	1.5 kHz to 3.5 kHz	Not Available	X
MW	Moans and grunts	60 Hz to 140 Hz	151 to 175	X
	Ratchet	850 Hz	N/A	X
	Clicks	<12 kHz	151	X
	Thump trains	100 Hz to 200 Hz	N/A	X
GW	FM up and down-sweeps	300 Hz	N/A	X
	Pulses	300 Hz to 825 Hz	N/A	X
	Clicks (calves only)	3.4 kHz to 4 kHz	N/A	X

Notes:

X = Small arms frequency overlaps with vocal / hearing range of that species; 0 = no overlap with vocal/hearing range of that species.
Sources: Summary in Richardson et al 1995. HW=humpback whale, FW=fin whale, BW=blue whale, SW=sei whale, MW=minke whale, KW=killer whale, GW=grey whale, WSD=white sided dolphin, HP=harbour porpoise, DP=Dall's porpoise, CSL=California sea lion, HS=harbour seal, FM=frequency modulated. * Levels were modelled up to 20 kHz. At that frequency, the weighting filters for HFC and MFC groups are already almost at peak values. Extending source levels to frequencies beyond 20 kHz is overly conservative, as the decay rate of 7.88 dB/decade is likely to increase at higher frequencies; however, experimental data showing sound levels at such high frequencies for weaponry is lacking.

Source	Type of Vocalization	Dominant Frequency	Sound Pressure Level (dB re 1µ Pa at 1 m)	Small Arms Munitions Dominant Frequency 7 Hz to 20 kHz*
Mid-frequency Cetaceans (MFC)				
KW	Calls	1.5 kHz to 3.5 kHz	155	X
	Whistles	5 kHz to 12 kHz	145	X
	Echolocation Clicks	12 kHz to 25 kHz	180	X
SW	Clicks	2 kHz to 4 kHz and 10 kHz to 16 kHz	160 to 180	X
WSD	Echolocation Clicks	60 kHz to 80 kHz	180	0
	Whistles	4 Hz to 12 Hz	Not Available	X
High-frequency Cetaceans (HFC)				
HP	Echolocation clicks	110 kHz to 150 kHz (peak frequencies 120 kHz to 130 kHz)	135 to 177	0
DP	Echolocation clicks	135 kHz to 149 kHz	165 to 175	0
Phocid Pinnipeds (PP)				
HS	Roar	400 Hz to 800 Hz	Not Available	X
	Bubbly growl	<0.1 kHz to 0.25 kHz	Not Available	X
	Grunt, groan	<0.1 kHz to 4 kHz	Not Available	X
	Creak	0.7 kHz to 2 kHz	Not Available	X
	Clicks	12 kHz to 40 kHz	Not Available	X
	Social sounds	500 Hz to 3,500 Hz	Not Available	X
Otariid Pinnipeds (OP)				
CSL	Barks	<3.5 kHz	Not Available	X
	Whinny	<1 kHz to 3 kHz	Not Available	X
	Clicks	0.5 kHz to 4 kHz	Not Available	X
	Buzzing	<1 kHz	Not Available	X

Notes:

X = Small arms frequency overlaps with vocal / hearing range of that species; 0 = no overlap with vocal/hearing range of that species. Sources: Summary in Richardson et al 1995. HW=humpback whale, FW=fin whale, BW=blue whale, SW=sei whale, MW=minke whale, KW=killer whale, GW=grey whale, WSD=white sided dolphin, HP=harbour porpoise, DP=Dall's porpoise, CSL=California sea lion, HS=harbour seal, FM=frequency modulated. * Levels were modelled up to 20 kHz. At that frequency, the weighting filters for HFC and MFC groups are already almost at peak values. Extending source levels to frequencies beyond 20 kHz is overly conservative, as the decay rate of 7.88 dB/decade is likely to increase at higher frequencies; however, experimental data showing sound levels at such high frequencies for weaponry is lacking.

4.1.4 Mitigation

Operationally achievable mitigation measures to eliminate and/or reduce the potential for adverse effects on marine mammals from small arms munition training are summarized in Table 20. Table 21 outlines the predicted effectiveness of proposed mitigation measures to avoid and reduce the effects of PTS, TTS, behavioural disturbance and masking based on using vessels as the mitigation platform. Mitigation effectiveness has been characterized based on the following criteria:

- **H - High effectiveness**: expected to eliminate the effect from occurring.
- **M - Moderate effectiveness**: expected to reduce the potential for the effect to occur.
- **L - Low effectiveness**: expected to minimally reduce the potential for the effect to occur.

Table 21 outlines the gaps identified for each individual mitigation measure. Residual effects associated with small arms munition training, taking into consideration the identified gaps in the overall mitigation strategy, are discussed in more detail in Section 4.1.5.

Table 20: Summary of Mitigation Measures

Mitigation Measure	Description
Acoustic Mitigation Avoidance Zone (MAZ)	A Mitigation Avoidance Zone (MAZ) will be implemented during active small arms munition training for all in water and hauled-out marine mammals. The occurrence of a marine mammal within the MAZ will trigger specific mitigation actions (e.g., cease fire) such to avoid injuring MMs from underwater and in-air noise from small arms munition training. The MAZ should be selected to protect against PTS and/or TTS effects (and when possible behavioural disturbance effects) and should consider the detection abilities of the platform used to monitor for marine mammals (as outlined in Table 21-A). Table 22 outlines the PTS and TTS marine mammal safety zones that should be considered when selecting a MAZ. Table 16 outlines the pinniped in-air disturbance zones that should be considered when selecting a MAZ. Underwater disturbance thresholds were not exceeded during the evaluation. The MAZ should be applied around each small arm for in-air and underwater marine mammal sightings (e.g., 360 degrees around each platform where the small arm is fired). In addition to the acoustic MAZs identified in this evaluation, Units are still required to maintain a MAZ/marine mammal safety zone consistent with the safety firing arc/area clear requirements specific for each weapon to avoid physical impacts from gunfire striking marine mammal. However, this evaluation focused solely on the acoustic effects to marine mammals associated with gunnery activities in OPAREA WH. As such, the safety firing arc/area clear requirements were not evaluated as part of the mitigation strategy.
Monitoring	Monitoring of the MAZ will occur during pre-operational searches and throughout small arms training activities. For monitoring to be highly effective, the full extent of the MAZ should be able to be observed by the monitoring system implemented (e.g., visual, radar/IFF). If the MAZ is not completely observable, the effectiveness of monitoring is reduced. **During daylight and good visibility conditions:** The MAZ will be visually monitored. **During daylight and low visibility conditions:** The MAZ will be either visually monitored or monitored by Electro-Optical Infrared (EOIR) and/or radar and/or night vision goggles. **During night-time conditions:** The MAZ will be monitored by EOIR and will be supplemented with radar or night vision goggles.

Mitigation Measure	Description
Visual Monitoring	Visual monitoring will be conducted by a minimum of one dedicated marine mammal observer.
Electro-Optical Infrared (EOIR) Monitoring	EOIR monitoring will include a dedicated EOIR operator where practical.
Night Vision Goggles (NVG)	A preliminary literature search indicates that night vision goggles (NVG) have limited effectiveness to detect marine mammals (Marine Mammal Observer Association 2020; Quan and Calambokidis 1999, Statoil USA E&P Inc. 2010) and potentially only at very close range (Frankel and Vigness-Raposa 2001). See Table 23 for recommendations on future studies to confirm the effectiveness of NVG for marine mammal monitoring.
Radar	Radar monitoring will include a dedicated radar operator where practical. There is a general lack of data on the ability of radar to detect marine mammals in real world conditions. Available data suggests that radar is effective in monitoring large marine mammals at close range (< 1 km) (Verfuss et al. 2018). Their use in detecting large marine mammals (polar bears and walrus) on floating ice has been reported; however, specific detection distances are not provided (Verfuss et al. 2018). See Table 23 for recommendations on future studies to confirm the effectiveness of radar for marine mammal monitoring.
Cease fire procedures	If a marine mammal is detected inside the MAZ during active small arms munition training, a cease-fire shall be called and training activities will be relocated or delayed until one of the three following conditions are met: 1. Marine mammal is observed exiting the MAZ 2. Marine mammal is believed to have exited the MAZ based on its course and speed 3. MAZ has been clear of any additional marine mammal sightings for a period of at least 15 min to account for maximum dive duration of marine mammal species likely to occur in the OPAREA WH (Annex D).
Pre-operational Search	A pre-operational search will be conducted prior to the start of training activities. Pre-operational searches will consist of a scan (visual + radar) of the water to determine that no marine mammals are present within the MAZ. Optimal time for pre-operational search in OPAREAWH is 15 minto account for maximum dive duration of marine mammal species likely to occur in the OPAREA WH (Annex D). If a marine mammal is detected within the MAZ during the pre-operational search, training activities will be delayed until the marine mammal has been observed exiting the MAZ or 15 min from the time the marine mammal was last detected in the MAZ.
Limit training activities in OPAREA WH during low visibility conditions	As training activities allow, small arms munitions activities will be conducted in daylight conditions and will avoid periods of low visibility (e.g., thick fog) and high sea states to maximize the ability to detect marine mammals in the MAZ.
Marine Species Awareness Training	Observers will receive Marine Species Awareness Training prior to small arms training exercises. Marine mammal identification tools will be made available to on-board observers and they shall be briefed on their use, as well as on methods for effective implementation of mitigation actions.

Mitigation Measure	Description
Reporting	All marine mammal sightings will be recorded. Information collected should include: the training activity (e.g., type of small arms being used at the time of observation), environmental conditions, species, number of individuals, and behaviour of the animal (i.e., particularly if any fleeing behaviour is observed). If a potentially sick or stranded animal is seen, contact RJOC (Regional Joint Operations Centre) and/or MARPAC FSE who will inform the local stranding network.
Sensitive areas and timing windows	Take sensitive areas and timing windows (refer to Annex E) into consideration when conducting training activities. Recommend avoiding as possible, firing training activities when SRKWs are observed to be active in the area. Operators should be engaging MARPAC FSE prior to engaging in gunnery activities to determine if there are any seasonal restrictions (e.g., more stringent approach distances) in place.
SRKW Critical Habitat Interim Order	Mandatory 400-m closest approach distances to killer whales within their designated critical habitat and British Columbia coastal waters east of Vancouver Island and south of Campbell River (Cape Mudge) and Malaspina Peninsula (Sarah Point) (Figure 2 – Annex A). The 400-m approach distance is in place year-round. Voluntary measures include turning off echo sounder when not in use and shutting engine off or putting it in neutral when within 400 m of a killer whale when operating in their designated critical habitat and British Columbia coastal waters east of Vancouver Island and south of Campbell River (Cape Mudge) and Malaspina Peninsula (Sarah Point). The Interim Order was in place 1 June until 30 November 2020; however, it is unclear if these measures will be made permanent under the Marine Mammal Regulations or *Canadian Shipping Act*.
Marine Mammal Regulations	In addition to the 400-m approach distance for SRKW identified above, there are other specific vessel approach requirements detailed in the Marine Mammal Regulations for other marine mammals. To simplify the various approach requirements, MARPAC has set the following policy requirements. In all Canadian Pacific Waters, all vessels shall adhere to the following approach distances: - When within 1,000 m of all whales, slow down to 7 knots or less. Avoid sudden course changes. - Stay at least 400 m away from all whales. - Stay at least 200 m away from all porpoises and dolphins. - Stay at least 100 m away from all pinnipeds (seals and sealions), otters or sea turtles, whether in water or hauled out on shore. - Place engine in neutral idle and allow animals to pass if your vessel is not in compliance with these approach distances. - Stay at least 100 m away from all marine bird colonies on land. The Marine Mammal Regulations also including stipulations that no person shall disturb a marine mammal. “Disturb” under the amended regulations includes to approach a marine mammal to, or to attempt to: - Feed it - Swim with it or interact with it - Move it or entice or cause it to move from the immediate vicinity in which it is found - Separate it from members of its group or go between it and a calf - Trap it or its group between a vessel and the shore or between a vessel and one or more other vessels - Tag or mark it

Mitigation Measure	Description
General Guidelines when in the Vicinity of Marine Mammals (DFO 2020)	BE CAUTIOUS, COURTEOUS and QUIET: Approach areas of known or suspected marine wildlife activity with extreme caution. LOOK in all directions before planning your approach or departure. PAY ATTENTION and move away, slowly and cautiously, at the first sign of disturbance or agitation. STAY on the OFFSHORE side of marine mammals when they are traveling close to shore. ALWAYS AVOID going through groups of porpoises or dolphins. Hold course and reduce speed gradually to discourage bow or stern-riding. DO NOT feed, swim with or interact with, tag or mark, move or entice, or cause to move, from the immediate vicinity in which you find marine wildlife. DO NOT separate a marine mammal from members of its group or go between it and a calf. DO NOT trap a marine mammal or its group between a vessel and the shore or between a vessel and one or more other vessels. NEVER approach using aircraft or drones. REPORT any collisions with marine mammals, or sightings of entangled, injured or dead marine mammals to RJOC and/or MARPAC FSE who will inform the appropriate marine animal response organization, including Fisheries and Oceans Canada.

Table 21: Effectiveness of Mitigation Measures for Small Arms Munition Training using Vessels as Mitigation Platform and Identified Gaps

<table>
<tr><th rowspan="2">Mitigation Measure</th><th colspan="4">Effectiveness</th><th rowspan="2">Justification</th><th rowspan="2">Gaps in Operationally Achievable Mitigation Measures</th></tr>
<tr><th>PTS</th><th>TTS</th><th>Behaviour</th><th>Masking</th></tr>
<tr><td>Mitigation Avoidance Zone (MAZ)</td><td>H</td><td>H</td><td>N/A for underwater noise

L for in-air noise</td><td>L</td><td>The MAZ is defined as the operationally achievable distance over which marine mammal mitigation is applied. For small arms activities, this applies to marine mammals in the water as well as those hauled-out on land.

Specific limitations to the application of visual, EOIR and radar techniques to monitor the MAZ are discussed below.</td><td>If the MAZ is smaller than the marine mammal safety zones outlined in Table 22, it will not protect against PTS and/or TTS effects in addition to behavioural disturbance and masking effects.</td></tr>
<tr><td>Visual Monitoring</td><td>H</td><td>H</td><td>N/A for underwater noise

M to L for in-air noise</td><td>M to L</td><td>The effectiveness of visual monitoring depends on the ability to observe the full extent of the marine mammal safety zones outlined in Table 22 from the vessel platform. Table 21-A summarizes the estimated visual monitoring distances at operational altitudes.

Table 21-A: Estimated Visual Monitoring Distances
<table>
<tr><th rowspan="2">Visual Observation Height (m)*</th><th colspan="4">Monitoring Distance for each MM Species Group (m)</th></tr>
<tr><th>LFC</th><th>MFC</th><th>HFC</th><th>OP/PP</th></tr>
<tr><td>0-5</td><td>2,500</td><td>1,500</td><td>1,000</td><td>500</td></tr>
<tr><td>>5-10</td><td>2,500</td><td>2,500</td><td>2,000</td><td>500</td></tr>
<tr><td>>10-15</td><td>2,500</td><td>4,000</td><td>1,000</td><td>500</td></tr>
<tr><td>>15-20</td><td>7,000</td><td>4,000</td><td>1,000</td><td>1,000</td></tr>
</table>
Notes:
Visual monitoring distances determined through a review of the literature on vessel distance sampling surveys (Barlow and Taylor 2005; Barlow 2006, Best et al. 2015; Calambokidis and Barlow. 2004; Carretta et al. 2000; Garrison et al. 2010; Gosselin and Lawson 2005; Hakamada and Matsuoka 2016; Heide-Jorgensen et al. 2007; Keple 2002; Moore and Barlow 2013; Palka 2000. Williams et al. 2006; Williams et al. 2016.) and professional experience.
* Visual observation height above the water is dependent on the type of vessel being used. Modelling parameters outlined in Table 6 of Annex B outline a range of heights from 1.5 to 12.6 m.

Visual monitoring of the 219 m TTS in-air pinniped safety zone and the 28 m underwater marine mammal safety zone is considered highly effective for all marine mammal species.

Behavioural Disturbance and Masking:
Although some in-air behavioural and masking effects and underwater masking effects may be mitigated by the implementation of a MAZ based on the visual monitoring distances outlined in Table 21-A (i.e., 500 to 1,000 m for OP/PP depending on the platform), the effectiveness is considered moderate to low due to the large extent of in-air behavioural effects anticipated as summarized in Table 16.</td><td>Visual monitoring will be able to fully cover the extent of the TTS marine mammal safety zone for all in-air and underwater noise injury thresholds (Table 22). Residual PTS and TTS effects are not considered likely. Behavioural and masking effects are possible.</td></tr>
</table>

Notes: LFC = low-frequency cetaceans, MFC=mid-frequency cetaceans, HFC = high-frequency cetaceans, OP=otariid pinnipeds, PP = phocid pinnipeds, N/A = not applicable, Hi = high, M = moderate, L=low.

<table>
<tr><th rowspan="2">Mitigation Measure</th><th colspan="4">Effectiveness</th><th rowspan="2">Justification</th><th rowspan="2">Gaps in Operationally Achievable Mitigation Measures</th></tr>
<tr><th>PTS</th><th>TTS</th><th>Behaviour</th><th>Masking</th></tr>
<tr><td>Electro-Optical Infrared (EOIR) Monitoring (e.g., Stabilized Electro-Optical Sighting System (SEOSS))</td><td>H to M</td><td>H to M</td><td>N/A - for underwater noise

L for airborne noise</td><td>L</td><td>The effectiveness of EOIR monitoring depends on the ability to observe the full extent of the marine mammal safety zones and the ability to provide a dedicated EOIR operator. Monitoring distances for EOIR compiled from the literature are presented in the Table 21-B.

Table 21-B: Estimated EOIR Monitoring Distance
<table>
<tr><th rowspan="2">System</th><th colspan="4">Monitoring Distance for each MM Species Group</th></tr>
<tr><th>LFC</th><th>MFC</th><th>HFC</th><th>OP/PP</th></tr>
<tr><td>EOIR</td><td>5 to 8 km (blows)</td><td>3 to 5 km</td><td>1.5 km</td><td>N/A</td></tr>
</table>
Note: EOIR monitoring distances determined through a review of the literature and communication with SME (Verfuss et al. 2018; Weissenberger and Zitterbart 2012; Zitterbart et al. 2013).
N/A = data not available in the literature.

PTS - EOIR monitoring within the <10 m underwater marine mammal safety zone is considered highly effective for all marine mammal species (including pinnipeds). However, the effectiveness is reduced to moderate if a dedicated EOIR operator is not possible. As there is a lack of data regarding the ability of EOIR to monitor for pinnipeds, monitoring within the 113 m PTS in-air pinniped safety zone has conservatively been set as moderate.

TTS- EOIR monitoring within the 28 m underwater marine mammal safety zone is considered highly effective for all marine mammal species (including pinnipeds). However, the effectiveness is reduced to moderate if a dedicated EOIR operator is not possible. As there is a lack of data regarding the ability of EOIR to monitor for pinnipeds, monitoring within the 219 m TTS in-air pinniped safety zone has conservatively been set as moderate.

Behavioural Disturbance and Masking: Although some in-air behavioural and masking effects and underwater masking effects may be mitigated by the implementation of EOIR monitoring of the TTS and PTS marine mammal safety zones, the effectiveness is considered low due to the large extent of in-air behavioural effects anticipated as summarized in Table 16.</td><td>EOIR monitoring will be able to fully cover the extent of the underwater PTS and TTS marine mammal safety zones for all marine mammals except OP/PP (Table 22). As there is no data available on the ability of EOIRs to detect pinnipeds, it is conservatively assumed that EOIR will not be fully effective in monitoring the in-air PTS and TTS safety zones for OP/PP. In addition, a dedicated EOIR operator during operations may not be possible due to the small crew size. The inability to provide a dedicated EOIR operator further limits this mitigation measure.

Residual PTS and TTS effects are considered possible for OP/PP for in-air noise. In-air behavioural effects are considered possible for pinnipeds hauled out. Masking effects are considered possible for all marine mammal species (in-air and underwater).</td></tr>
<tr><td>Night Vision Goggles</td><td>L</td><td>L</td><td>L</td><td>L</td><td>The effectiveness of NVG monitoring depends on the ability to observe the full extent of the marine mammal safety zones.
PTS – Effectiveness off NVG monitoring within the <10 m underwater and 113 m in-air marine mammal safety zones is considered low for all marine mammal species (including pinnipeds). There is a lack of data regarding the effectiveness of NVG to monitor for marine mammals, when NVG have been used they have been ineffective and NVG can only be used in specific circumstances, e.g., there must be some level of ambient light.

TTS - NVG monitoring within the 28 m underwater and 219 m in-air marine mammal safety zones is considered highly effective for all marine mammal species (including pinnipeds). There is a lack of data regarding the effectiveness of NVG to monitor for marine mammals, when NVG have been used they have been ineffective and NVG can only be used in specific circumstances, e.g., there must be some level of ambient light.

Behavioural Disturbance and Masking: The effectiveness of NVG to monitor for behaviour and masking effects is considered low due to the large extent of in-air behavioural effects anticipated as summarized in Table 16. NVG are also considered ineffective for monitoring for marine mammals at night due to lack of data and low effectiveness at detecting marine mammals when they have been used.</td><td>A preliminary literature search indicates that NVG have limited effectiveness to detect marine mammals (Marine Mammal Observer Association 2020; Quan and Calambokidis 1999, Statoil USA E&P Inc. 2010.) and potentially only at very close range (Frankel and Vigness-Raposa 2001). There is a lack of data regarding the effectiveness of NVG to monitor for marine mammals, when NVG have been used they have been ineffective and NVG can only be used in specific circumstances, e.g., some level of ambient light and cannot be used in complete darkness. Therefore, it is conservatively assumed that NVGs will not be fully effective in monitoring the underwater and in-air PTS and TTS safety zones and behavioural and masking effects for all marine mammals.</td></tr>
</table>

Notes: LFC = low-frequency cetaceans, MFC=mid-frequency cetaceans, HFC = high-frequency cetaceans, OP=otariid pinnipeds, PP = phocid pinnipeds, N/A = not applicable, Hi = high, M = moderate, L=low.

<table>
<tr><th rowspan="2">Mitigation Measure</th><th colspan="4">Effectiveness</th><th rowspan="2">Justification</th><th rowspan="2">Gaps in Operationally Achievable Mitigation Measures</th></tr>
<tr><th>PTS</th><th>TTS</th><th>Behaviour</th><th>Masking</th></tr>
<tr><td>Radar</td><td>H to L</td><td>H to L</td><td>N/A for underwater noise

L for in-air noise</td><td>L</td><td>The effectiveness of radar monitoring depends on the ability to observe the full extent of the marine mammal safety zones and the ability to provide a dedicated radar operator. Monitoring distances for radar compiled from the literature are presented in the Table 21-C below.

Table 21-C: Estimated radar Monitoring Distance
<table>
<tr><th>System</th><th colspan="4">Monitoring Distance for each MM Species Group</th></tr>
<tr><th></th><th>LFC</th><th>MFC</th><th>HFC</th><th>OP/PP</th></tr>
<tr><td>radar</td><td>< 1 km</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>
Note:
radar monitoring distances determined through a review of the literature and communication with SME (De Prospo et al. 2005; Forsyth 2011; Verfuss et al. 2018). N/A = data not available in the literature.

PTS - radar monitoring within the <10 m underwater marine mammal safety zone is considered highly effective for all marine mammal species (including pinnipeds). However, the effectiveness is reduced to moderate if a dedicate radar operator is not possible. As there is a lack of data regarding the ability of radar to monitor for pinnipeds, monitoring within the 113 m PTS in-air pinniped safety zone has conservatively been set as low.

TTS - radar monitoring within the 28 m underwater marine mammal safety zone is considered highly effective for all marine mammal species (including pinnipeds). However, the effectiveness is reduced to moderate if a dedicate radar operator is not possible. As there is a lack of data regarding the ability of radar to monitor for pinnipeds, monitoring within the 219 m TTS in-air pinniped safety zone has conservatively been set as low.

Behaviour and Masking: Although some in-air behavioural and masking effects and underwater masking effects may be mitigated by the implementation of radar monitoring of the TTS and PTS marine mammal safety zones, the effectiveness is considered low due to the large extent of in-air behavioural effects anticipated as summarized in Table 16.</td><td>Radar monitoring will be able to fully cover the extent of the underwater PTS and TTS marine mammal safety zones for all marine mammals except OP/PP (Table 22). As there is no data available on the ability of radar to detect pinnipeds, it is conservatively assumed that radar will not be fully effective in monitoring the in-air PTS and TTS safety zones for OP/PP. In addition, a dedicated radar operator during operations may not be possible due to the small crew size. The inability to provide a dedicated radar operator further limits this mitigation measure.

Residual PTS and TTS effects are considered possible for OP/PP for in-air noise. In-air behavioural effects are considered possible for pinnipeds hauled out. Masking effects are considered possible for all marine mammal species (in-air and underwater).</td></tr>
<tr><td>Shut down/cease fire procedures</td><td>H</td><td>H</td><td>H</td><td>H</td><td>Cease fires already implemented within the current mitigation strategy.</td><td>There are no identified gaps in the ability to call a shut-down/cease fire if a marine mammal is detected within the marine mammal safety zone.</td></tr>
<tr><td>Pre-operational Search</td><td>H</td><td>H</td><td>H</td><td>H</td><td>Operationally achievable to perform a full 15-minute pre-operational search.</td><td>There are no identified gaps in the ability to perform a pre-operational search within the marine mammal safety zone.</td></tr>
<tr><td>Limit training during low visibility conditions</td><td>H</td><td>H</td><td>H</td><td>H</td><td>If the marine mammal safety zone (Table 22) cannot be visually cleared due to low visibility/night-time conditions, then the training activity should be delayed until the full extent of the zones can be observed.

Limiting training during low visibility conditions (e.g., precipitation and high sea state) is operationally feasible. Under existing firing safety orders, Commanding Officers ensure that due diligence is observed when determining whether a range is clear. Consideration is given to recent reports of vessels, aircraft, objects, or marine mammals observed in the operating area. Additionally, USCG limits gunnery training activities to daytime (1 hour after sunrise to 1 hour before sunset).

Although training is limited during low visibility conditions, RCN/RCAF have identified that small and large caliber firings at night are required to meet training objectives which will require additional mitigation measures. Halifax class vessels therefore utilize SEOSS (Stabilized Electro-Optical Sighting System), an electro optical camera with IR mode which will be implemented during night-time shoots, along with NVG. The Kingston class vessels do not have SEOSS but NVGs would be used by onboard lookouts.</td><td>Limiting training during low visibility conditions (e.g., poor visibility during daytime conditions such as fog and/or heavy sea states) is considered highly effective if the Commanding Officers deem it unsafe to proceed. However, night time firings are a mandatory RCN/RCAF training requirement and avoiding night-time conditions is not considered achievable and therefore this mitigation is not effective for those scenarios.</td></tr>
<tr><td>Marine Species Awareness Training</td><td>H</td><td>H</td><td>H</td><td>H</td><td>Marine mammal observer training is expected by the regulators and used throughout industries to train non-biologists in marine mammal observation and identification techniques.</td><td>No gaps identified for this measure.</td></tr>
<tr><td>Reporting</td><td>H</td><td>H</td><td>H</td><td>H</td><td>Increases the knowledge base of the effects of small arms munitions and could alert other operators to the presence of marine mammals in the area.</td><td>No gaps identified for this measure.</td></tr>
</table>

Notes: LFC = low-frequency cetaceans, MFC=mid-frequency cetaceans, HFC = high-frequency cetaceans, OP=otariid pinnipeds, PP = phocid pinnipeds, N/A = not applicable, Hi = high, M = moderate, L=low.

Mitigation Measure	Effectiveness				Justification	Gaps in Operationally Achievable Mitigation Measures
	PTS	TTS	Behaviour	Masking		
Sensitive areas and timing windows	H to L	H to L	H to L	H to L	Depending on how sensitive timing windows are considered by the operators the effectiveness of this measure ranges from high (if timing is avoided) to low (if timing is not avoided). The IA for Steller sea lion does not overlap with WH and the IA for grey whales overlaps with a small portion of WH therefore it can be considered operationally achievable that gunnery activities will not occur within Steller sea lion or grey whale IAs. The effectiveness for this mitigation measure is high for Steller sea lions and high to moderate for grey whales. The IA for harbour porpoise and sensitive timing windows overlap with WH and it is not operationally feasible to avoid sensitive areas and timing windows for harbour porpoise. The effectiveness of this mitigation measure for harbour porpoise is reduced to low.	This mitigation measure is not effective for all species sensitive areas or timing windows. It is not operationally achievable to avoid the sensitive timing window in the harbour porpoise IA, from April to October; this timing window coincides with the primary training window for Reserve Units and the most benign weather for training activities.
Designated Marine Protected Areas (MPAs; Bowie Seamount, Hecate Strait & Queen Charlotte Sound Glass Sponge Reefs, Endeavour Hydrothermal Vents)	N/A				Mitigation measure not relevant to assessment of underwater noise. Included in table for reference only.	N/A
Killer whale rubbing beaches	N/A				Mitigation measure not relevant to assessment of underwater noise. Included in table for reference only.	N/A
Race Rocks Provincial Ecological Reserve	N/A					
National Wildlife Areas (NWA)	N/A					
Scott Islands Protected Marine Area	N/A					
Migratory Bird Sanctuaries	N/A					
National Parks and Park Reserves	N/A					
Provincial Ecological Reserves	N/A					
Provincial Parks and Protected Areas	N/A					

Notes: LFC = low-frequency cetaceans, MFC=mid-frequency cetaceans, HFC = high-frequency cetaceans, OP=otariid pinnipeds, PP = phocid pinnipeds, N/A = not applicable, Hi = high, M = moderate, L=low.

Table 22: Marine Mammal Injury Safety Zones for TTS and PTS

In-air/Underwater	TTS Safety Zone (m) based on R_{max}	PTS Safety Zone (m) based on R_{max}
In-air[1]	219 m	113 m
Underwater[2]	28 m	< 10 m

Notes:

Based on most conservative scenario modelled = 1) M2 and MK38 aggregate scenario using NMFS 2018 threshold for phocid carnivores in-air, 2) M2 scenario using the Southall et al. 2007 threshold for HFC.

4.1.5 Residual Effects

Considering mitigation measures identified in Section 4.1.4 (Table 20), and their predicted effectiveness as identified in Table 21, residual effects to marine mammals from the small arms munition training activities are predicted to be limited to behavioural disturbance and masking effects for in-air noise sources, and masking effects for underwater noise sources. The following section summarizes the effectiveness of mitigation measures and discusses the potential resulting residual effects to individuals and populations likely to be present in OPAREA WH.

4.1.5.1 In-air Noise

PTS and TTS effects from in-air noise is considered unlikely from the small arms munition training activities for all marine mammal species groups during daylight conditions. Visual monitoring of the 113 m PTS in-air marine mammal safety zone and the 219 m in-air TTS marine mammal safety zone from a vessel is considered highly effective. TTS and PTS effects are considered mitigable and no residual effects are likely. During nighttime conditions, EOIR, radar and NVG may not be able to monitor the in-air PTS and TTS safety zones for pinnipeds hauled-out on land therefore these effects are considered possible. Mitigation measures are also not considered effective in avoiding behavioural disturbance and masking effects to pinnipeds above water (in-air); therefore, these effects are considered residual adverse effects and are discussed in more detail below.

TTS, behavioural disturbance and masking effects are considered temporary at the individual level with recovery occurring over a short period of time (e.g., within several days or months) following the completion of the training activities. PTS effects are considered permanent and could lead to mortality of the individual. Effects at the population level are dependent on the potential for exposure (e.g., spatial overlap) in combination with the health of the population affected (and its ability to withstand the effects).

There are no identified Steller sea lion haul-outs in OPAREA WH. The closest haul-outs are located north of Port Renfrew and south of Race Rocks Provincial Ecological Reserve (Figure 6– Annex A; Olesiuk 2018, Jeffries et al. 2000, Port of Vancouver 2019a). The haul-out near Port Renfrew is approximately 12 km away from the north-western boundary of OPAREA WH and is used by Steller sea lions primarily during winters. Race Rocks Provincial Ecological Reserve is located approximately 30 km away from the south-eastern boundary of OPAREA WH and is considered a winter and year-round haul-out for this species. Race Rocks Provincial Ecological Reserve is also used year-round by Northern elephant seal and is identified as a small rookery for this species with one to three pups being born at this site between December and March (Race Rocks Ecological Reserve 2019; Olesiuk and Bigg 1984). The largest in-air PTS and TTS marine mammal safety zones were associated with the M2 (113 m) and MK38 aggregate scenario (219 m). There are no known harbour seal or Steller sea lion haul-outs this close to OPAREA WH (Figure 5 and 6– Annex A); therefore, the potential for in-air noise to cause PTS and TTS effects to hauled-out pinnipeds during night-time conditions is considered unlikely.

The largest behavioural disturbance safety zone was calculated for the M2 and MK38 aggregate scenario and was approximately 15.6 km. It is considered unlikely that small arms activities in OPAREA WH would cause behavioural disturbance of individuals hauled-out at Race Rocks Provincial Ecological Reserve. This disturbance range does overlap with the Steller sea lion haul-out near Port Renfrew (12 km away) and therefore behavioural disturbance of individuals hauled-out at this site during the winter months is considered possible. However, this is only considered likely if training activities occur within approximately 3 km of the north-western boundary of OPAREA WH when individuals are hauled-out at this site. For the other scenarios modelled, the in-air behavioural disturbance zones were <10 km and therefore considered unlikely to affect the Port Renfrew and Race Rocks Provincial Ecological Reserve haul-out sites. There are five harbour seal haul-outs located within close proximity to OPAREA WH (Figure 5– Annex A) ranging from 4.0 km to 15.5 km from the boundary of OPAREA WH. Behavioural disturbance of harbour seal individuals is considered possible at these sites for most scenarios modelled because they occur within the 15.6 km behavioural disturbance safety zone. In addition, individuals at the surface could also be affected. Behavioural reactions of hauled-out individuals could range from no reaction, to startle response, increased alertness, increased activity, fleeing behaviour, mothers abandoning pups when fleeing, and stampeding (United States Pacific Fleet 2019). However, it is most likely that behavioural responses will be limited to brief alerting and orienting response with no significant behavioural responses expected to occur (Finneran et al. 2017).

In-air masking effects to pinnipeds are considered possible as a result of small arms activities due to the overlap in frequencies over which pinnipeds hear (e.g., functional hearing range = 50 Hz to 86 kHz for PP and 60 Hz to 39 kHz for OP; Southall et al. 2007) and the frequencies over which the small arms fire are emitted (between 7 Hz and 20 kHz). Steller sea lion generally use in-air vocalizations to establish territories during mating and to maintain mother-pup communication (Richardson et al. 1995). Harbour seals also produce a wide variety of in-air vocalizations, including short barks, tonal honks, grunts, growls, roars, moans, and pup contact calls (University of Rhode Island and Inner Space Center 2019). In-air vocalizations by male harbour seals have been attributed to aggressive behaviours and interactions (Van Parijs and Kovacs 2002; Van Parijs et al. 2003). Due to the impulsive nature of the gunfire, there is less potential for masking of pinniped communications as individuals would be able to hear in between successive shots/fires.

Steller sea lion are currently listed as Special Concern under SARA. Main threats to Steller sea lion include disturbance while on land, particularly at their rookeries. Despite current levels of anthropogenic activities and associated in-air sounds, aerial surveys conducted by DFO indicated that the number of Steller sea lion in BC waters has been increasing at an average annual rate of 3.8% since 1971 (Olesiuk 2018). Potential for masking of in-air vocalizations of Steller sea lions from small arms training activities is low due to the relatively large distances between small arms activities and known haul-out sites. Only one Steller sea lion haul-out near Port Renfrew is anticipated to be affected by small arms activities (12 km away) and only likely if training activities occur within approximately 3 km of the north-western boundary of OPAREA WH when individuals are hauled-out at this site. This site is not identified as a rookery and is not considered a major winter haul-out, further limiting the potential for population-level effects on this species from exposure to in-air noise from small arms activities.

Harbour seal and northern elephant seal populations are considered healthy and are not at risk. Harbour seal could be affected at several known haul-out sites close to OPAREA WH with the closest haul-out located 4.05 km from the OPAREA WH boundary (Figure 5 – Annex A). A small number of elephant seals frequent the Race Rocks Provincial Ecological Reserve with pups observed at this site making it the most northern rookery for this species. However, no behavioural responses are expected to occur at the Race Rocks Provincial Ecological Reserve based on the overall distance of this site to OPAREA WH. All pinnipeds that do experience behavioural disturbance from small arms activities are expected to resume normal behaviour shortly after the activity has ceased (Demarchi et al. 2012). No significant behavioural response from small arms activities are expected (Finneran et al. 2017).

4.1.5.2 Underwater Noise

PTS and TTS effects from underwater noise is considered unlikely from the small arms munition training activities for all marine mammal species groups. PTS thresholds were only reached for HFC for the M2, M2 and M240 aggregate and M2 and MK38 aggregate scenarios (R_{max} = <10 m). TTS thresholds were reached for the HFC for all scenarios and for LFC for the M240, M2, MK38, and all aggregate scenarios. Monitoring of the <10 m PTS underwater marine mammal safety zone and the 28 m underwater TTS marine mammal safety zone from a vessel is considered highly effective. TTS and PTS effects are considered mitigable and residual effects are not considered likely.

As previously stated in Section 4.1.3.4 and outlined in Annex B, the underwater noise threshold for behavioural disturbance for impulsive noise sources (e.g., 160 dB SPL_{rms}; NMFS 2013) was not attained for any of the small arm scenarios considered in the acoustic modelling. Residual underwater behavioural effects are therefore not considered further in the present evaluation. Mitigation measures are not considered effective in avoiding masking effects to marine mammals underwater; therefore, these effects are considered residual adverse effects and are discussed in more detail below.

Masking effects are considered temporary at the individual level with recovery occurring over a short period of time after the completion of the training activities causing the effect. Effects at the population level are dependent on the potential for exposure (e.g., spatial overlap) in combination with the health of the population affected (and its ability to withstand the effects).

Masking effects to LFC are considered possible as a result of small arms activities due to acoustic overlap between the LFC functional hearing range (e.g., 0.007 to 35 kHz; Southall et al. 2007) and the small arm sources (frequencies of 7 Hz to 20 kHz). Underwater noise from the small arm operations may also overlap with humpback whale songs and grey whale vocalizations as outlined in Table 19.. However, due to the expected low density of humpback whale near OPAREA WH and their preference for foraging areas along the continental shelf (Levesque and Jamieson 2015; Nichol et al. 2017), the potential for this effect to occur is considered low.

The humpback whale population along the north Pacific coast appear to be recovering at a moderate rate ranging between 4% (estimate based on populations comparisons from 1993 and 2006) and 7% (estimate based on population comparisons from 1966 and 2006; DFO 2013). Some population studies suggest that the North Pacific population has largely recovered from industrial whaling (based on a pre-industrial whaling estimate of 15,000; Rice's 1978 in DFO 2013). In addition, in 2017, the species was downlisted from Threatened to Special Concern under Schedule 1 of SARA (Canadian Gazette 2017).

There are three populations of grey whales residing in the Strait of Juan de Fuca: the Northern Pacific Migratory population, Pacific Coast Feeding Group population and the Western Pacific population. The Northern Pacific Migratory population experienced declines in 1999 and 2000 but recovered and have remained relatively stable at approximately 21,000 (COSEWIC 2017). The Pacific Coast Feeding Group population is a small population (e.g., 243 individuals) that occurs in nearshore BC waters during the summer months to feed. Due to its small size, the population is considered vulnerable (COSEWIC 2017). The Western Pacific population migrate along the West Coast of Canada to summer feeding areas in Russia. This population is growing but currently numbers only

174 individuals. There is a grey whale IA that overlaps with the north-western portion of OPAREA WH OPAREA (Figure 4 – Annex A).

As the OPAREA WH is located within SRKW critical habitat and within key foraging areas used by this population during the summer months, potential effects to this population are of particular importance. As stated above, modelling results for all scenarios indicate that small arms noise will not exceed the underwater disturbance threshold for any marine mammal species including MFC (i.e., killer whales) (see Section 4.1.3.4). Modeling results also indicate that the PTS and TTS thresholds for MFC will not be reached under any scenario (Table 17).

Masking of MFC communication is considered possible as a result of small arms activities due to the overlap in frequencies over which MFC hear and communicate (e.g., functional hearing range = 150 Hz to 160 kHz; Southall et al. 2007) and the frequencies over which the small arm sources are emitted (frequencies of 7 Hz to 20 kHz). Overlap between noise generated by small arms operations and killer whale vocalizations and echolocation clicks is outlined in Table 19. Killer whale calls are important for maintaining group cohesion, communicating between cow-calf pairs, communicating information on the location of prey and potential threats, and maintaining social interactions (Heise et al. 2017). High frequency echolocation clicks are used (15 to 100 kHz) to avoid obstacles navigate and find prey, with killer whales able to detect salmon up to at least 250 m away (Au et al. 2004; SMRU 2014b, c). If a MAZ is selected that protects against PTS/TTS and is based on the ability to detect marine mammals from the vessel platform (as outlined in Table 20) it would reduce the potential for masking effects to SRKW within their critical habitats (Figure 2 – Annex A). Additionally, if the closest approach distance outlined in the SRKW Critical Habitat Interim Order (400 m), are followed by small arms training vessels, then the potential for masking effects to SRKW within their critical habitats from small arms training activities will be further reduced.

SRKW are a nutritionally stressed population facing imminent threat due to reduced prey availability, acoustic and physical disturbance and contaminant loading (DFO 2018a). SRKWs are considered to have a low resilience to imposed stresses associated with anthropogenic underwater noise activities in OPAREA WH due to their continued state of decline and vulnerability. As per the *Species at Risk Act,* it is also prohibited to damage or destroy the critical habitat of a species listed as Extirpated, Endangered or Threatened. Underwater noise has been identified as an activity that could result in the destruction of SRKW critical habitat. However, also noted in the recovery strategy is that 'some activities may impact critical habitat regardless of whether or not the whales are present within the area, while others would require the presence of the whales, dependent on the activity and the feature, function, or attribute affected by that activity' (DFO 2018a). If the small arms training activities are avoided when SRKW are observed to be active in the area (as outlined in Table 20) the potential impairment of their critical habitat would only occur at times when the whales were absent from the area (not actively using or occupying the critical habitat). With the implementation of marine mammal monitoring and shut-down procedures within the MAZ, the potential for small arms training activities to result in masking effects and destruction of critical habitat to SRKW is reduced.

Masking effects to HFC are also considered possible as a result of small arms activities due to the overlap in frequencies over which HFC hear and communicate (e.g., functional hearing range = 275 Hz to 160 kHz; Southall et al. 2007) and the frequencies over which the small arms sources are emitted (frequencies of 7 Hz to 20 kHz). Overlap with HFC echolocation clicks is not anticipated as a result of small arms operations as outlined in Table 19. There are no accurate population estimates for harbour porpoise or Dall's porpoise in BC waters. Aerial surveys conducted in the Strait of Georgia and Washington State inland waters reported a significant increase in harbour porpoise abundance between 1996 and 2003 (Hall 2004). They are currently listed at Special Concern under SARA (Government of Canada 2011a). Dall's porpoise in Washington State waters are described by the NMFS as reasonably abundant (NOAA 2015b, 2017) and are considered not at risk in Canada (Government of Canada 2011b).

Masking effects to pinnipeds are also considered possible as a result of small arms activities operations due to the overlap in frequencies over which pinnipeds hear and communicate (e.g., functional hearing range = 50 Hz to 86 kHz for PP and 60 Hz to 39 kHz for OP; Southall et al. 2007) and the frequencies over which the small arms sources are emitted (frequencies of 7 Hz to 20 kHz). Steller sea lion generally use in-air vocalizations to establish territories during mating and to maintain mother pup communication. However, Steller sea lions are not very vocal underwater and therefore underwater masking effects from small arms operations are considered unlikely for this species. Overlap between noise generated by small arms operations and harbour seal vocalizations is possible as outlined in Table 19 Harbour seal and northern elephant seal populations are considered healthy and not at risk by COSEWIC (Government of Canada 2011c, d).

4.1.6 Summary

Acoustic propagation modelling of in-air and underwater noise from small-arms military training exercises was undertaken by JASCO to determine distances to established acoustic injury and disturbance thresholds for marine mammals. Five weapons of various calibre were modelled individually, in addition to three aggregate scenarios that include two weapons each (M2/M240, M2/MK38 and C8/Pt). Three sets of criteria were considered in the in-air propagation model and included PTS, TTS and behavioural disturbance thresholds for pinnipeds for impulsive sounds (Southall et al. 2007, 2019). Two sets of criteria were considered in the underwater noise model and included those that define thresholds for injury (PTS and TTS) that incorporate frequency weighting for the five distinct marine mammal hearing groups (NOAA 2018) and the NMFS (2013) 160 dB re 1 µPa SPL threshold for behavioural response for impulsive sounds for all marine mammal species.

Modelling results for in-air noises in OPAREA WH indicated that the largest distances (R_{max}) to existing marine mammal injury thresholds (based on non-weighted SPL_{peak} injury thresholds from Southall et al. 2019) were associated with TTS for pinniped in-air, equivalent to 219 m for the MK38 during training. For underwater noise, modelling results indicated that the largest distances (R_{max}) to existing marine mammal injury thresholds (based on 24-h auditory weighted SEL injury thresholds) were associated with TTS for HFC, equivalent to 28 m for the M2 and MK38 aggregate scenario. Behavioural disturbance for in-air noise was estimated to occur at a maximum distance from the source (R_{max}) of 15.6 km for the M2 and MK38 aggregate scenario. The underwater noise threshold for behavioural disturbance was not reached by any of the small arm scenarios modelled.

With the application of operationally achievable mitigation measures (e.g., visual monitoring of the MAZ etc.), residual effects were limited to behavioural disturbance and masking effects associated with in-air noise and masking effects associated with underwater noise. Species most likely to be affected include harbour seal and Steller sea lion at nearby haul-outs. Expected behavioural responses by these animals include brief alerting and orienting response with no significant behavioural responses (Finneran et al. 2017). Masking effects related to underwater noise are most likely to affect SRKW when foraging or traveling in nearshore areas, particularly in areas where SRWK critical habitat overlaps with OPAREA WH. Other species potentially affected by masking effects include harbour porpoise, humpback whale and grey whales as these species are known to feed and migrate in and adjacent to OPAREA WH. Masking effects are expected to be limited for all marine mammal species affected due to the lack of frequency overlap between small arms operations and the vocalizations of SRKW and harbour porpoise, in addition to the expected low densities of humpback and grey whale in OPAREA WH.

5.0 INFORMATION GAPS AND RECOMMENDATION FOR FUTURE STUDIES

Table 23 provides an overview of existing information gaps and subsequent recommendations for future studies. Many of these studies could be conducted in collaboration with DFO, research organizations and/or the U.S. Navy.

Table 23: Information Gaps and Recommendation for Future Studies

Gap	Recommendation	Description
Behavioural responses of marine mammals to small arms munition activities.	Implementation of observational marine mammal behaviour studies during small arms munitions training	There is a general lack of information regarding the behavioural responses of marine mammals to in-air gunfire. Visual-based monitoring during active small arms training activities should record observations of marine mammals near the activity to see how the animals react to the activity. Marine mammals observed inside or outside the MAZ or marine mammal safety zone should be recorded and observed over the course of the small arms activity. Behavioural observations should be noted including swimming direction and speed and any behavioural.
Potential for acoustic masking in marine mammals from small arms munition training (i.e., reduced communication space)	Acoustic masking studies	Acoustic masking typically occurs when the masking noise and the signal of interest share similar frequencies and overlap in time (Richardson et al. 1995). Masking was not considered in the model for the following reasons: 1) no established regulatory thresholds for masking exist, 2) predicting masking effects is difficult as masking is species-specific and thus requires detailed information on a species' hearing ability (i.e., audiograms) which is lacking for many marine mammal species, and 3) more research is needed to understand the process of masking, the risk of masking by anthropogenic activities such as shipping, the ecological significance of masking, and what anti-masking strategies are used by animals and their degree of effectiveness before masking can be incorporated into regulation strategies or approaches for mitigation (Erbe et al. 2016).
Marine mammal density estimates	Transect-based marine mammal density surveys implementing distance sampling techniques	Seasonal marine mammal density data is lacking in OPAREA WH. The data available for most areas is considered out-dated (e.g., early 2000's) and is heavily reliant on limited datasets. Site-specific marine mammal density surveys using transect-based distance sampling techniques would provide valuable data on the seasonality, habitat use, density and abundance of marine mammals specific to OPAREA WH, with results directly informing operational scheduling including identification of periods of least risk to marine mammals with respect to training activities.
New marine mammal alert system	Investigating the potential for DND to participate in the WhaleReport Alert System (WRAS; http://wildwhales.org/wras/).	A new marine mammal alerting system that could be incorporated into future mitigation strategies.

Gap	Recommendation	Description
Night Vision Goggles (NVG)	Verify the effectiveness of NVGs in detecting marine mammals during night-time conditions.	The effectiveness of NVG to monitor for marine mammals is relatively unknown. A study to confirm the effectiveness of NVG in monitoring marine mammals during nighttime conditions should be conducted.
EOIR	Verify the effectiveness of EOIR in detecting pinnipeds during night-time conditions.	The effectiveness of EOIR to monitor for pinnipeds is relatively unknown. A study to confirm the effectiveness of EOIR in monitoring pinnipeds (in the water and hauled-out on land) during nighttime conditions should be conducted.
Radar	Verify the effectiveness of radar in detecting marine mammals during night-time conditions.	The effectiveness of radar to monitor for pinnipeds, MFC and HFC is relatively unknown. A study to confirm the effectiveness of radar in monitoring pinnipeds (in the water and hauled-out on land) and MFC and HFC during nighttime conditions should be conducted.
Safety firing arc/area clear requirements	MAZ/marine mammal safety zone consistent with the safety firing arc/area clear requirements	Further evaluation may be warranted to validate the ability to define a MAZ based on the safety firing arcs to evaluate the effectiveness of maintaining a MAZ of these sizes with current operational capabilities.
NAVORD 4995-0, NAVORD 4995-3 and MARPACORD 3350-1	NAVORD 4995-0, NAVORD 4995-3 and MARPACORD 3350 should be updated to reflect current mitigation strategy.	NAVORD 4995-0, NAVORD 4995-3 and MARPACORD 3350-1 should be updated to reflect all recommended mitigation measures identified in this report. CAF/RCAF Orders need to be updated/developed to reflect the same when RCAF/CAF air assets are firing weapons in MARPAC OPAREAs.
Additional modelling scenarios	Recommend additional scenarios are modelled to address client comment that Cyclones are also used at the range to fire weapons.	Recommendation of further modelling for weapons shot from a helicopter platform at 40 to 500 ft height above the water.

6.0 EXPERTISE FROM OTHER PARTIES

6.1 Federal Government Bodies

To be provided from PSPC/DND.

6.2 Third-Party Groups

No third parties were contacted to assist in the development of this evaluation.

7.0 CLOSURE

We trust this information is sufficient for your needs at this this time. Should you have any questions or concerns, please do not hesitate to contact the undersigned.

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https://golderassociates.sharepoint.com/sites/126707/project files/6 deliverables/issued to client_for wp/20141332-005-r-rev0/20141332-005-r-rev0-task 5 final rpt-01dec_20.docx

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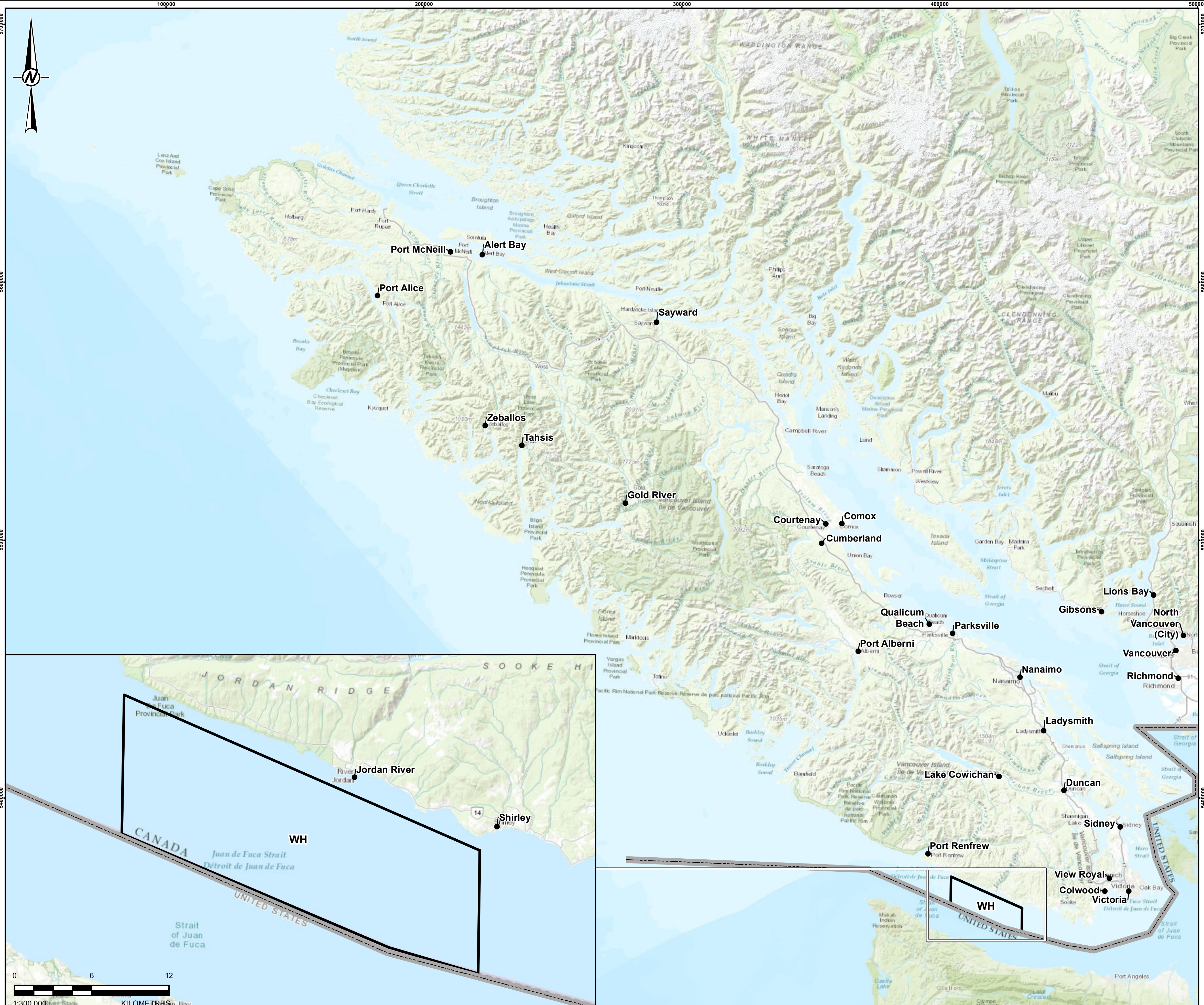
ANNEX A

FIGURES



LEGEND

- CANADIAN SEA RANGE
- POPULATED PLACE
- CANADA/USA BORDER

0 30 60

1:1,500,000 KILOMETRES

REFERENCE(S)

1. POPULATED PLACES OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. CANADA/USA BORDER OBTAINED FROM DIGITAL GEOLOGY MAP OF BRITISH COLUMBIA, 2005.
3. IMAGERY BASE SOURCE ESRI, HERE, GARMIN, USGS, NRCAN AND THE GIS USER COMMUNITY.

COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT

DEPARTMENT OF NATIONAL DEFENCE (DND)

PROJECT

EVALUATION OF UNDERWATER AND IN-AIR ACOUSTIC IMPACTS ON MARINE MAMMALS FROM SMALL ARMS MUNITIONS IN OPAREA WH

TITLE

SMALL ARMS MUNITION FIRING RANGE IN MARPAC OPAREA WH

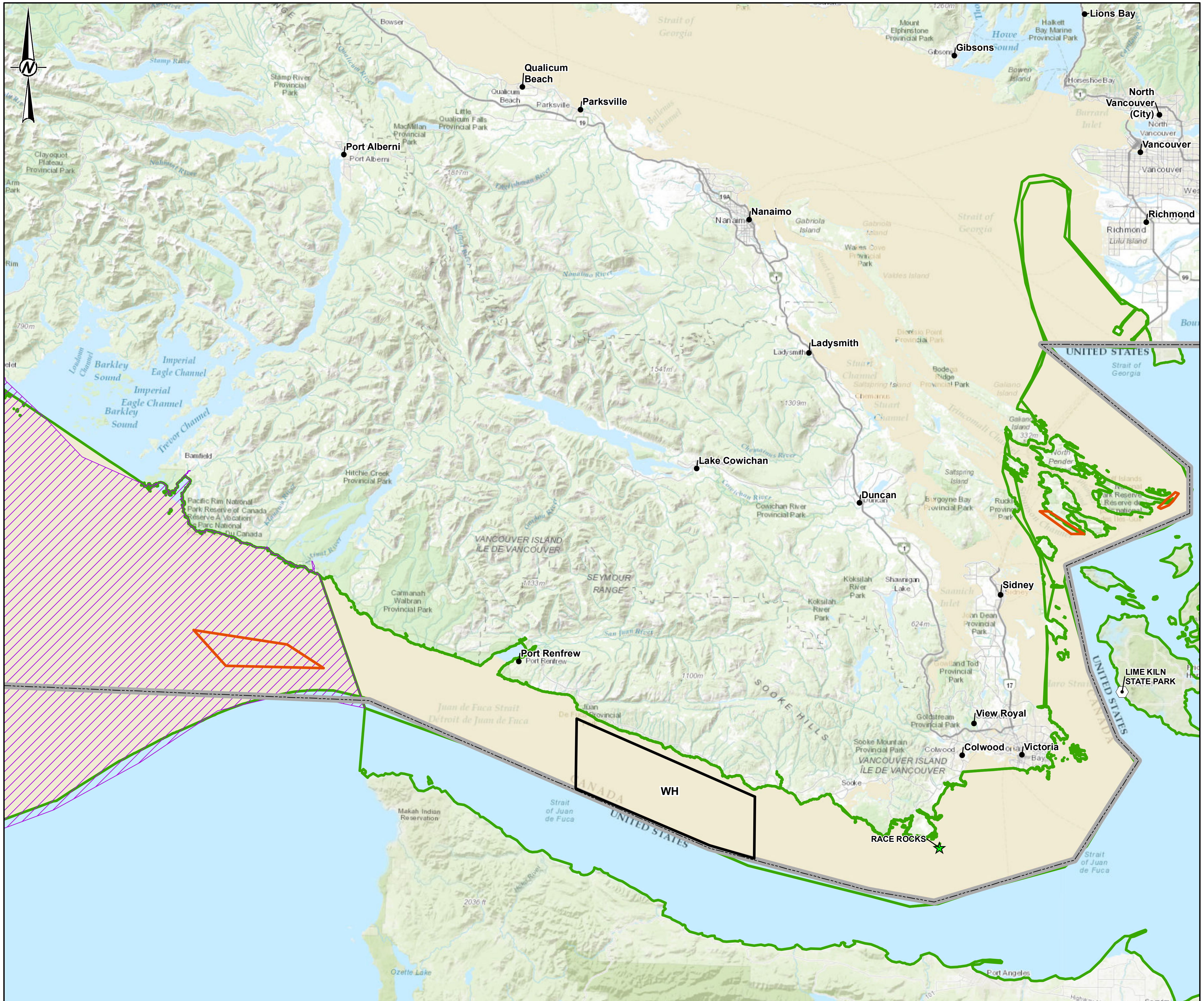
CONSULTANT

GOLDER

YYYY-MM-DD	2020-11-27
DESIGNED	KZ
PREPARED	JP
REVIEWED	KG
APPROVED	BW

PROJECT NO.	PHASE	REV.	FIGURE
20141332	2000/2005	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



0 12,000 24,000

1:600,000 METRES

LEGEND

- CANADIAN SEA RANGE
- POPULATED PLACE
- LIME KILN STATE PARK
- RACE ROCKS
- SRKW CRITICAL HABITAT
- SRKW AND NRKW CRITICAL HABITAT
- SRKW 400m APPROACH DISTANCE
- INTERIM SANCTUARY ZONE
- CANADA/USA BORDER

REFERENCE(S)

1. KILLER WHALE CRITICAL HABITAT WAS DIGITIZED FROM THE RECOVERY STRATEGY FOR THE NORTHERN AND SOUTHERN RESIDENT KILLER WHALES IN CANADA, DFO2018A.
2. INTERIM SANCTUARY ZONES DIGITIZED FROM DFO2019A.
3. SOUTHERN RESIDENT KILLER WHALE 400M APPROACH DISTANCE DIGITIZED FROM DFO2020.
4. IMAGERY SOURCE ESRI, NRCAN, GEOBASE, AND THE GIS USER COMMUNITY. COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT
DEPARTMENT OF NATIONAL DEFENCE (DND)

PROJECT
EVALUATION OF UNDERWATER AND IN-AIR ACOUSTIC IMPACTS ON MARINE MAMMALS FROM SMALL ARMS MUNITIONS IN OPAREA WH

TITLE
SENSITIVE SRKW AREAS NEAR MARPAC OPAREA WH

CONSULTANT
GOLDER

YYYY-MM-DD	2020-11-19
DESIGNED	KZ
PREPARED	JP
REVIEWED	KG
APPROVED	BW

PROJECT NO.	PHASE	REV.	FIGURE
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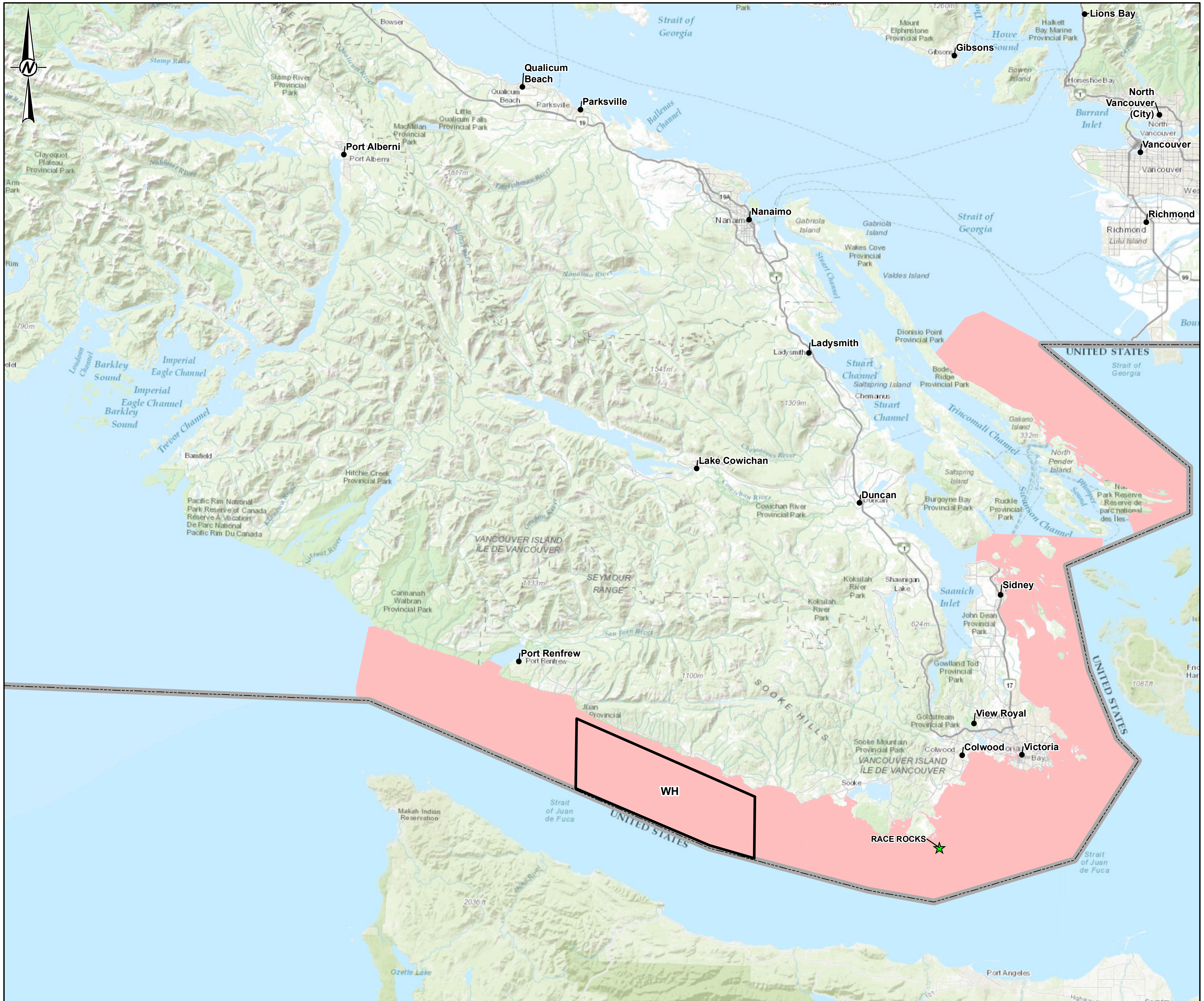

LEGEND

- CANADIAN SEA RANGE
- POPULATED PLACE
- RACE ROCKS
- IMPORTANT AREA FOR HARBOUR PORPOISE
- CANADA/USA BORDER

0 12,000 24,000

1:600,000 METRES

REFERENCE(S)

1. IMPORTANT AREA FOR THE HARBOUR PORPOISEOBTAINED FROM FISHERIES AND OCEANS CANADA. HARBOUR PORPOISE DATA DOWNLOADED ON SEPTEMBER 6, 2012.
2. IMAGERY SOURCE ESRI, NRCAN, GEOBASE, AND THE GIS USER COMMUNITY. COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT

DEPARTMENT OF NATIONAL DEFENCE (DND)

PROJECT

EVALUATION OF UNDERWATER AND IN-AIR ACOUSTIC IMPACTS ON MARINE MAMMALS FROM SMALL ARMS MUNITIONS IN OPAREA WH

TITLE

SENSITIVE HARBOUR PORPOISE AREAS NEAR MARPAC OPAREA WH

CONSULTANT

GOLDER

YYYY-MM-DD	2020-11-19
DESIGNED	KZ
PREPARED	JP
REVIEWED	KG
APPROVED	BW

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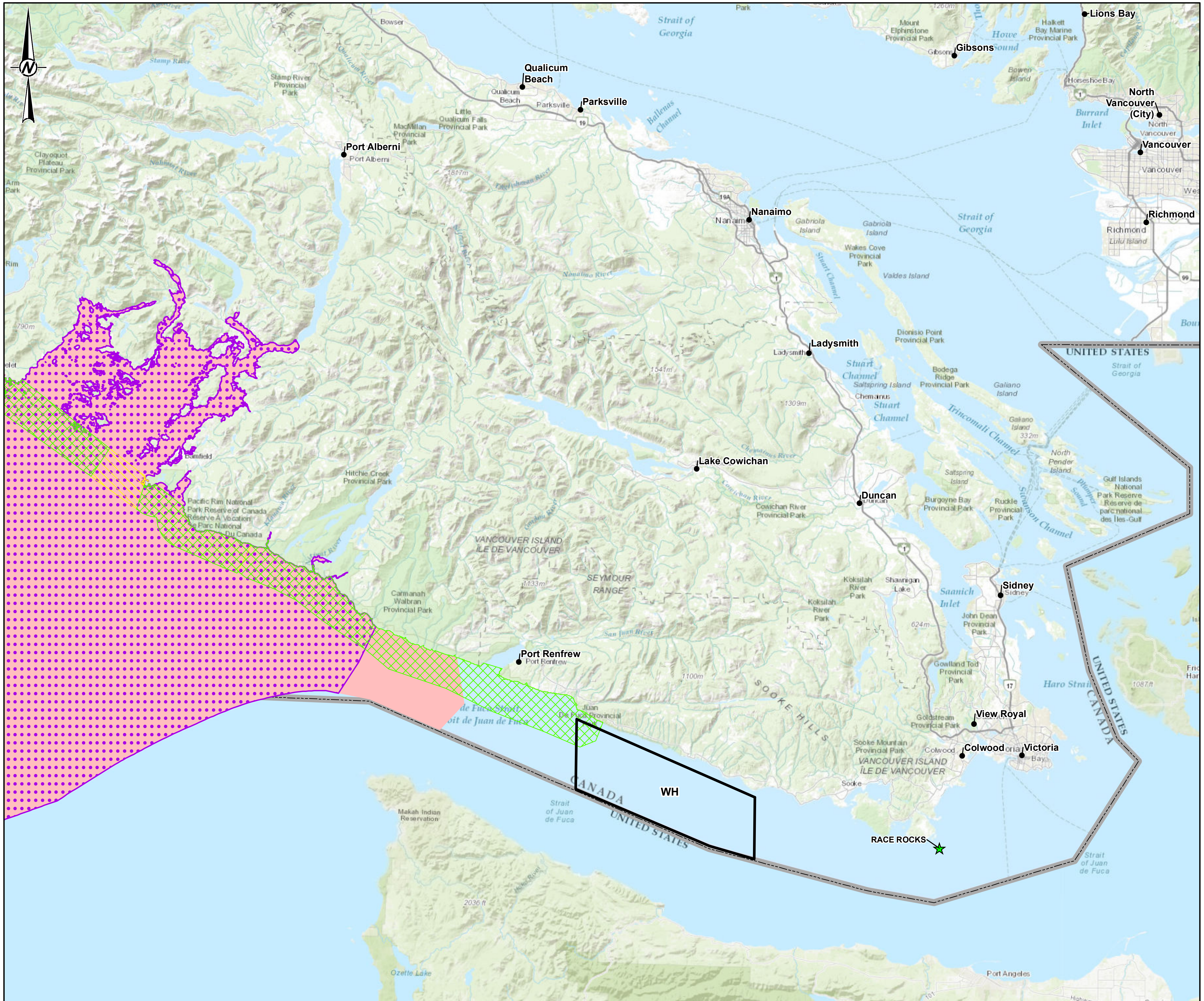

LEGEND

- CANADIAN SEA RANGE
- POPULATED PLACE
- RACE ROCKS
- IMPORTANT AREA FOR GREY WHALE FORAGING
- IMPORTANT AREA FOR GREY WHALE MIGRATION
- PREVIOUSLY PROTECTED CRITICAL HABITAT FOR HUMPBACK WHALE
- IMPORTANT AREA FOR HUMPBACK WHALE (HIGH CONCENTRATION FEEDING AREA)
- CANADA/USA BORDER

0 12,000 24,000

1:600,000 METRES

REFERENCE(S)

1. IMPORTANT AREAS FOR GREY WHALES OBTAINED FROM FISHERIES AND OCEANS CANADA. DATA DOWNLOADED ON SEPTEMBER 6, 2012.
2. IMPORTANT AREA FOR HUMPBACK WHALES OBTAINED FROM FISHERIES AND OCEANS CANADA. DATA DOWNLOADED ON SEPTEMBER 6, 2012.
3. HUMPBACK WHALE CRITICAL HABITAT WAS DIGITIZED FROM THE RECOVERY STRATEGY FOR THE NORTH PACIFIC HUMPBACK WHALE IN CANADA, DFO 2013.
4. HUMPBACK WHALE HAS BEEN DOWN-LISTED TO A SPECIES OF SPECIAL CONCERN. ITS CRITICAL HABITAT IS NO LONGER PROTECTED UNDER SARA.
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COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT
DEPARTMENT OF NATIONAL DEFENCE (DND)

PROJECT
EVALUATION OF UNDERWATER AND IN-AIR ACOUSTIC IMPACTS ON MARINE MAMMALS FROM SMALL ARMS MUNITIONS IN OPAREA WH

TITLE
SENSITIVE HUMPBACK WHALE AND GREY WHALE AREAS NEAR MARPAC OPAREA WH

CONSULTANT
GOLDER

YYYY-MM-DD	2020-11-19
DESIGNED	KZ
PREPARED	JP
REVIEWED	KG
APPROVED	BW

PROJECT NO.	PHASE	REV.	FIGURE
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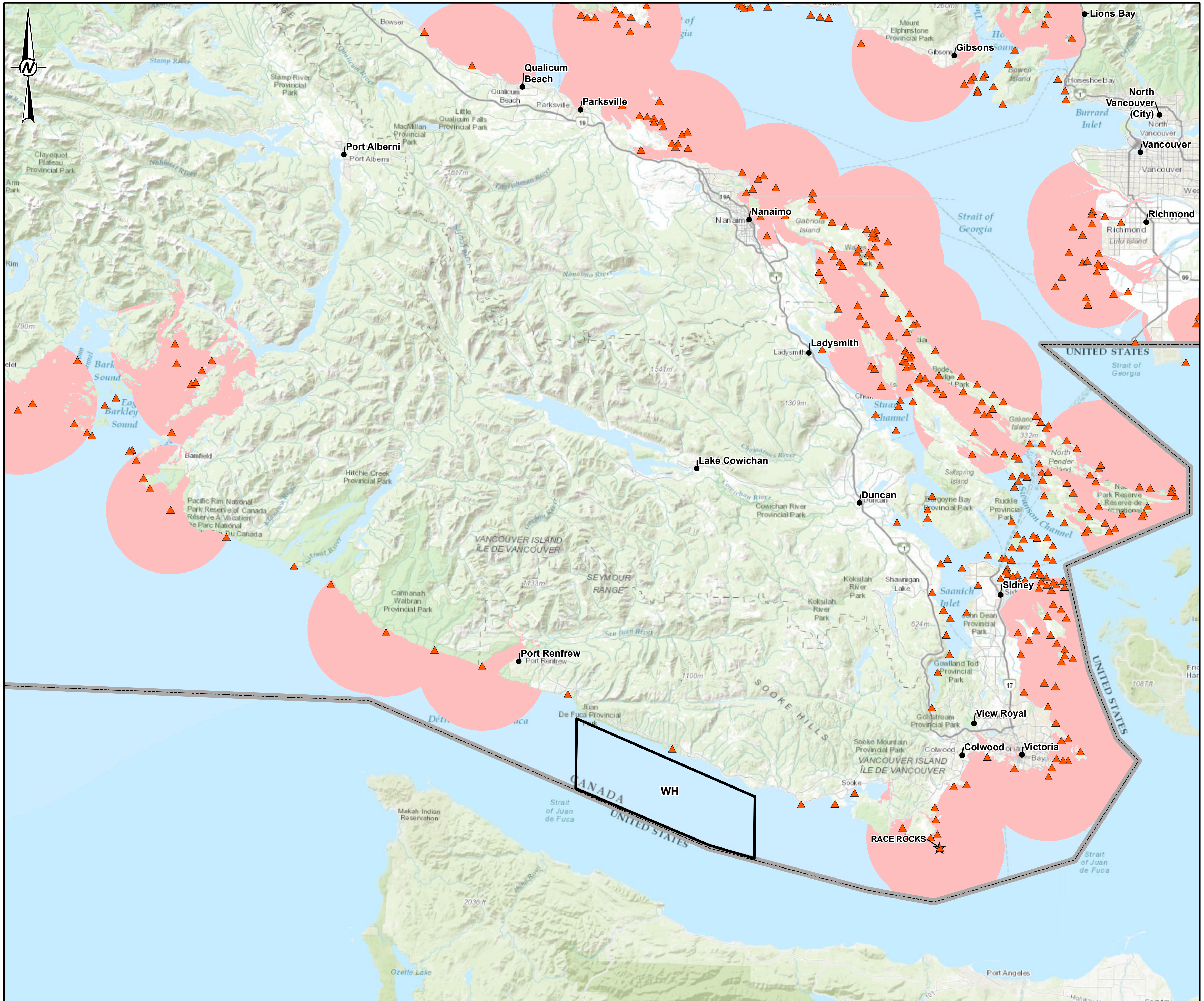

LEGEND

- CANADIAN SEA RANGE
- POPULATED PLACE
- RACE ROCKS
- HARBOUR SEAL HAUL OUT
- IMPORTANT AREA FOR HARBOUR SEALS
- CANADA/USA BORDER

0 12,000 24,000

1:600,000 METRES

REFERENCE(S)

1. IMPORTANT AREA FOR THE HARBOUR SEALS AND HARBOUR SEAL HAUL OUTS OBTAINED FROM FISHERIES AND OCEANS CANADA. HARBOUR PORPOISE DATA DOWNLOADED ON SEPTEMBER 6, 2012.
2. IMAGERY SOURCE ESRI, NRCAN, GEOBASE, AND THE GIS USER COMMUNITY. COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT
DEPARTMENT OF NATIONAL DEFENCE (DND)

PROJECT
EVALUATION OF UNDERWATER AND IN-AIR ACOUSTIC IMPACTS ON MARINE MAMMALS FROM SMALL ARMS MUNITIONS IN OPAREA WH

TITLE
SENSITIVE HARBOUR SEAL AREAS NEAR MARPAC OPAREA WH

CONSULTANT

GOLDER

YYYY-MM-DD	2020-11-19
DESIGNED	KZ
PREPARED	JP
REVIEWED	KG
APPROVED	BW

PROJECT NO.	PHASE	REV.	FIGURE
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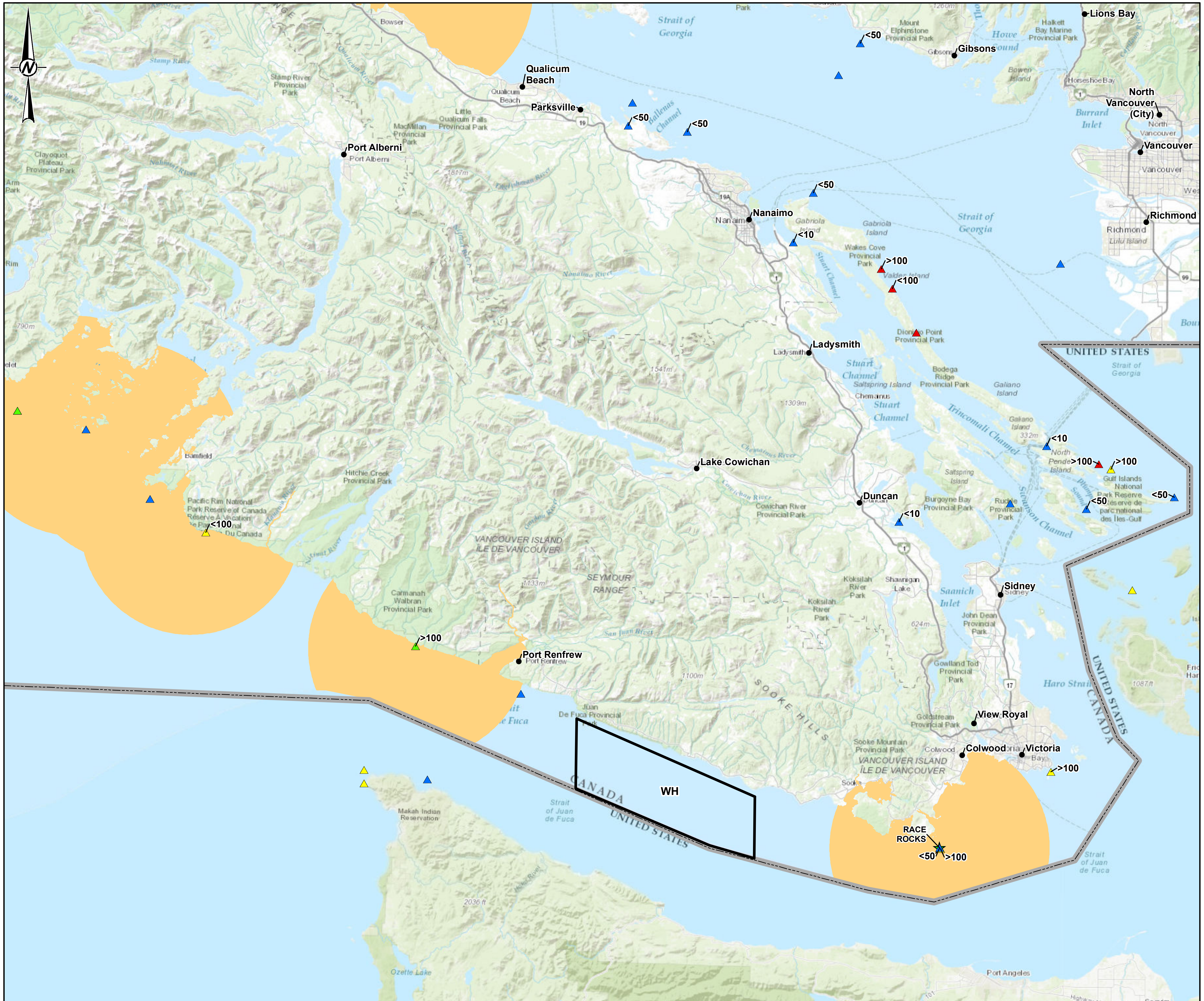

LEGEND

- CANADIAN SEA RANGE
- POPULATED PLACE
- RACE ROCKS
- STELLER SEA LION WINTER HAUL OUT
- STELLER SEA LION YEAR-ROUND HAUL OUT
- STELLER SEA LION HAUL OUT UNKNOWN TIME OF YEAR
- STELLER SEA LION MAJOR WINTER HAUL OUT
- IMPORTANT AREA FOR STELLER SEA LION
- CANADA/USA BORDER

0 12,000 24,000
1:600,000 METRES

REFERENCE(S)

1. IMPORTANT AREAS FOR STELLER SEA LIONS OBTAINED FROM FISHERIES AND OCEANS CANADA. DATA DOWNLOADED ON OCTOBER 26, 2018.
2. STELLER SEA LION HAUL OUTS WITH COUNTS: OLESIUK 2018, JEFFRIES ET AL. 2000, PORT OF VANCOUVER 2019A. RECENT TRENDS IN ABUNDANCE OF STELLER SEA LIONS (EUMETOPIAS JUBATUS) IN BRITISH COLUMBIA. DFO CANADA SCIENCE ADVISORY SECRETARIAT RESEARCH DOCUMENT 2018/006. V + 67 P. JEFFRIES, SJ., PJ GEARIN, HR HUBER, DL SAUL, AND DA PRUETT. 2000. ATLAS OF SEAL AND SEA LION HAULOUT SITES IN WASHINGTON. WASHINGTON DEPARTMENT OF FISH AND WILDLIFE, WILDLIFE SCIENCE DIVISION. WASHINGTON. PP. 150. AND ROBERTS BANK TERMINAL 2 MARINE STUDY AREA ASSESSMENT FIGURE 8.2-3, PITCHER ET AL. 2007, JEFFRIES.
3. IMAGERY SOURCE ESRI, NRCAN, GEOBASE, AND THE GIS USER COMMUNITY. COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT
DEPARTMENT OF NATIONAL DEFENCE (DND)

PROJECT
EVALUATION OF UNDERWATER AND IN-AIR ACOUSTIC IMPACTS ON MARINE MAMMALS FROM SMALL ARMS MUNITIONS IN OPAREA WH

TITLE
SENSITIVE STELLER SEA LION AREAS NEAR MARPAC OPAREA WH

CONSULTANT

GOLDER

YYYY-MM-DD	2020-11-19
DESIGNED	KZ
PREPARED	JP
REVIEWED	KG
APPROVED	BW

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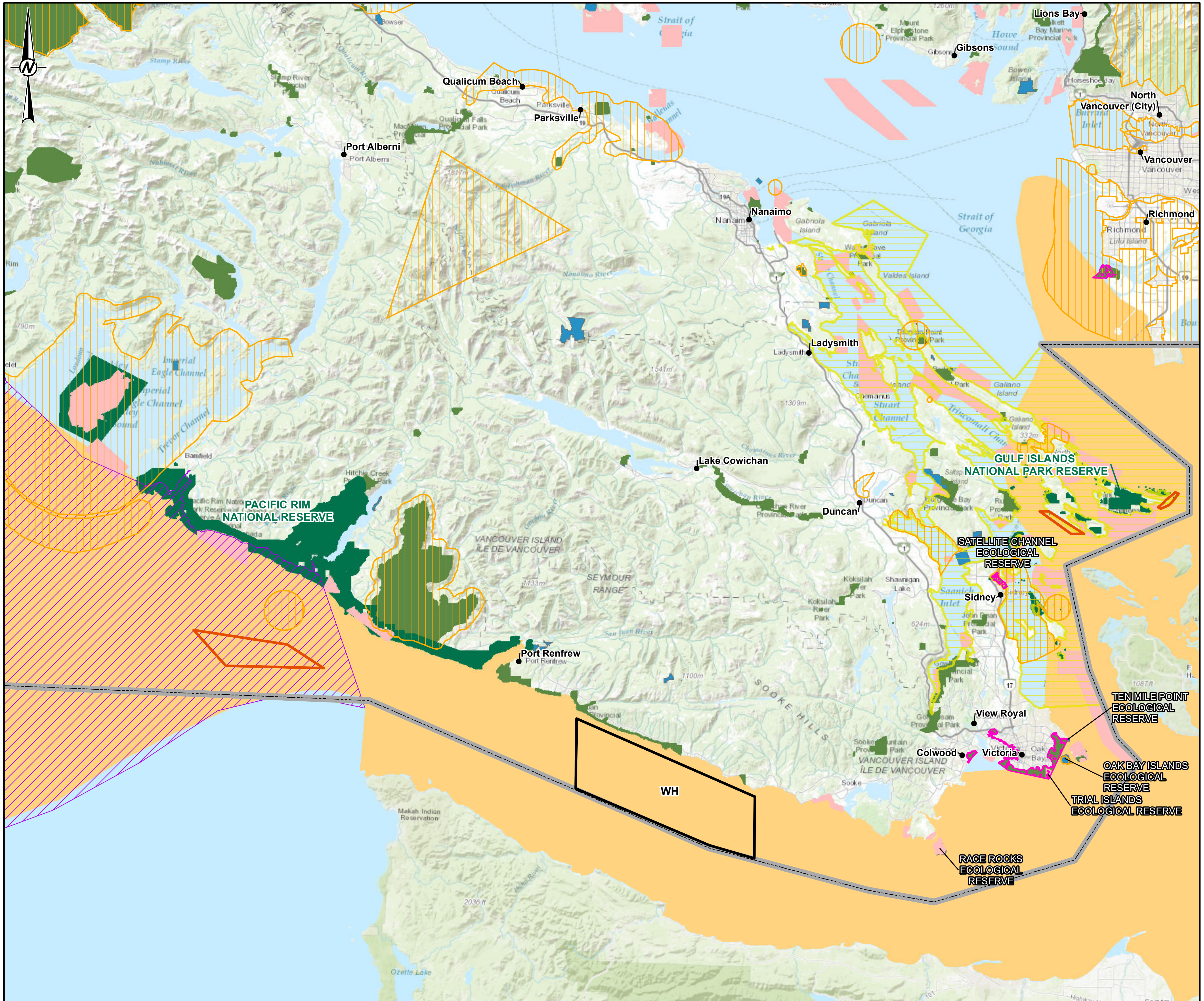

LEGEND

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- POPULATED PLACE
- PROVINCIAL ECOLOGICAL RESERVE
- SRKW CRITICAL HABITAT
- SRKW AND NRKW CRITICAL HABITAT
- INTERIM SANCTUARY ZONE
- ROCKFISH CONSERVATION AREA
- NATIONAL PARK
- PROVINCIAL PARK, PROTECTED AREA OR CONSERVANCY
- ECOLOGICAL RESERVE
- PROPOSED SOUTHERN STRAIT OF GEORGIA NATIONAL MARINE CONSERVATION AREA (NMCA)
- MIGRATORY BIRD SANCTUARY
- IMPORTANT BIRD AREA
- CANADA/USA BORDER

0 12,000 24,000

1:600,000 METRES

REFERENCE(S)

1. KILLER WHALE CRITICAL HABITAT WAS DIGITIZED FROM THE RECOVERY STRATEGY FOR THE NORTHERN AND SOUTHERN RESIDENT KILLER WHALES IN CANADA, DFO 2018.
2. INTERIM SANCTUARY ZONES DIGITIZED FROM DFO (2019).
3. PROVINCIAL ECOLOGICAL RESERVE, PARK, PROTECTED AREA OR CONSERVANCIES, AND NATIONAL PARK DATA OBTAINED FROM THE MINISTRY OF LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT.
4. IMAGERY SOURCE ESRI, NRCAN, GEOBASE, AND THE GIS USER COMMUNITY.
COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT
DEPARTMENT OF NATIONAL DEFENCE (DND)

PROJECT
EVALUATION OF UNDERWATER AND IN-AIR ACOUSTIC IMPACTS ON MARINE MAMMALS FROM SMALL ARMS MUNITIONS IN OPAREA WH

TITLE
PROTECTED AREAS NEAR MARPAC OPAREA WH

CONSULTANT
GOLDER

YYYY-MM-DD	2020-11-19
DESIGNED	KZ
PREPARED	JP
REVIEWED	KG
APPROVED	BW

PROJECT NO.	PHASE	REV.	FIGURE
20141332	2000/2005	0	7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25mm

ANNEX B

JASCO Report - Small Arms Munitions at OPAREA Whiskey Hotel

Small Arms Munitions at OPAREA Whiskey Hotel

In-air and Underwater Noise Modelling

Submitted to:

Katelyn Zottenberg
Golder Associates Ltd.
Task order: 18106015-JASCO-2019-003

Authors:

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4 November 2020

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Document 01871
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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Contents

Figures

Tables

Executive Summary

The Canadian Department of National Defence requested an effect assessment of underwater and in-air noise generated by small-arms military training exercises on board a vessel at the MARPAC OPAREA Whiskey Hotel (WH) training area, located approximately 1 km south of the Vancouver Island coastline. JASCO Applied Sciences conducted the numerical modelling for this assessment, with model inputs selected to conservatively assess the extent of sound propagation. Five weapons of various caliber were modelled individually, in addition to three aggregate scenarios which include (non-simultaneous) firing of two different weapons within a 24 hour period. The modelling methodology considered:

- Each weapon's calibre, spectral properties and directionality of the noise generated by muzzle blast upon shooting, azimuth, angle of declination, and height above the water.
- The impact of environmental parameters, such as water sound speed profile, bathymetry, seabed geoacoustics, and atmospheric conditions.

The models were used to estimate sound levels over a large area around a modelling location. Representative scenarios with a conservative maximum number of shots per day were simulated to calculate per-shot and cumulative sound energy that could be emitted in a single day (denoted SEL_{24h}). From these estimated sound levels, distances to thresholds for temporary threshold shift (TTS), permanent threshold shift (PTS), and behavioural impact were computed for in-air and underwater propagation. Sound propagation was strongly driven by the weapon directionality, with sound levels along the line-of-shot ~14 dB higher than in the opposite direction. In-air propagation reached longer distances to thresholds compared to underwater propagation, due to the high transmission loss (~30 dB) that the sound experiences when coupling from the air into the water.

The largest spatial extent for behavioural effects zones was for pinnipeds in air, at a maximum distance of 9.3 km for the MK38 machine gun and 15.6 km for the aggregate scenario that includes the MK38 and the M2 machine guns. Impact zones defined by the threshold for temporary hearing threshold shift (TTS) for the phocid carnivores in air hearing group covered the largest spatial extents compared to the other species considered, with a maximum distance of 219 m.

For underwater sound propagation, the longest distances to SEL_{24h} TTS thresholds for underwater propagation (NMFS 2018) corresponded to the high-frequency cetaceans, with R_{max} = 20 m for the M2 and R_{max} = 28 m for the aggregate scenario with the M2 and the MK38. The underwater behavioural threshold (160 dB re 1 µPa) was never exceeded.

1. Introduction

JASCO Applied Sciences (JASCO) conducted numerical acoustic propagation modelling for in-air sound and underwater sound generated by five small calibre weapons, commonly used during military training exercises in the MARPAC OPAREA Whiskey Hotel (WH) training area. Of particular concern is the fact that the OPAREA WH is located in the Southern Resident Killer Whale (SRKW) critical habitat. The modelling scope of this study included computing sound footprints for the cumulative effect of multiple firing of the following weapons: general service pistol, C8 automatic rifle, M240 machine gun, Browning M2 heavy machine gun, and MK38 machine gun. The modelling was conducted to estimate distances from the small calibre gunfire at sea to marine mammal behavioural, temporary hearing threshold shift, and permanent hearing threshold shift sound level thresholds. The results in this report are intended to inform decision makers regarding the use of the OPAREA WH and for establishing Mitigation Avoidance Zones (MAZ) during training exercises.

The OPAREA WH training area is used by the United States Coast Guard (USCG) and the Royal Canadian Navy (RCN) for military exercises. Training sessions involve warning shots (bursts of 3 to 5 shots) and disabling fire (bursts of 9 to 15 shots) using automatic weapons (M240 machine gun, Browning M2 heavy machine gun, and MK38 machine gun) shot from various types of vessels towards targets at the sea surface. Training also includes Naval Boarding Party (NBP) operations with the general service 9 mm Sig Sauer pistol and the C8 assault rifle.

Section 2 details the noise effects criteria that were applied for this analysis including sound thresholds for behavioural disturbance and noise-induced hearing damage for several marine species. Section 3 describes the methods applied for this analysis, including a description of the noise-generating mechanism from shooting small weapons, the weapon parameters used for modelling, the modelling location and shooting configuration, and the sound propagation modelling approach for both in-air and underwater propagation. Section 4 presents results of the modelling study including the maximum modelled distances to sound pressure level (SPL) thresholds for behavioural response (for underwater sounds) and sound exposure level (SEL) thresholds for temporary and permanent noise induced hearing impacts (for both in-air and underwater sounds) for each weapon. Maps showing the sound footprints are also provided in this section. Section 5 provides a discussion of the results and the conclusions of the analyses. Appendix A explains the metrics used to characterize underwater acoustic fields. Additional details about the impact criteria considered are in Appendix B. Appendix C gives a detailed description of the sound propagation modelling methodology and of the environmental parameters that were input to the models. Appendix D is a copy of the Scenario Matrix that summarizes the DND-approved model assumptions that were applied for this work.

1.1. Study Overview

The OPAREA WH is a 30 × 11 km area, with its northern bound running parallel to shore approximately 1 km south of the Vancouver Island coastline (Figure 1). In accordance with (IAW) naval orders (MARPACORD 3350-1) all surface vessel firings are restricted to parallel firing to the shore, and all operations must be conducted outside a three mile radius of Point-No-Point. When conducting surface firing against a surface towed target, the tug/target is to be stationed no further east than a line drawn 180 degrees true from San Simon Point.

Military exercises can occur anytime during the year. For this reason, atmospheric and environmental parameters that yield the most conservative results (i.e., the longest in-air and underwater acoustic propagation) were selected for this analysis.

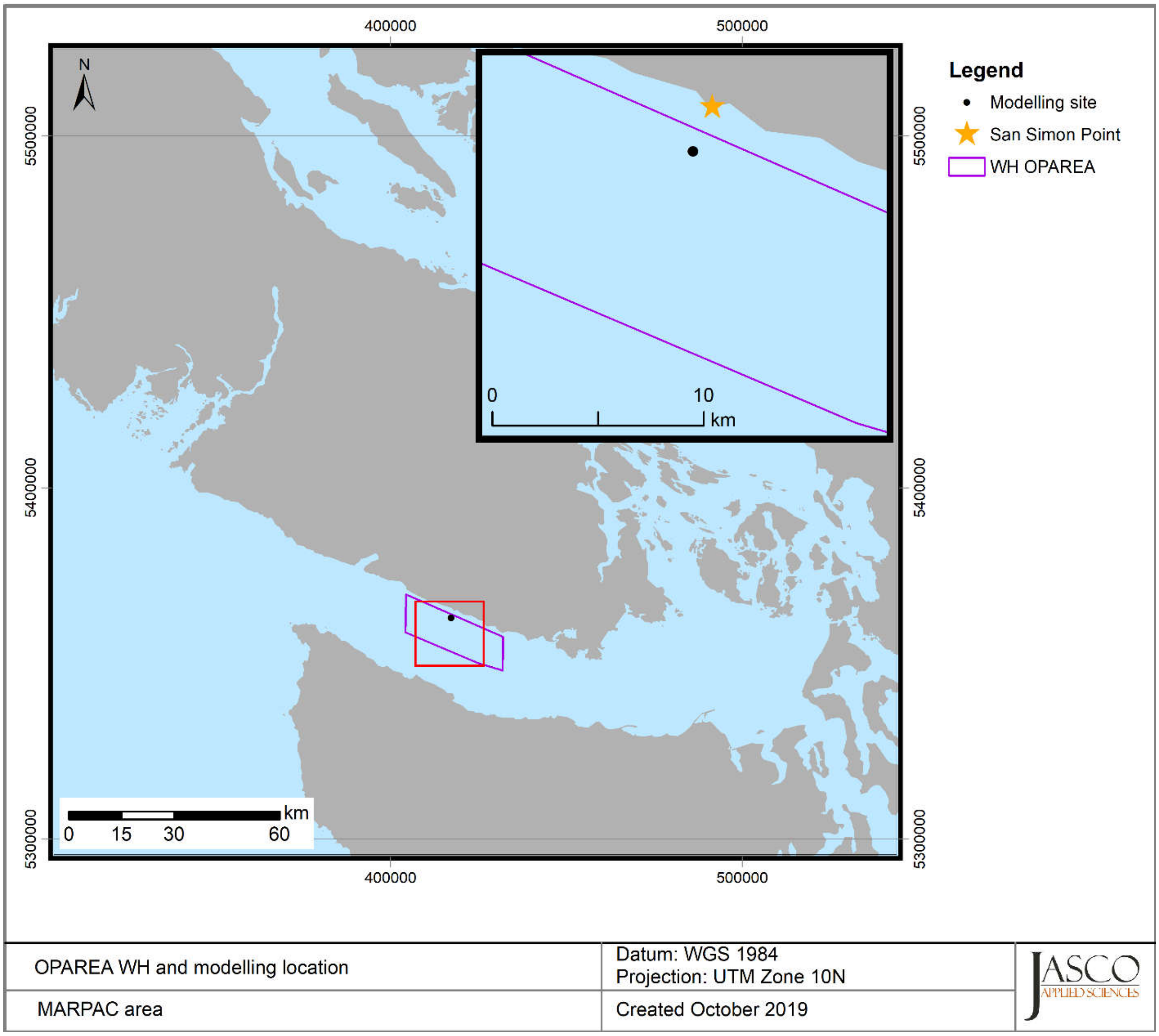

Figure 1. Map showing the location of OPAREA WH, as well as the location selected for acoustic modelling of the shooting of small calibre weapons.

The acoustic footprint of each weapon was assessed individually, because some training sessions would only include one type of weapon. In addition, aggregate scenarios that involve non-simultaneous use of two weapons within the same 24 h period were considered (Table 1). Modelling was conducted assuming shooting toward northwest direction, at an azimuth of 295°.

Table 1. Small arms training scenarios at OPAREA WH considered in this study.

Scenario	Weapon	Latitude	Longitude	UTM zone	Easting (m)	Northing (m)	Shooting azimuth	Water depth (m)
1	General service pistol	48° 24.78471' N	124° 7.13260' W	10	417206	5362819	295°	45
2	C8 automatic rifle							
3	M240 machine gun							
4	Browning M2 heavy machine gun							
5	MK38 machine gun							
6	M2 and M240 machine guns							
7	M2 and MK38 machine guns							
8	General service pistol and C8 automatic rifle							

2. Noise Effects Criteria

Noise can affect marine fauna in several ways, including eliciting behavioural response or causing temporary or permanent hearing threshold shifts. For this study, JASCO modelled in-air and underwater sound propagation from five small calibre weapons and determined distances to thresholds for impacts to marine mammals. Two sets of criteria were considered: those that define thresholds for onset of noise-induced hearing damage (both temporary threshold shift (TTS) and permanent threshold shift (PTS)), and those that define thresholds for behavioural disturbance as probabilities of a behavioural response at a given received sound level.

For in-air noise, results are presented in terms of the following noise criteria:

- Frequency-weighted sound exposure level (SEL; $L_{E,24h}$) for TTS and PTS for phocid carnivores in air (PCA) and other marine carnivores in air (OCA), based on Southall et al. (2019).
- Thresholds for PTS of pinnipeds in air, based on Southall et al. (2007).
- Behavioural thresholds for pinnipeds in air, based on Southall et al. (2007).

For underwater noise, results are presented in terms of the following criteria:

- Frequency-weighted sound exposure level (SEL; $L_{E,24h}$) for TTS and PTS of marine mammals based on NMFS (2018).
-
- NMFS (2013) 160 dB re 1 µPa SPL threshold for behavioural response for impulsive sounds for all marine mammal species.

Appendix B contains a more detailed explanation of these criteria.

2.1. In-air Noise Criteria for Pinnipeds

Table 2 lists the PTS thresholds for pinnipeds in air (Southall et al. 2007), Table 3 lists the TTS and PTS thresholds for phocid carnivores in air (PCA) and other marine carnivores in air (OCA) (Southall et al. (2019)), and Table 4 lists the pinniped behavioural impact thresholds (Southall et al. 2007).

Table 2. Thresholds for onset of permanent threshold shift (PTS) for pinnipeds in air (Southall et al. 2007), for impulsive sounds.

Sound level	PTS threshold
Peak sound pressure level*	149 dB re 20 µPa
Sound exposure level**	144 dB re 20 µPa^2·s

* Threshold value is unweighted (flat; see Appendix B).
** Threshold value is M_{pa} weighted (see Appendix B).

Table 3. Thresholds for onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) for phocid carnivores in air (PCA) and other marine carnivores in air (OCA) from Southall et al. (2019), for impulsive sounds.

Functional hearing group or species	Weighted SEL_{24h} (dB re 20 µPa²·s)		Peak sound pressure level (dB re 20 µPa)	
	PTS threshold	TTS threshold	PTS threshold	TTS threshold
PCA	138†	123†	144	138
OCA	161‡	146‡	167	161

† Threshold values are PCA-weighted (see Appendix B).
‡ Threshold values are OCA-weighted (see Appendix B).

Table 4. Acoustic criteria used for assessing behavioral impacts in pinnipeds in air (Southall et al. 2007), for impulsive sounds.

Sound level	Behavioural threshold
Peak sound pressure level*	109 dB re 20 µPa
Sound exposure level**	100 dB re 20 µPa²·s

* Threshold value is unweighted (flat; see Appendix B).
** Threshold value is M_{pa} weighted (see Appendix B).

2.2. Underwater Noise Criteria

Table 5 lists the underwater sound criteria for PTS and TTS (NMFS 2018), which are also used by the US Navy. Peak sound pressure level (PK) thresholds (NMFS 2018) were not reached by any of the sources, and therefore are not presented herein.

Table 5. Thresholds for temporary threshold shift (TTS) and permanent threshold shift (PTS) for marine mammals underwater (NMFS 2018), for impulsive sounds.

Functional hearing group or species	Weighted SEL_{24h} (dB re 1 µPa²·s)	
	PTS threshold	TTS threshold
LF cetaceans	183	168
MF cetaceans	185	170
HF cetaceans	155	140
Phocid pinnipeds in water	185	170
Otariid pinnipeds in underwater	203	188

We assessed behavioural disturbance potential using the NMFS (2013) 160 dB re 1 µPa SPL threshold for impulsive sounds for all marine mammal species

3. Methods

This section describes the methods used to model in-air and underwater sound footprints for each weapon.

3.1. Noise from Small Calibre Weapons

There are three noise-generating mechanisms associated with firing a gun (Pater and Shea 1981, Lee et al. 1997): the muzzle blast caused by the sudden release of propellant gases, noise generated as the bullet enters the water, and the shockwave from the supersonic bullet that is released into the air.

Muzzle blast noise propagates in all directions from the gun barrel, according to a radiation pattern that exhibits louder sounds along the line-of-fire and quieter sounds behind the gun. Experimental data suggests a reduction of approximately 14 dB for noise levels measured behind the weapon, compared to those measured in front (Pater and Shea 1981). Typical measurements of muzzle blast show the direct arrival (5–10 ms duration) followed by a ground (or water surface) bounce (Flamme et al. 2011, Nakashima and Farinaccio 2015). Spectral analysis shows that the dominant frequencies for muzzle noise are 150 to 300 Hz. Modelling in this investigation focused on muzzle blast noise, due to its impact in all directions from the point of shooting.

Noise due to a bullet entering the water can be generated by the impact itself, the oscillations of the water after the impact, and cavitation noise from the collapsing bubbles formed behind the bullet (Urick and Kuperman 1984, Lee et al. 1997). This noise source is not considered in this study because it is atypical, given that most of the shooting is aimed at a floating target.

Shockwave noise propagates along the surface of a cone, trailing the bullet. Its wavefront advances at an angle of $\delta = 90 - \alpha_{MC}$ degrees with respect to the line-of-fire (Peterson and Schomer 1994), where $\alpha_{MC} = \sin^{-1}(c_{air}/v_p)$, known as the Mach angle, is a function of the speed of sound in the air c_{air}, and the muzzle velocity v_p. Shockwave noise also depends on the characteristics of the bullet and the distance traveled from the line-of-fire to a potential listener, and it is characterized by its short duration (~300 μs) and dominant spectral peaks around 2000 to 4000 Hz. The potential impact of this type of noise to underwater listeners is mostly limited to a narrow swath along the line-of-fire, with the width determined by the weapon's height above the water, the critical angle of the air-to-water interface, and the declination angle of the weapon. Due to its reduced area of impact and the unlikely possibility of marine mammals remaining near the line-of-fire, bow shockwave noise is not considered in this investigation.

3.2. Characteristics of Weapon Sound Sources

Shooting exercises at OPAREA WH are performed from different vessels and involve different shooting sequences. Although the general service pistol and the C8 automatic rifle (Pt and C8, respectively; Table 6) are authorized for firing in OPAREA WH, their use in training sessions is unlikely and acoustic modelling of their impact is included in this work for completeness only. If used during training, shooting would occur at a height of 12.5–12.6 m above water, with declination angles of 11–28° (i.e., aiming at targets at a 65–24 m range from the vessel).

Training sessions with machine guns usually involve two types of firings: warning shots (bursts of 3 to 5 shots) and disabling fire (bursts of 9 to 15 shots). The exact combination of both types of firings in a given session depends on the training objective of the military units. For conservative modelling, USCG/RCN provided JASCO with the maximum number of shots per weapon expected per session (Table 6), which was used to compute the acoustic field required for cumulative metrics. Modelling was conducted to estimate the acoustic footprint of each individual gun, as well as two-gun combinations: M2/M240 and M2/MK38.

JASCO modelled the most conservative source height and declination angle for in-air propagation. The source levels used for in-air modelling (Figure 2) were obtained from JASCO's GUNSL model (Appendix C.2.2) and correspond to the smallest declination angle.

For underwater modelling, source levels at the largest declination angle result in the most conservative conditions, as the line-of-fire (which has the loudest levels) tends toward hitting the water at normal incidence. (Chapman and Ward 1990) reported that the transmission loss for underwater propagation due to an in-air point source is not sensitive to the source height above the water. The source levels for underwater propagation obtained from JASCO's GUNSL are shown in Figure 3 (note the reference pressure of 1 µPa). As a conservative measure, the source levels were extrapolated in frequency up to 20 kHz, using a measurement-based decay rate of 7.88 dB/decade (Murphy and Tubbs 2007).

Table 6. Specifications for the small-calibre weapons modelled in OPAREA WH.

Acronym	Calibre (mm)	Description	Muzzle velocity (m/s)	angle (º)	Height above water (m)	Maximum shots per day
Pt	9	General service pistol (9 mm Browning Hi-Power or Sig Sauer P225)	365	11−28	12.5−12.6	450
C8	5.56	C8, C7, or MK16A1 automatic rifles	840	11−28	12.5−12.6	1800
M240	7.62	M240 or C6 machine guns	853	0−15	1.5	1200
M2	12.7 (0.5 calibre)	Browning M2 heavy machine gun	887	0−20	10 or 3	1200
MK38	25	MK38 machine gun, mounted on USCG cutters and AOVP HDW Class vessels	1100	0−20	10	440

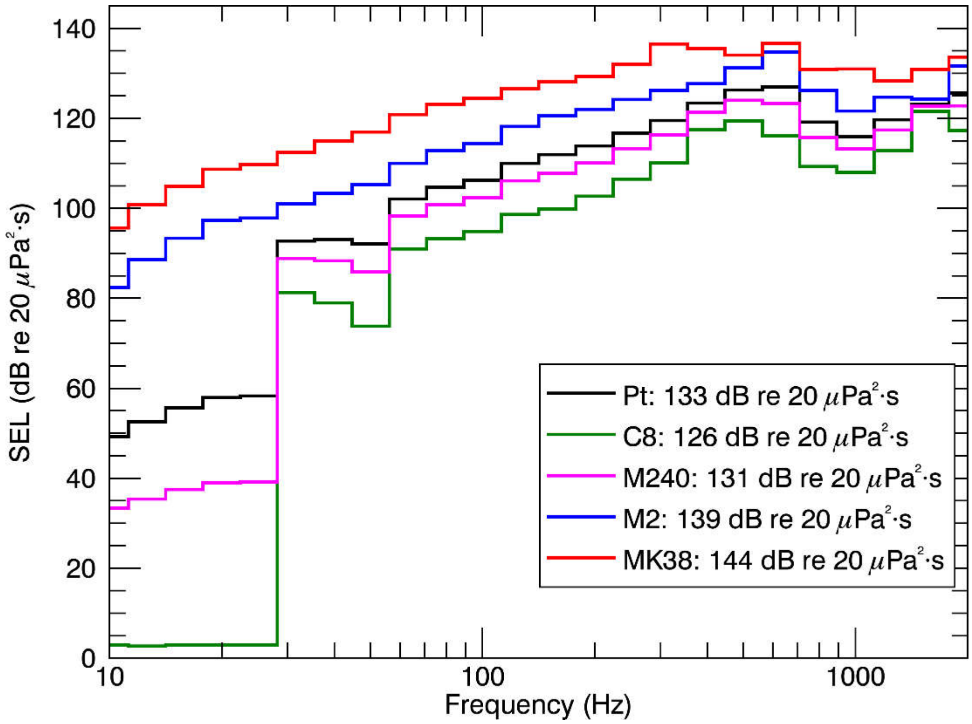

Figure 2. Frequency-dependent source levels used for in-air modelling, in 1/3-octave-bands. The broadband SEL source level per weapon is indicated in the legend.

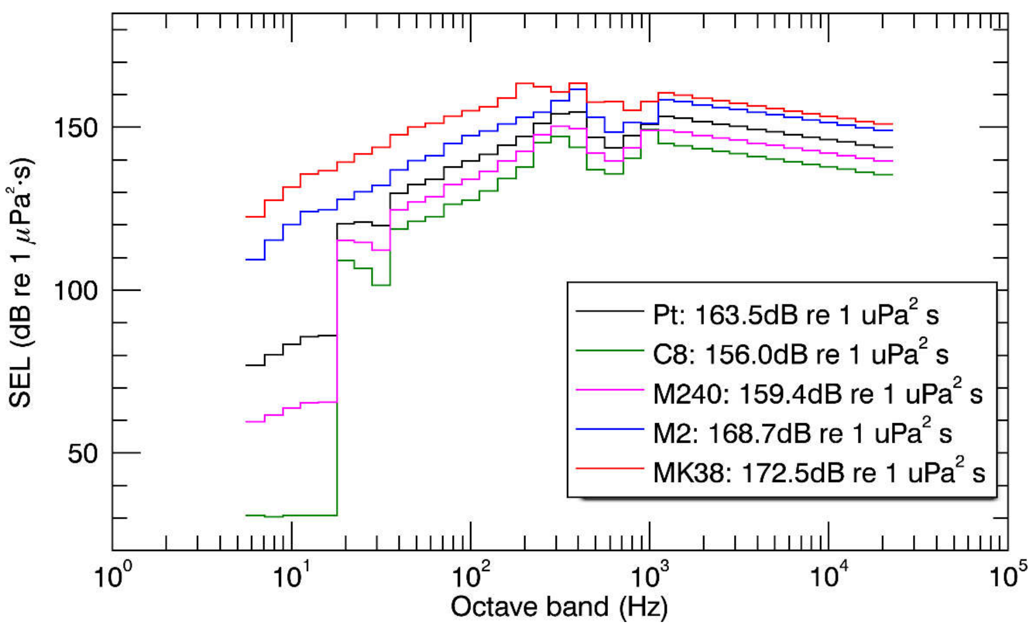

Figure 3. Frequency-dependent source levels used for underwater modelling, in 1/3-octave-bands. The broadband SEL source level per weapon is indicated in the legend.

3.3. Sound Propagation Modelling

The loss in acoustic level as sound propagates through air depends on atmospheric conditions, which determine the sound speed as a function of elevation above the water. Similar to underwater propagation, sound ducts forming in the atmosphere can trap sound, leading to propagation over long distances from the source. In this work, the following approaches were used for in-air acoustic propagation modelling:

- To estimate distances to thresholds of cumulative metrics, JASCO's Impulse Noise Propagation Model (INPM) was used to determine sound propagation above the sea level that could affect marine mammals with their head above the water's surface (Appendix C.2.1). Modelling was conducted assuming the animal's ears at a height of 20 cm above the water. INPM's Gun Firing Noise Source level (GUNSL) module (Appendix C.2.2) was used to obtain 1/3-octave-band levels for each weapon, based on the weapons calibre, azimuth, and declination angle. Conservative modelling was implemented by selecting the input parameters that yielded the longest in-air sound propagation, as follows:
  - The atmospheric profile for March provided the best path for sound propagation, in particular due to a refraction path that becomes evident at ~8 km range from the source (Appendix C.2.1).
  - For each weapon, the smallest declination angle provided the best path for sound propagation in-air.
  - For the M2, a 3 m weapon height was the most conservative. The Pt and C8 weapons were modelled at 12.53 m height.
  - It was assumed that no acoustic shielding was provided by the vessel at azimuths 90° to 270°, which results in conservative area and $R_{95\%}$ estimates. In the field, the vessel is likely to provide additional sound attenuation towards the back of the weapon.
- To estimate distances to PK thresholds, the empirical scaling model (Appendix C.3) from Fansler et al (1997) was applied to estimate PK levels above the water as a function of distance and azimuth from the line-of-fire. For conservative modelling, PK levels from Fansler were increased by 6 dB, to account for the wave reflected off the water surface, which would add almost perfectly in phase with the direct arrival (given the receiver height, only 20 cm above the water).

For underwater propagation, sound from the muzzle blast can reach a receiver through several paths (Figure 4): after refracting at the air-water interface (path A), after refracting and interacting with the seabed (path B), or through energy coupling via the ship's hull (path C). Due to the critical angle of the water, paths A and B are constrained to 13º beyond normal incidence to couple into the water. Any noise from the muzzle blast propagating at wider angles would reflect and propagate horizontally as an evanescent wave that decays rapidly with depth. How sound couples with the ship hull is strongly dependent on where the weapon is located on the ship. Studies aboard the *USS Cole* suggest that underwater sound generated this way is not dominant over muzzle blast noise, and it is unlikely to harm marine mammals (DoN 2011). Underwater sound levels were estimated by applying normal mode theory of air-to-water sound transmission in the ocean (Appendix C.1). Conservative selection of parameters for underwater propagation modelling included the following:

- The January sound speed profile was modelled because it exhibits the steepest surface duct among all months.
- For all weapons, 1/3-octave-band source levels were re-computed using the largest angle of declination. This maximized the acoustic energy that entered the water at angles below the air-to-water critical angle.
- Distances to thresholds for underwater sound propagation were estimated by finding the maximum level over all depths at any location in the modelling grid.

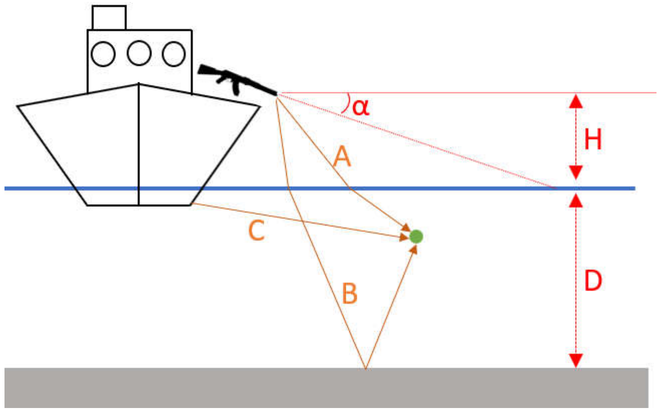

Figure 4. Paths for gun-generated noise propagating into the water: Rays A and B correspond to refracted and refracted-reflected paths, while Ray C represents coupling of the firing noise into the water through the vessel structure.

4. Results

Sound propagation modelling results using the most conservative input parameters are provided in the following formats:

- For pinnipeds in air, we provide tables of the distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS), tables of the distances to PK injury thresholds, tables of the distances to SEL_{24h} and PK behavioural response thresholds, and contour maps to SEL_{24h} thresholds for temporary threshold shift (TTS) and injury.
- For marine mammals underwater, we provide tables of the distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) and contour maps to SEL_{24h} thresholds for temporary threshold shift (TTS).

PK thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater were not reached by any weapon even at the shortest distances, neither was the behavioural disturbance threshold of 160 dB re 1 μPa.

4.1. Ranges for Injury and Hearing Sensitivity Changes

4.1.1. Distances to In-air Thresholds

Tables 7 to 13 present distances to SEL_{24h} thresholds for PTS and TTS for pinnipeds in air (Southall et al. 2019), and the corresponding maps with contours to SEL_{24h} TTS thresholds are presented in Figures 5 to 11. Distances to PK thresholds for PTS and TTS (Southall et al. 2019) are presented in Table 15. Distances to thresholds for PTS (PK and SEL_{24h}) based on Southall et al. (2007) are presented in Tables 16 to 22.

Table 7. *Pt*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	<10	<10	<314	123	<10	<10	<314
Other marine carnivores in air	161	—	—	—	146	—	—	—

A dash indicates the threshold was not reached.

Table 8. *C8*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	<10	<10	<314	123	<10	<10	<314
Other marine carnivores in air	161	—	—	—	146	—	—	—

A dash indicates the threshold was not reached.

Table 9. *M240*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	16	14	314	123	72	66	6648
Other marine carnivores in air	161	—	—	—	146	—	—	—

A dash indicates the threshold was not reached.

Table 10. *M2*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	36	33	1257	123	147	134	27759
Other marine carnivores in air	161	—	—	—	146	<10	<10	<314

A dash indicates the threshold was not reached.

Table 11. *MK38*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	**PTS threshold distances and ensonified areas**				**TTS threshold distances and ensonified areas**			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	<10	<10	<314	123	169	155	30791
Other marine carnivores in air	161	—	—	—	146	<10	<10	<314

A dash indicates the threshold was not reached.

Table 12. *M2 and M240 (aggregate)*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	**PTS threshold distances and ensonified areas**				**TTS threshold distances and ensonified areas**			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	39	36	1521	123	154	140	30791
Other marine carnivores in air	161	—	—	—	146	11	10	154

A dash indicates the threshold was not reached.

Table 13. *M2 and MK38 (aggregate)*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	**PTS threshold distances and ensonified areas**				**TTS threshold distances and ensonified areas**			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	42	39	1662	123	207	189	53093
Other marine carnivores in air	161	—	—	—	146	<10	<10	<314

A dash indicates the threshold was not reached.

Table 14. *C8 and Pt (aggregate)*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 20 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
Phocid carnivores in air	138	<10	<10	<314	123	96	90	5542
Other marine carnivores in air	161	—	—	—	146	—	—	—

A dash indicates the threshold was not reached.

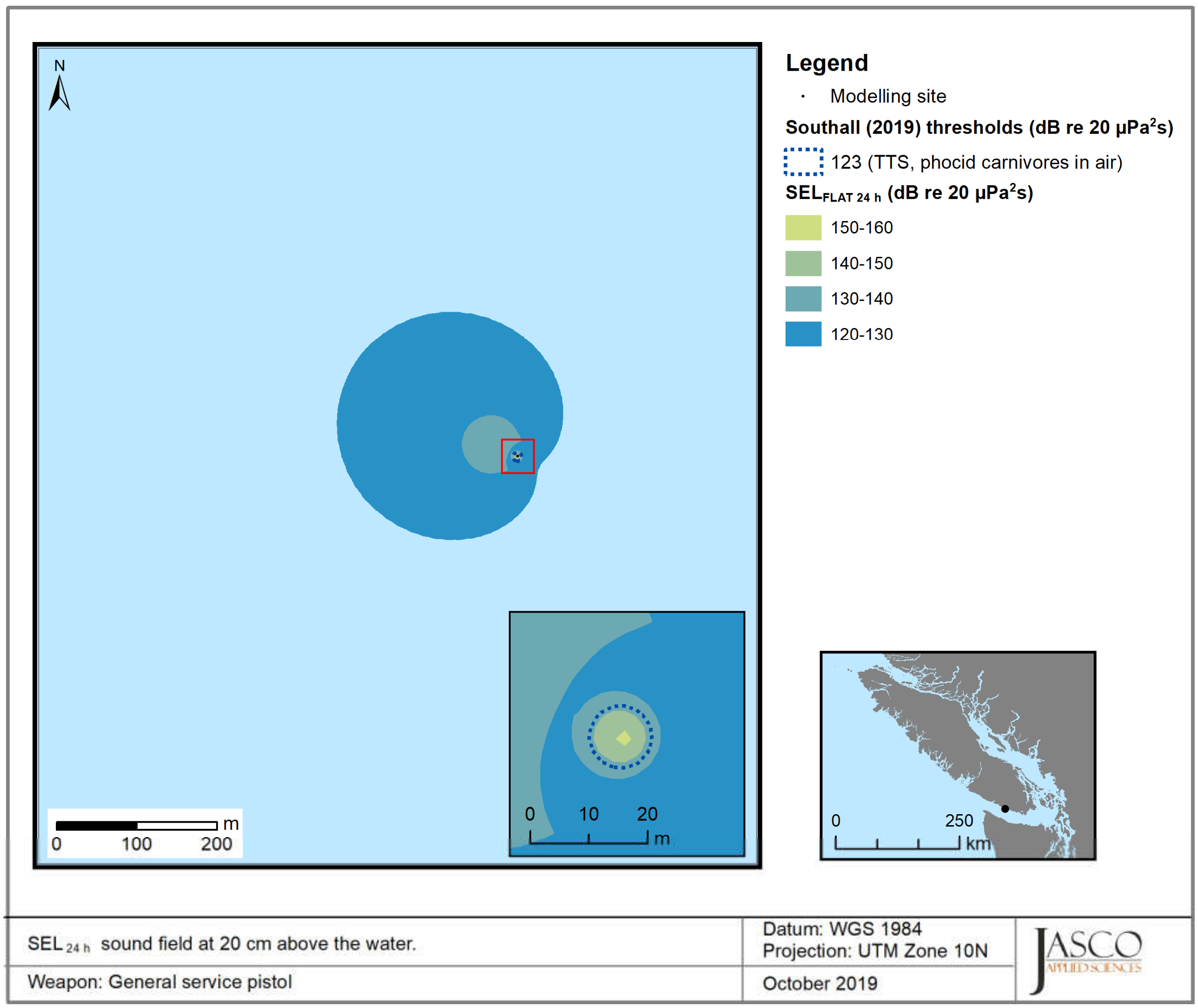

Figure 5. *Pt*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

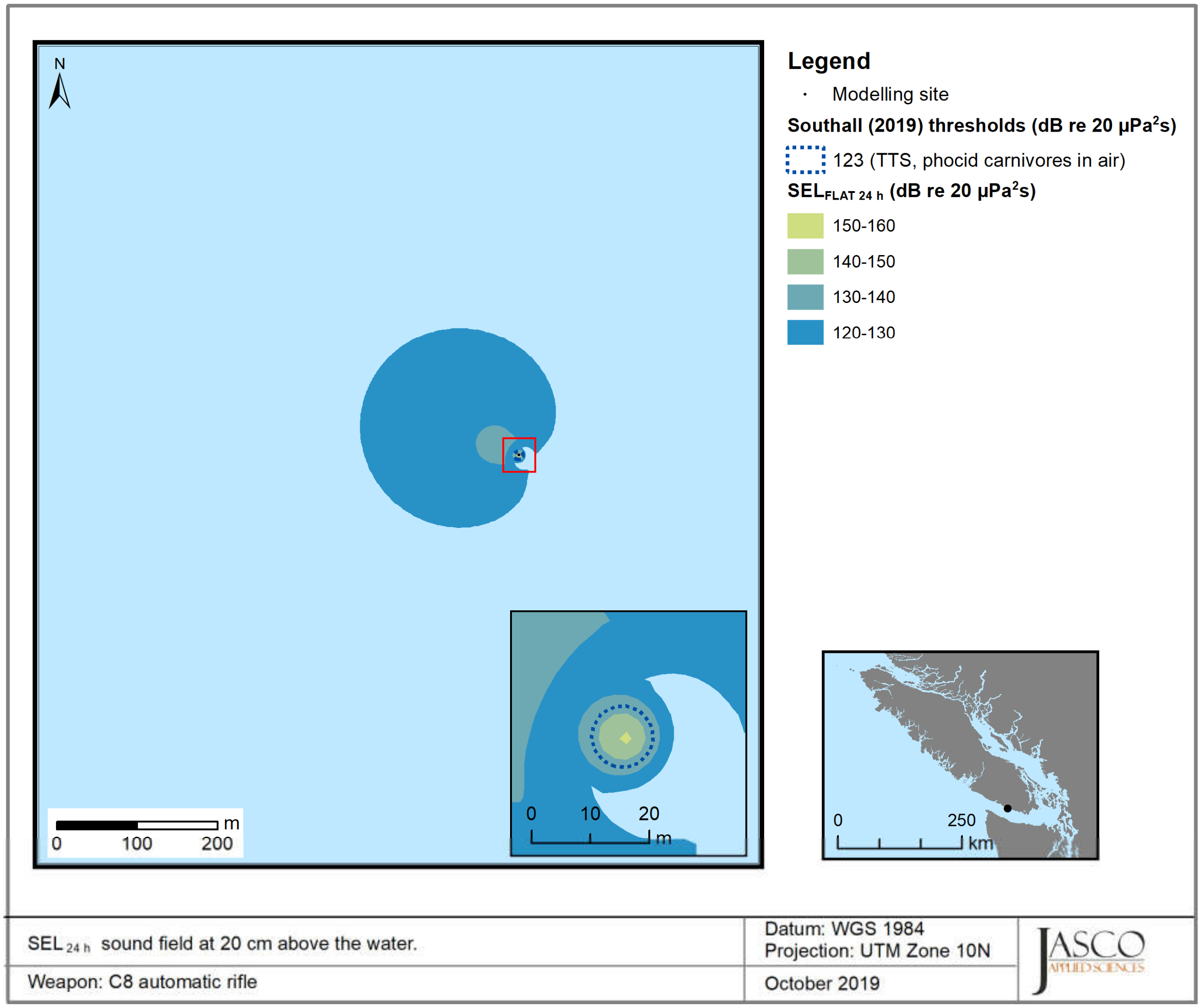

Figure 6. *C8*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

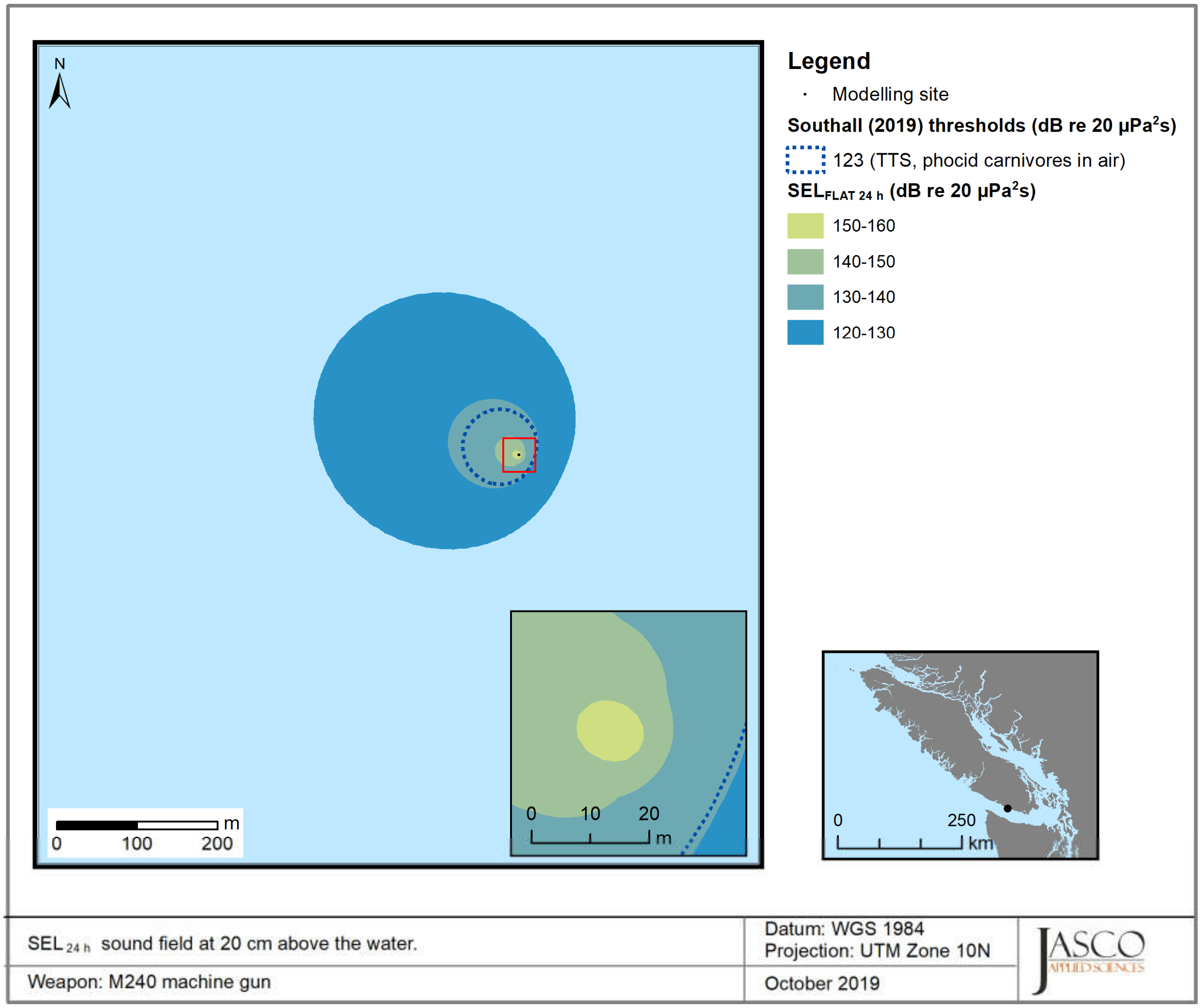

Figure 7. *M240*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

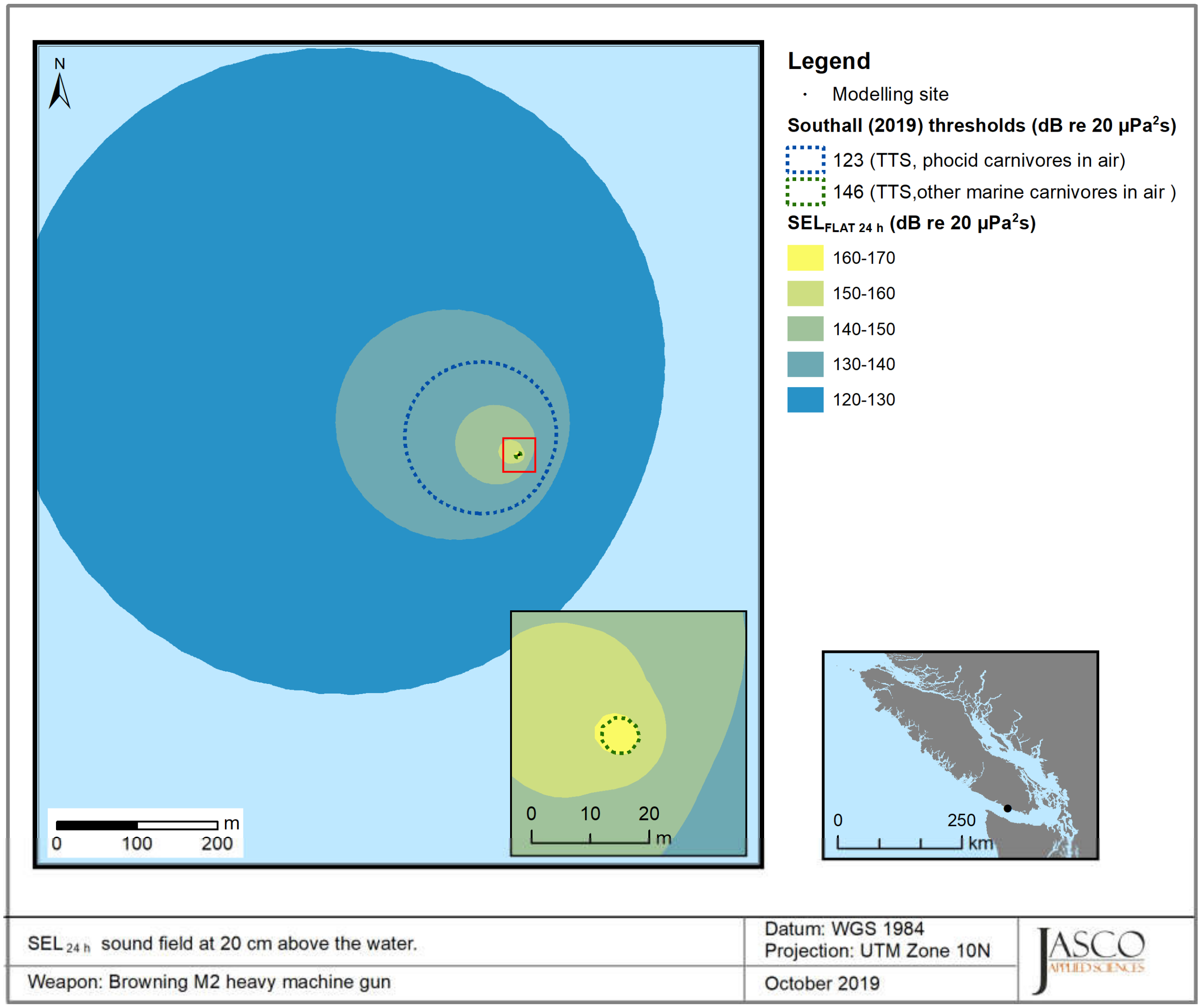

Figure 8. *M2*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

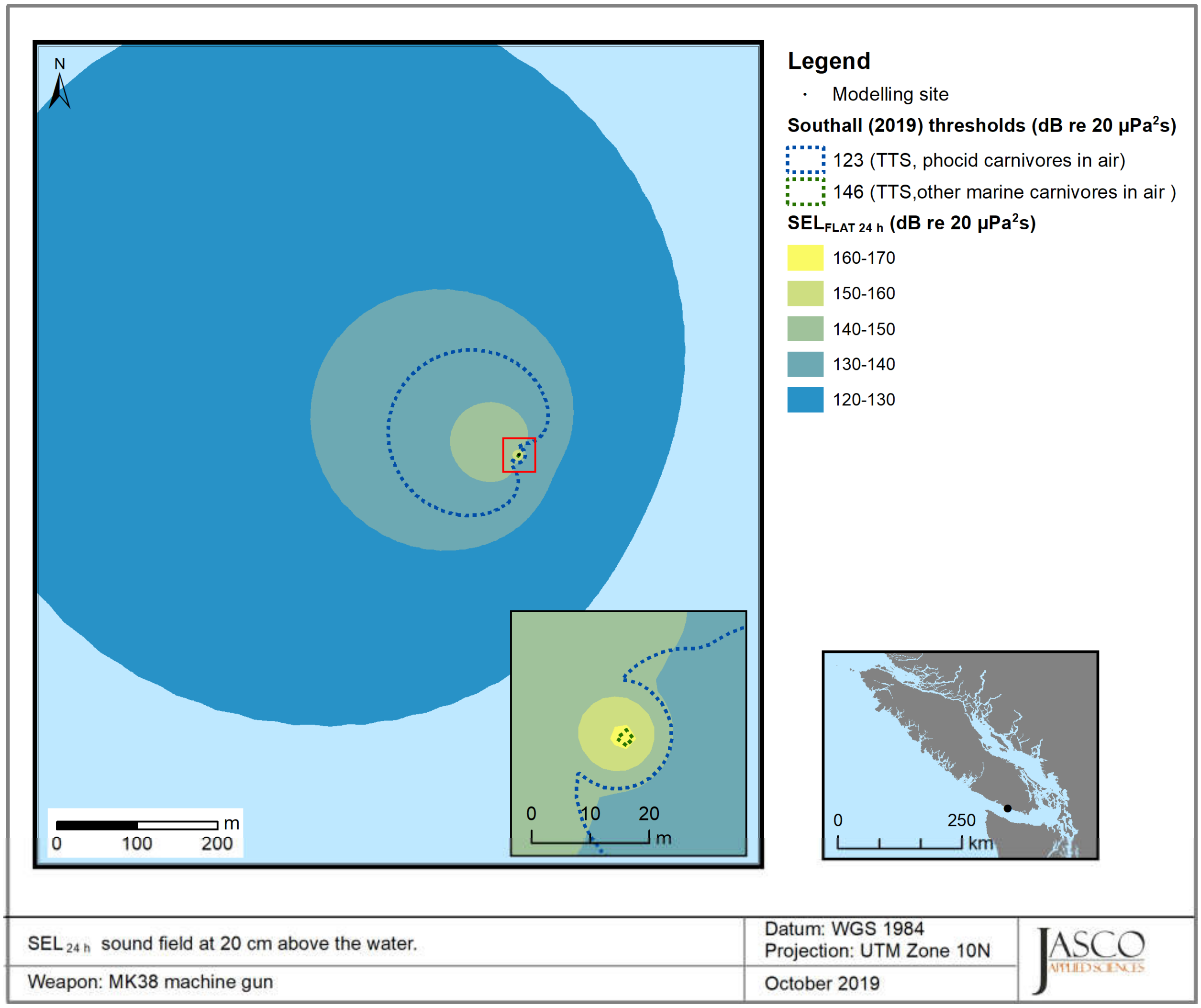

Figure 9. *MK38*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

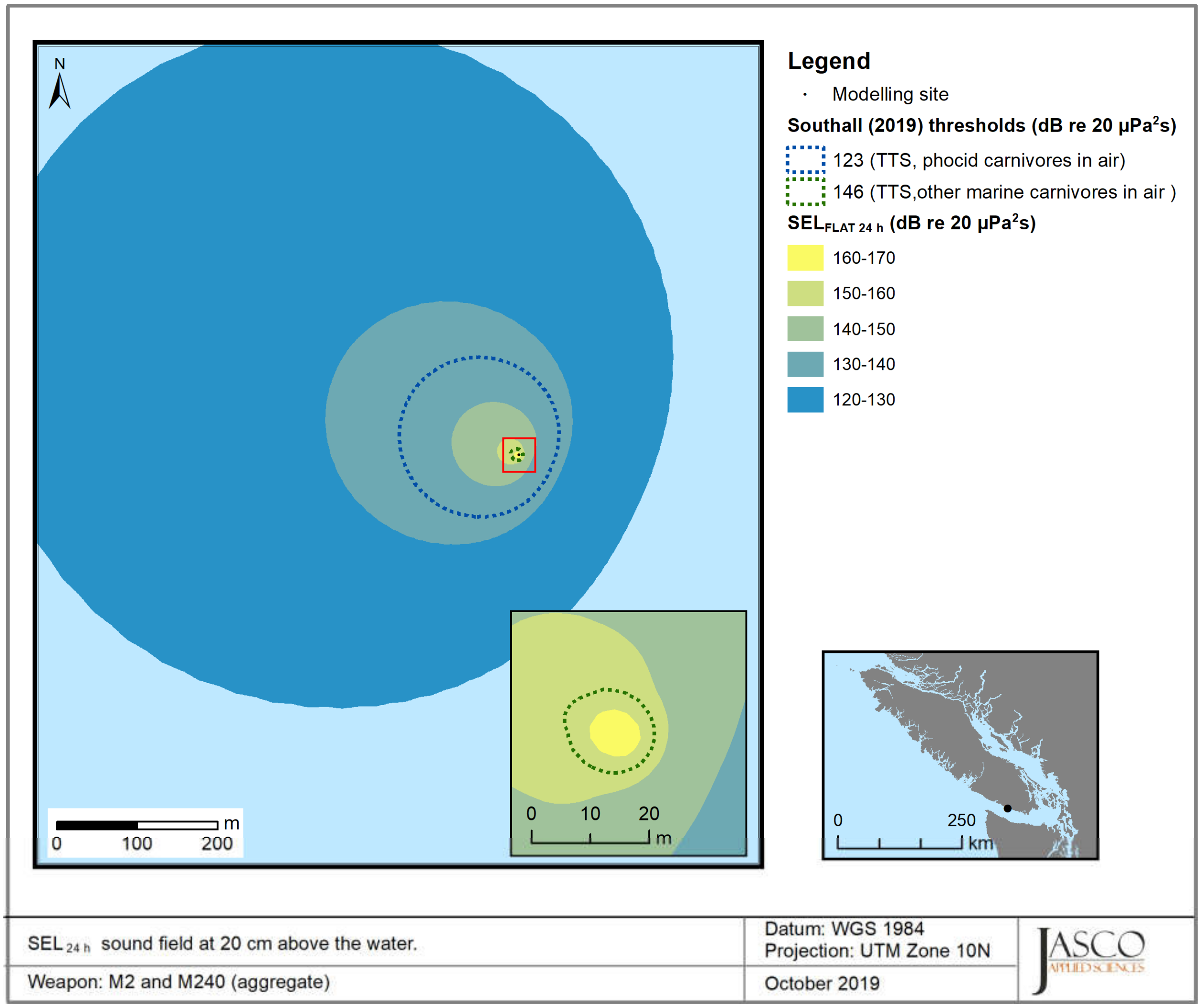

Figure 10. *M2 and M240 (aggregate)*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

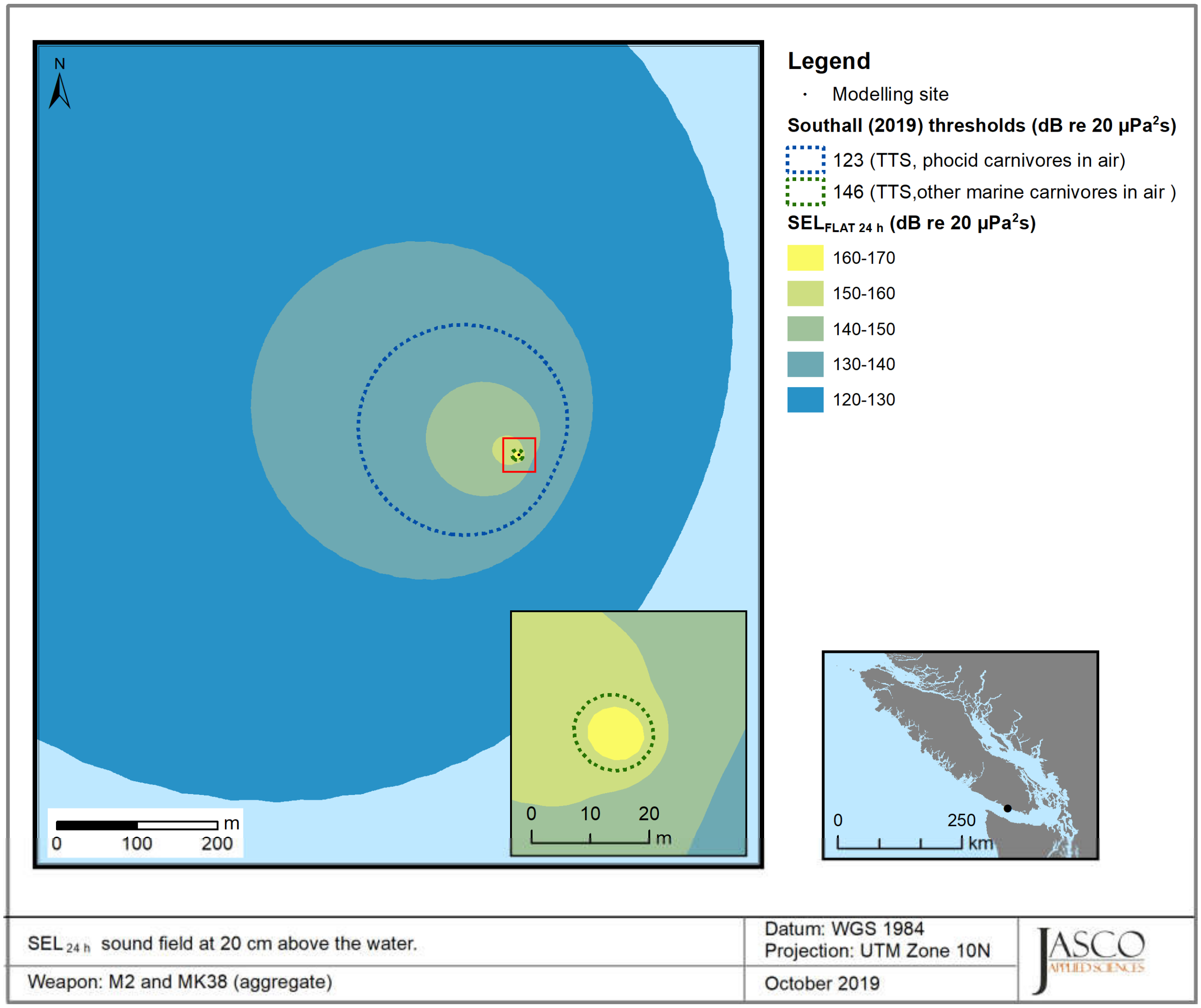

Figure 11. *M2 and MK38 (aggregate)*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

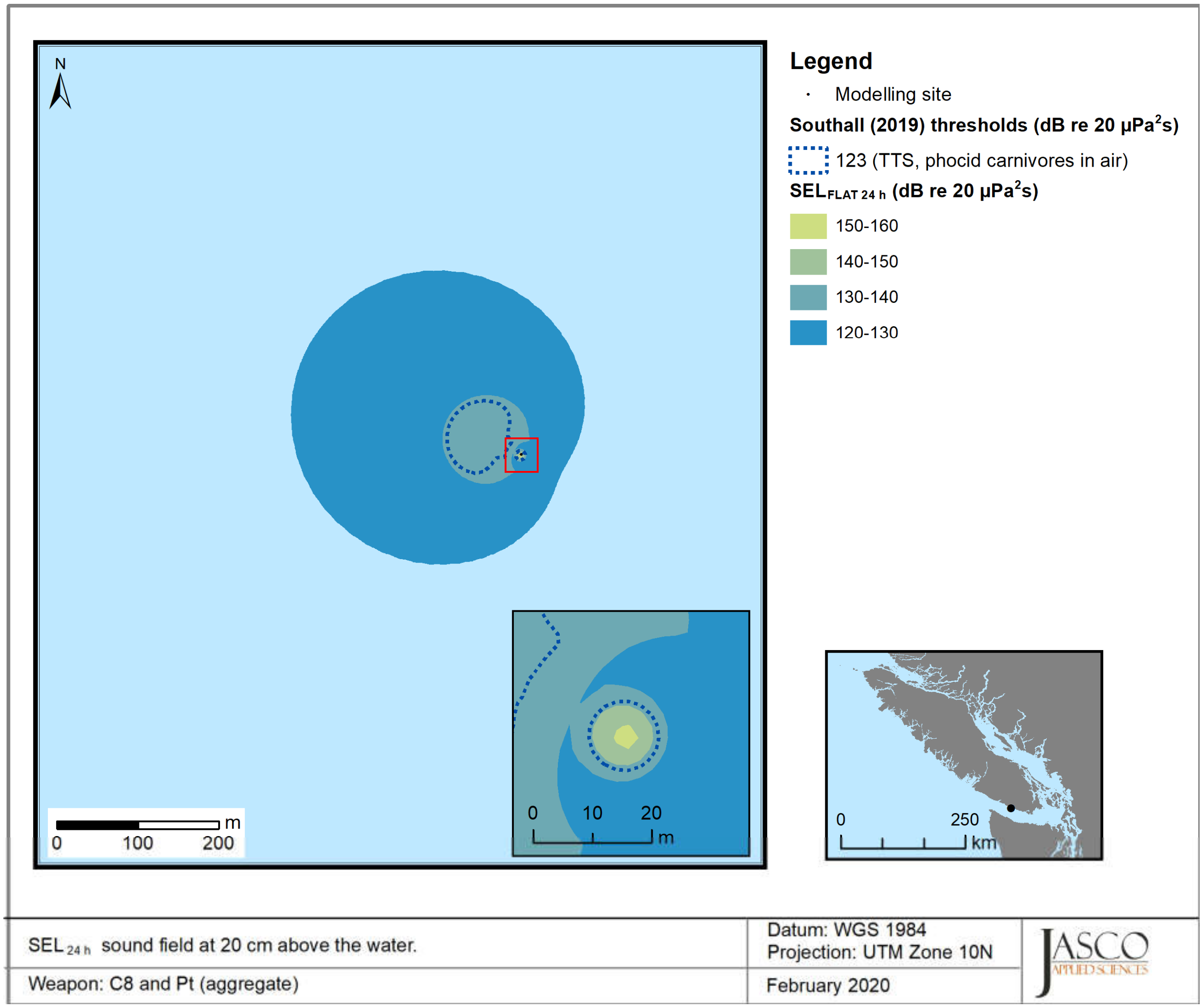

Figure 12. *C8 and Pt (aggregate)*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (Southall et al. 2019) and injury of pinnipeds in air (Southall et al. 2007).

Table 15. Distances and ensonified areas to peak thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air (Southall et al. 2019).

Hearing group	Threshold for peak (L_{pk}; dB re 20 µPa)	PTS threshold distances and areas										Threshold for peak (L_{pk}; dB re 20 µPa)	TTS threshold distances and areas									
		Pt		C8		M240		M2		MK38			Pt		C8		M240		M2		MK38	
		R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)		R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)	R_{max} (m)	Area (m^2)
Phocid carnivores in air	144	<10	79	16	314	19	380	20	452	113	12868	138	13	<314	31	1018	37	1385	39	1521	219	48305
Other marine carnivores in air	167	—	—	—	<314	<10	<314	<10	<314	<10	<314	161	—	—	<10	<314	<10	<314	<10	<314	16	314

A dash indicates the threshold was not reached.

Table 16. *Pt*: Distances to permanent threshold shift (PTS) thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 149 dB re 20 μPa	<10	<10	<314
SEL_{24h}: 144 dB re 20 μPa²·s	<10	<10	<314

Table 17. *C8*: Distances to permanent threshold shift (PTS) thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 149 dB re 20 μPa	<10	<10	<314
SEL_{24h}: 144 dB re 20 μPa²·s	<10	<10	<314

Table 18. *M240*: Distances to permanent threshold shift (PTS) thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 149 dB re 20 μPa	<10	<10	<314
SEL_{24h}: 144 dB re 20 μPa²·s	19	17	380

Table 19. *M2*: Distances to permanent threshold shift (PTS) thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 149 dB re 20 μPa	11	10	154
SEL_{24h}: 144 dB re 20 μPa²·s	49	46	2642

Table 20. *MK38*: Distances to permanent threshold shift (PTS) thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 149 dB re 20 μPa	64	59	4072
SEL_{24h}: 144 dB re 20 μPa²·s	43	40	1257

Table 21. *M2 and M240 (aggregate)*: Distances to permanent threshold shift (PTS) threshold for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
SEL_{24h}: 144 dB re 20 μPa²·s	53	48	3019

Table 22. *M2 and MK38 (aggregate)*: Distances to permanent threshold shift (PTS) threshold for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
SEL_{24h}: 144 dB re 20 μPa²·s	69	64	4778

Table 23. *C8 and Pt (aggregate)*: Distances to permanent threshold shift (PTS) threshold for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
SEL_{24h}: 144 dB re 20 μPa²·s	<10	<10	<314

4.1.2. Distances to Underwater Thresholds

Tables 24 to 30 present distances to SEL_{24h} thresholds for PTS and TTS for marine mammals based on NMFS (2018), and the corresponding maps with contours to thresholds are presented in Figures 13 to 19.

Table 24. *Pt*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 μPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	—	—	—
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	—	—	—	140	<10	<10	<314
Phocids underwater	185	—	—	—	170	—	—	—
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

Table 25. *C8*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	—	—	—
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	—	—	—	140	<10	<10	<314
Phocids underwater	185	—	—	—	170	—	—	—
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

Table 26. *M240*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	<10	<10	<314
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	—	—	—	140	<10	<10	<314
Phocids underwater	185	—	—	—	170	—	—	—
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

Table 27. *M2*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	<10	<10	<314
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	<10	<10	<314	140	20	18	616
Phocids underwater	185	—	—	—	170	<10	<10	<314
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

Table 28. *MK38*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	<10	<10	<314
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	—	—	—	140	15	14	380
Phocids underwater	185	—	—	—	170	<10	<10	<314
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

Table 29. *M2 and M240 (aggregate)*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	<10	<10	<314
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	<10	<10	<314	140	22	20	707
Phocids underwater	185	—	—	—	170	<10	<10	<314
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

Table 30. *M2 and MK38 (aggregate)*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	11	<10	314
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	<10	<10	<314	140	28	26	1134
Phocids underwater	185	—	—	—	170	<10	<10	<314
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

Table 31. *C8 and Pt (aggregate)*: Distances to SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for marine mammals underwater (NMFS 2018).

Hearing group	PTS threshold distances and ensonified areas				TTS threshold distances and ensonified areas			
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
LF cetaceans	183	—	—	—	168	<10	<10	<314
MF cetaceans	185	—	—	—	170	—	—	—
HF cetaceans	155	—	—	—	140	<10	<10	<314
Phocids underwater	185	—	—	—	170	—	—	—
Otariids underwater	203	—	—	—	188	—	—	—

A dash indicates the threshold was not reached.

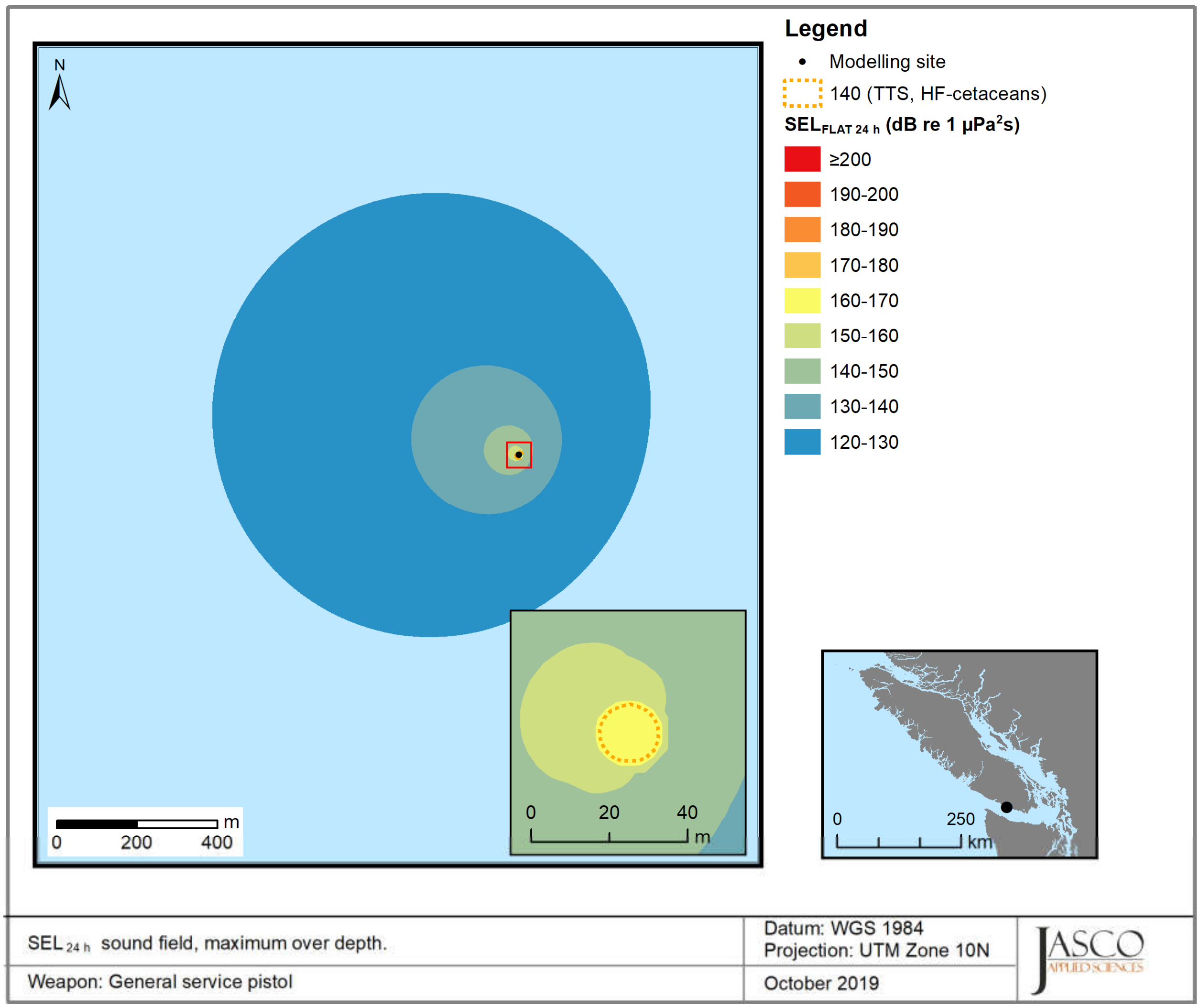

Figure 13. *Pt*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

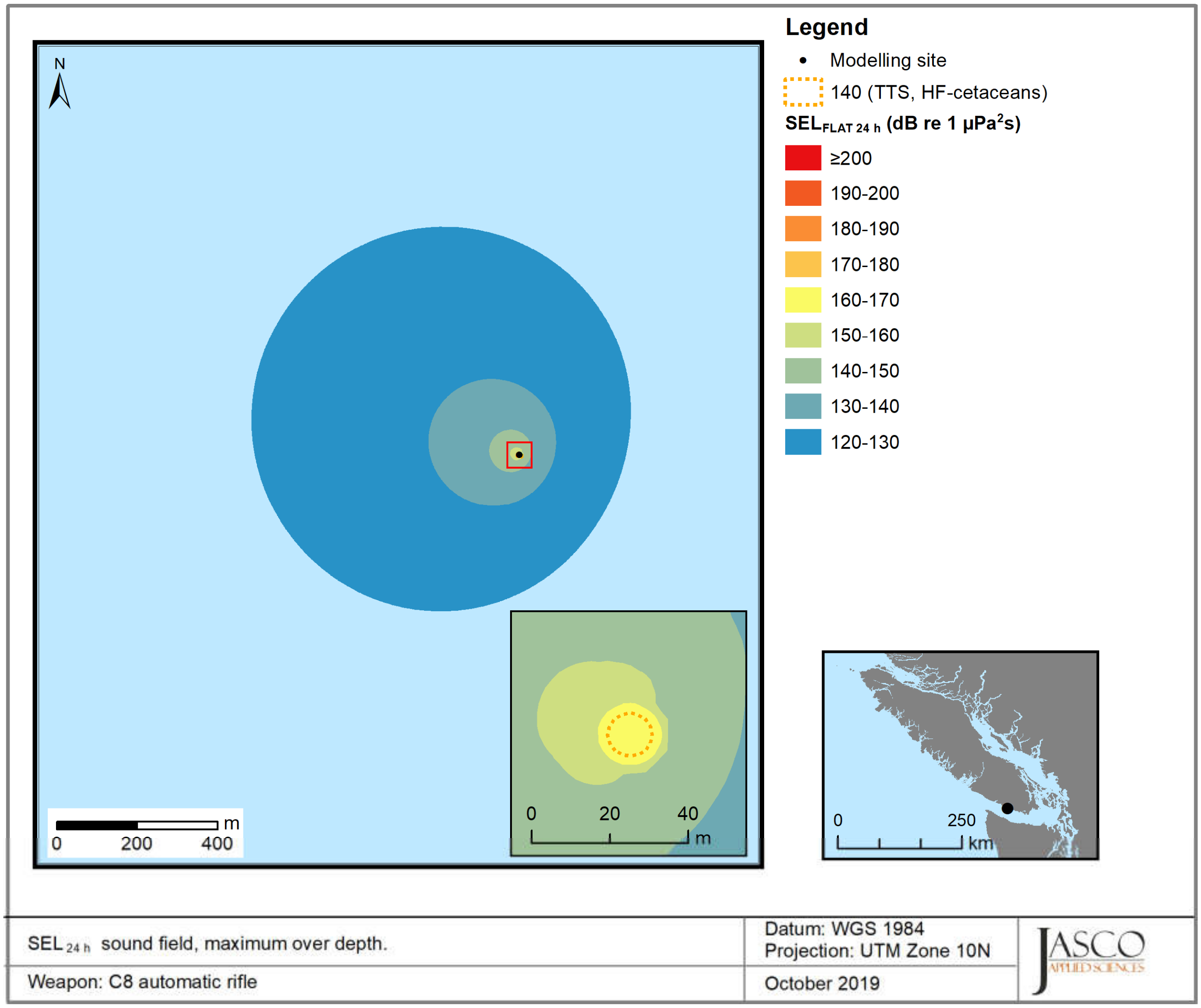

Figure 14. *C8*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

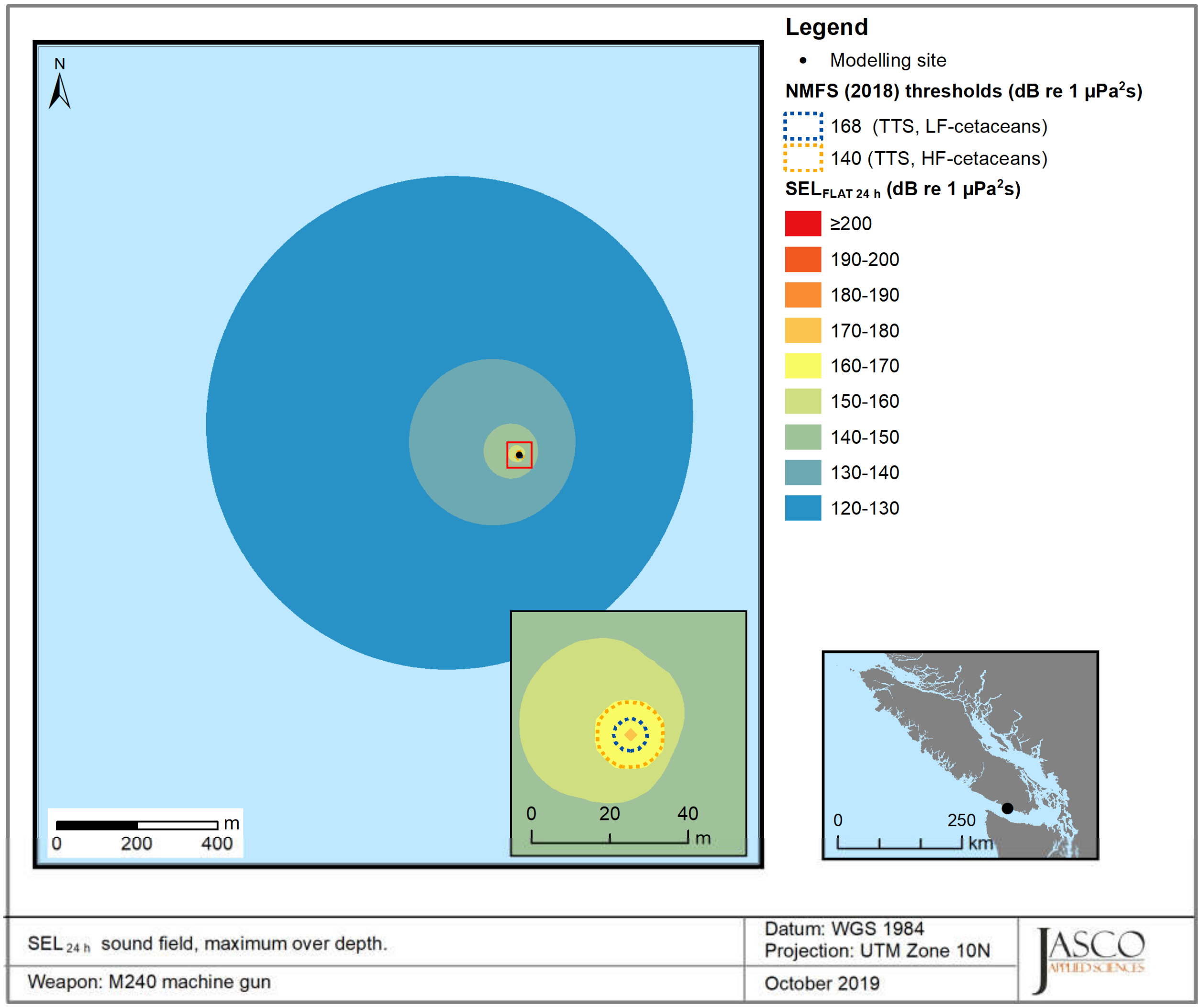

Figure 15. *M240*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

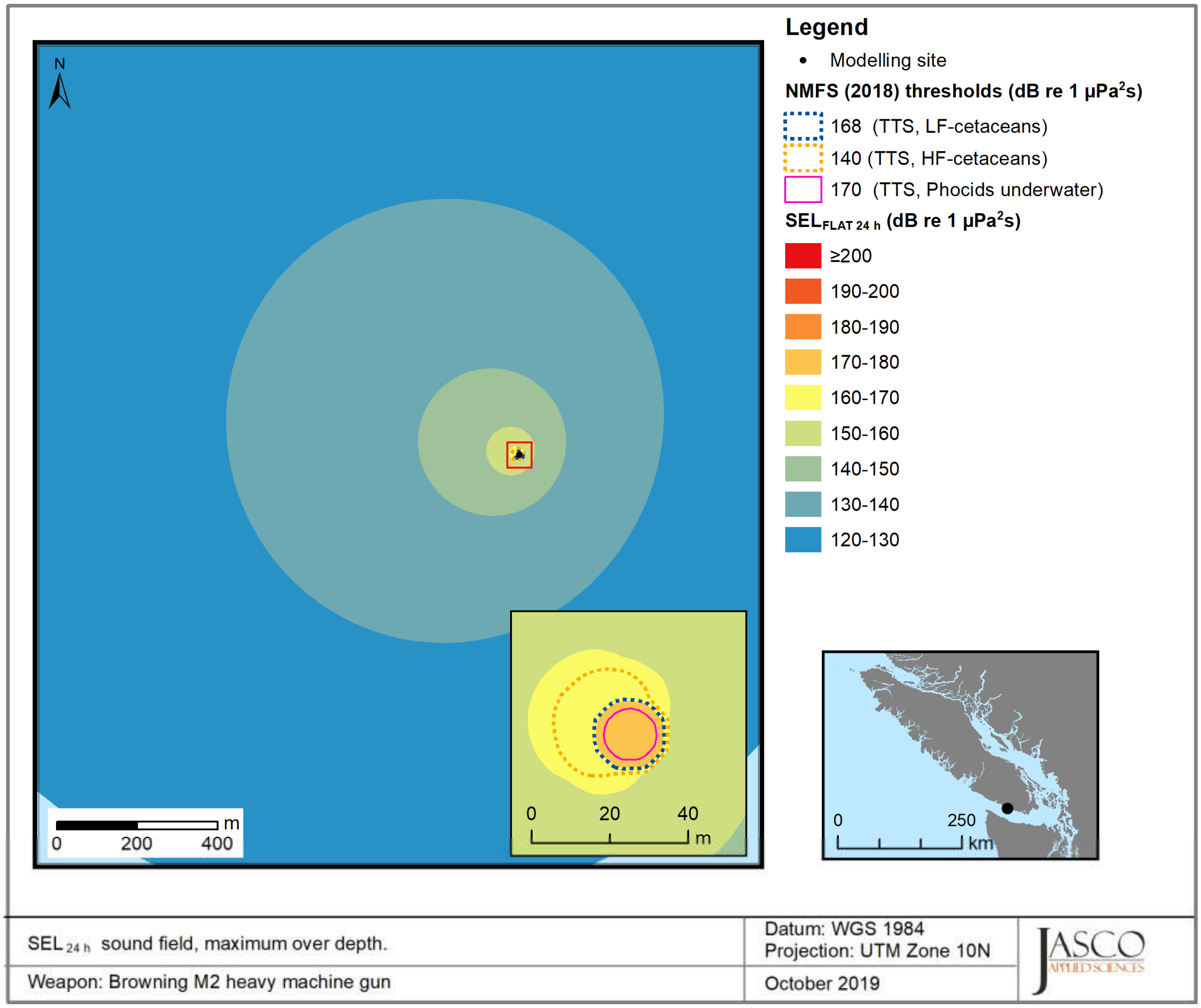

Figure 16. *M2*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

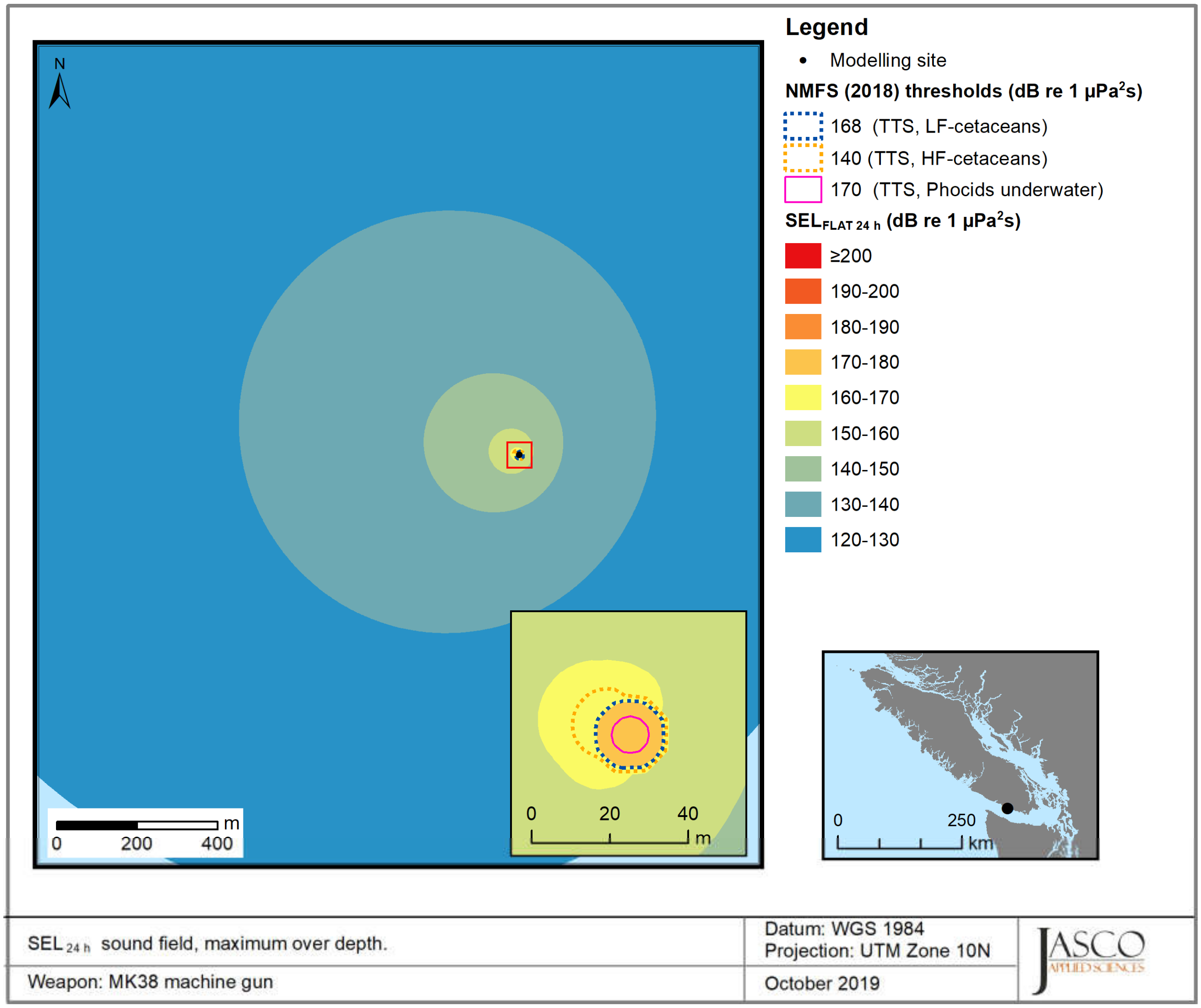

Figure 17. *MK38*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

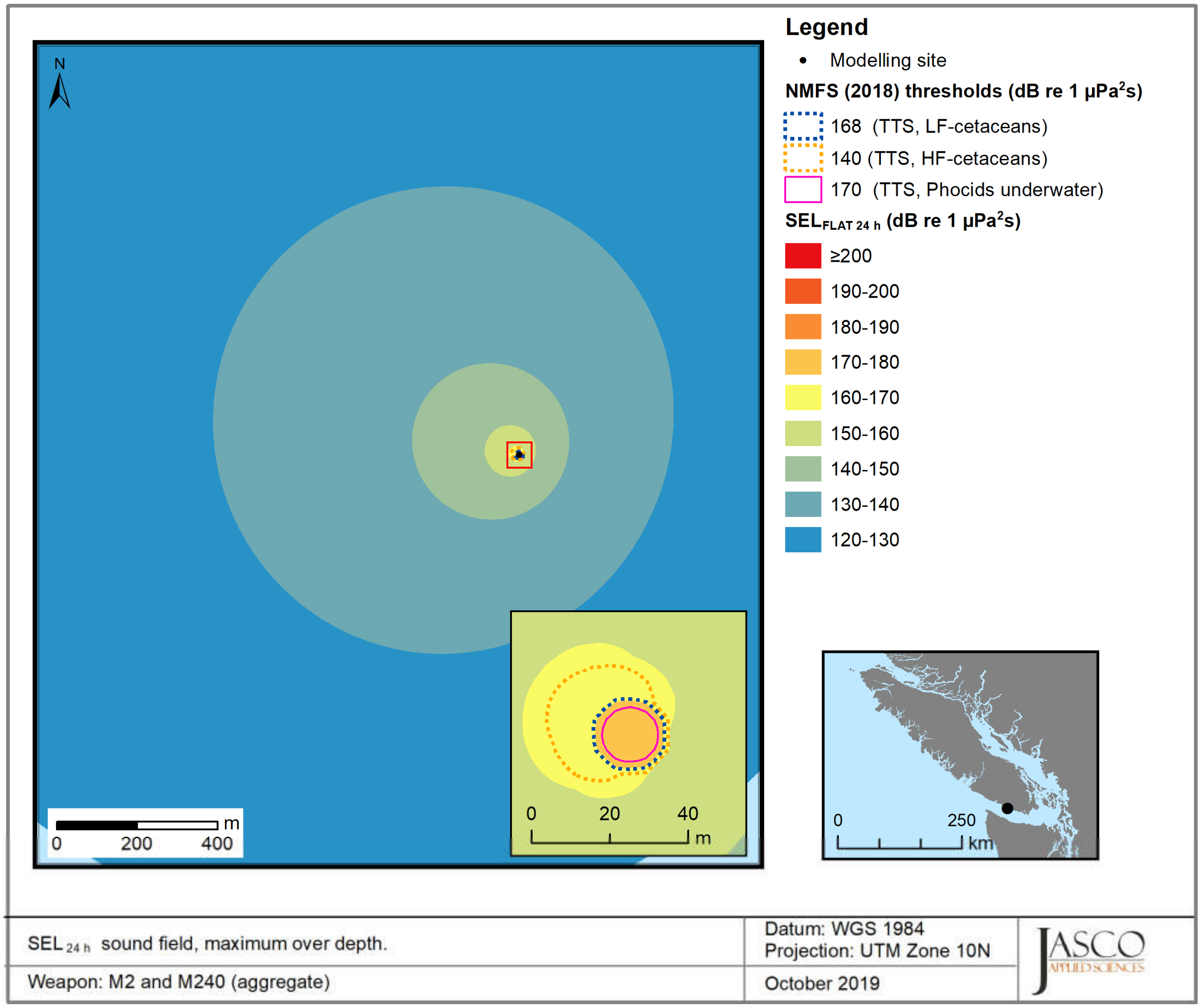

Figure 18. *M2 and M240 (aggregate)*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

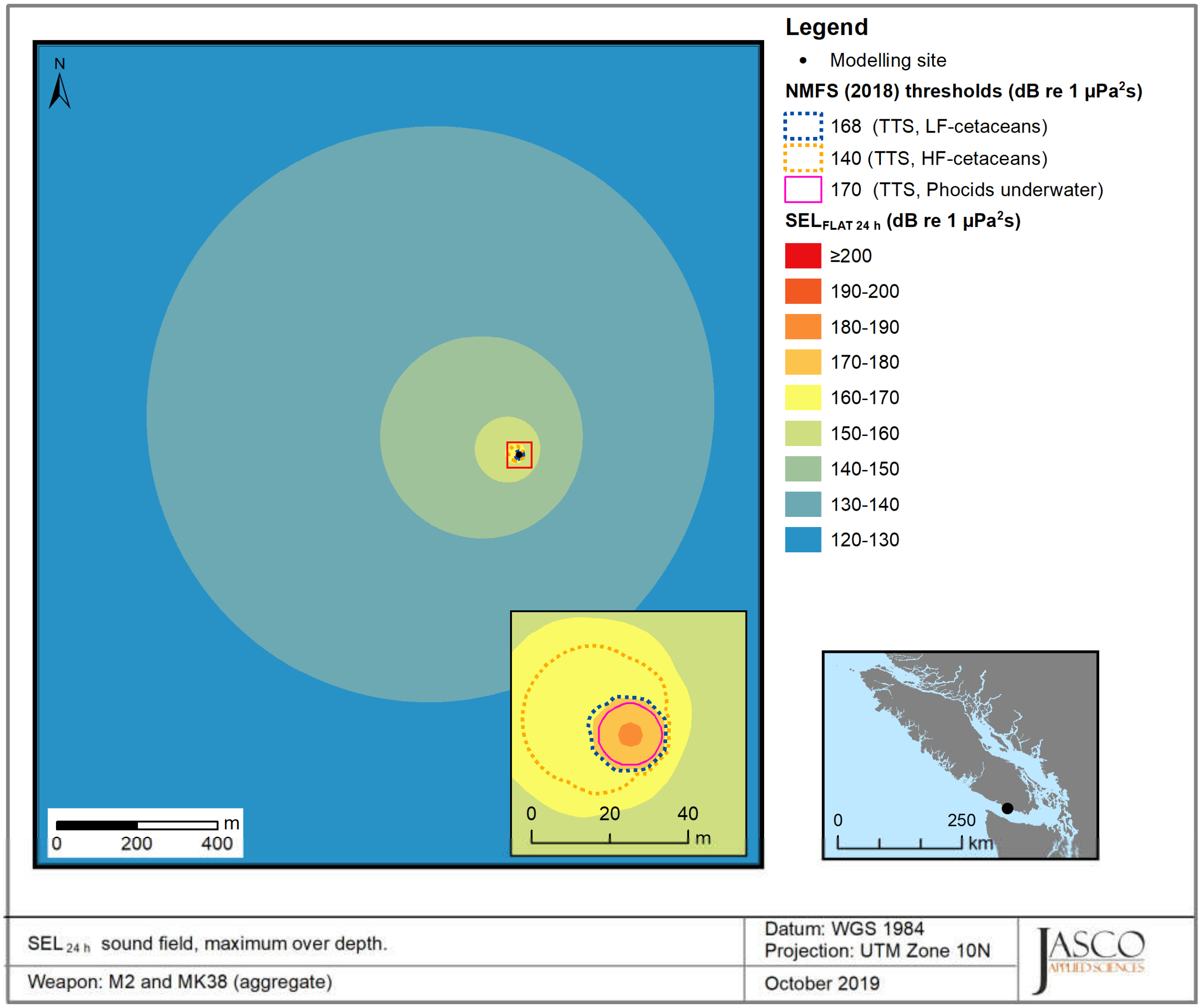

Figure 19. *M2 and MK38 (aggregate)*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

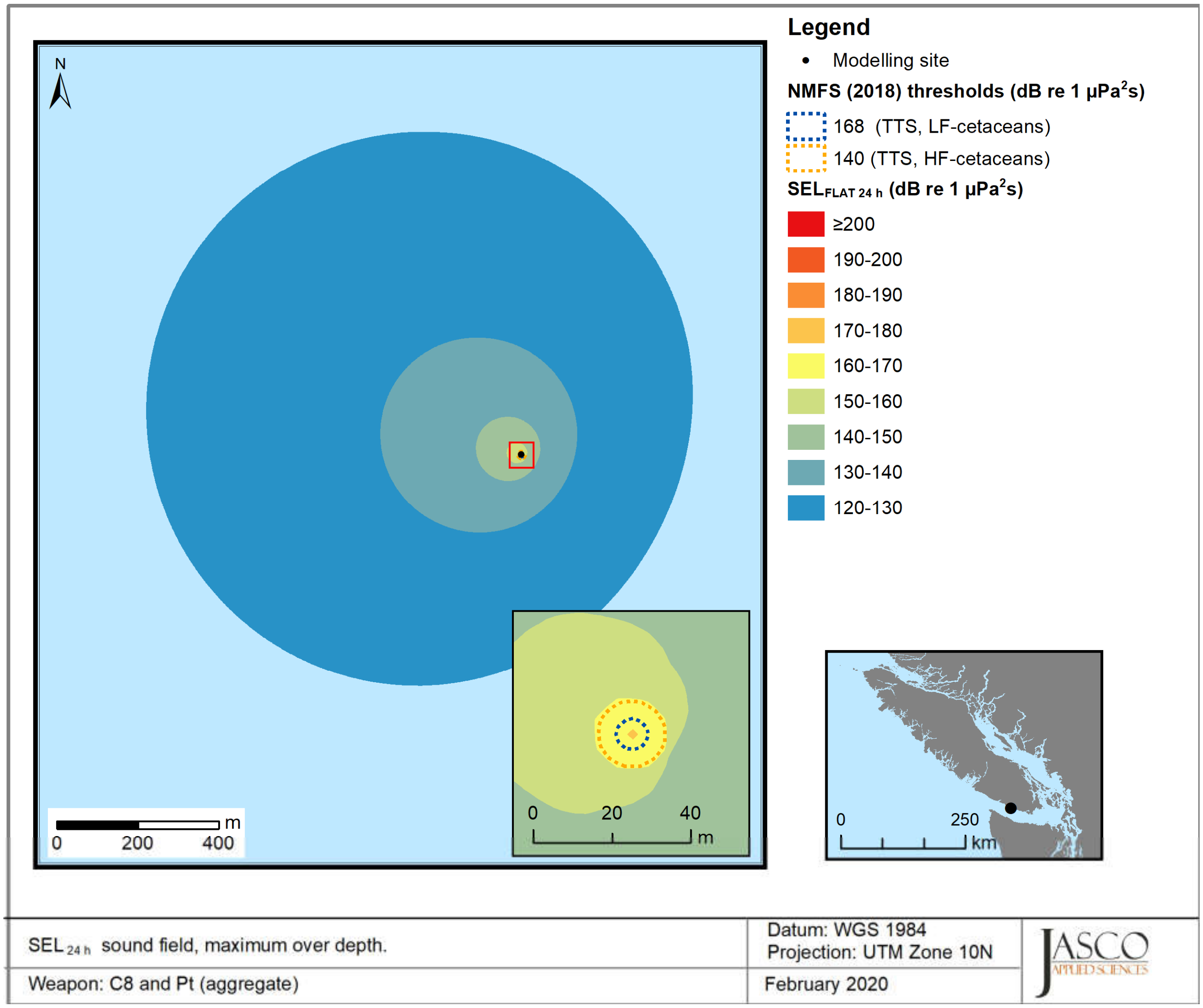

Figure 20. *C8 and Pt (aggregate)*: Contours to SEL_{24h} thresholds for temporary threshold shift (TTS) (NMFS 2018).

4.2. Ranges for Behavioral Response

Tables 32 to 39 present distances to behavioural response thresholds (SEL_{24h} and PK) for pinnipeds in air (Southall et al. 2007).

4.2.1. Distances to In-air Thresholds

Table 32. *Pt*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 109 dB re 20 µPa	357	327	130741
SEL_{24h}: 100 dB re 20 µPa²·s	1319	1198	2.3x10 ⁶

Table 33. *C8*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 109 dB re 20 µPa	734	673	572803
SEL_{24h}: 100 dB re 20 µPa²·s	1161	1054	1.8 x10 ⁶

Table 34. *M240*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 109 dB re 20 µPa	854	783	779128
SEL_{24h}: 100 dB re 20 µPa²·s	1826	1660	4.1 x10 ⁶

Table 35. *M2*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 109 dB re 20 µPa	887	814	846223
SEL_{24h}: 100 dB re 20 µPa²·s	9071	8821	33.3 x10 ⁶

Table 36. *MK38*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m²)
PK: 109 dB re 20 µPa	3045	2796	11.7 x10⁶
SEL_{24h}: 100 dB re 20 µPa²·s	9340	9019	69.8 x10 ⁶

Table 37. *M2 and M240 (aggregate)*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m^2)
SEL_{24h}: 100 dB re 20 μPa^2·s	9091	8917	42.1 x10^6

Table 38. *M2 and MK38 (aggregate)*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m^2)
SEL_{24h}: 100 dB re 20 μPa^2·s	15642	9171	104.0 x10^6

Table 39. *C8 and Pt (aggregate)*: Distances to behavioural response thresholds for pinnipeds in air (Southall et al. 2007).

Threshold	R_{max} (m)	$R_{95\%}$ (m)	Area (m^2)
SEL_{24h}: 100 dB re 20 μPa^2·s	1588	1443	3.40 x10^6

5. Discussion and Conclusions

Acoustic propagation modelling was conducted to estimate sound levels at the OPAREA WH due to small calibre weapons fired on board of military vessels towards floating targets. Typical training sessions were simulated to calculate single-weapon sound energy and cumulative sound energy from multiple weapons during 24 h. From these calculations, distances to thresholds for behavioural disturbance and for noise-induced hearing loss (both temporary and permanent) were computed for several species of marine fauna in-air and underwater.

Where uncertainties in operating conditions existed, the models were parametrized to yield realistically conservative noise levels. The following conservative assumptions were applied to the methods used in this study so that the results would not underestimate potential effects on marine life:

- A preliminary study of the transmission loss in air was conducted to determine that the atmospheric profile corresponding to March results in the longest distances to thresholds. This study also determined that the smallest weapon declination angle for each weapon yields the most conservative results for in-air modelling.
- In-air PK at 20 cm above the water were increased by 6 dB, to account for cases where the water-reflected wave added up in phase with the wave that arrived directly from the weapon's barrel.
- Air attenuation for in-air PK modelling assumes calm atmospheric conditions, leading to conservative estimates. Including attenuation due to wind would yield shorter distances to thresholds, but the results would not be representative of the worst-case scenario.
- The underwater modelling approach incorporated water column conditions for the month that exhibited the most conservative sound speed profile (i.e., January).
- Because marine mammals may use a wide depth range, the distances to thresholds (R_{max}) for underwater auditory injury represent the maximum sound levels over all depths.
- Distances to SEL thresholds were computed assuming a stationary receiver. Given the small distance to most TTS and PTS thresholds, it is important to point out the unlikelihood that an animal would remain stationary at distances so close to the vessel for the entire training period.

Regulations at OPAREA WH for small arms training only allows shooting parallel to the coastline (azimuths 295 or 115°). Modelling was conducted for firing azimuth 295°, resulting in higher noise exposure in that direction given the characteristic directionality of small arm muzzle blast noise (i.e., highest levels along the line-of-fire and lowest levels in the opposite direction).

For in-air propagation, impact zones defined by the SEL_{24h} thresholds for permanent threshold shift (PTS) and temporary hearing threshold shift (TTS) according to Southall et al. (2019) are summarized in Table 40. The longest distances to TTS threshold were for phocid carnivores in air, with R_{max} = 219 m (PK metric) for the MK38 and R_{max} = 207 m (SEL_{24h} metric) for the aggregate scenario combining the M2 and the MK38. As shown in Table 40, the addition of a second gun in aggregate scenarios had minimal effect to determine impact zones, since the most relevant criteria in almost all cases was the distance to PK thresholds.

Table 40. Maximum distances to thresholds for permanent threshold shift (PTS) and temporary threshold shift (TTS) for pinnipeds in air.

Type of scenario	Hearing group	PTS threshold distances			TTS threshold distances		
		R_{max} (m)	Threshold	Weapon(s)	R_{max} (m)	Threshold	Weapon(s)
Single weapon	Phocid carnivores in air	113	L_{pk}	MK38	219	L_{pk}	MK38
	Other marine carnivores in air	<10	L_{pk}	MK38	16	L_{pk}	MK38
Aggregate	Phocid carnivores in air	113	L_{pk}	MK38	219	L_{pk}	M2 and MK38
	Other marine carnivores in air	<10	L_{pk}	MK38	11	$L_{E,24h}$	M2 and M240

Regarding Southall et al. (2007), the longest distance to the PTS threshold was R_{max} = 69 m (SEL_{24h} metric), corresponding to the aggregate scenario 7 (M2 and MK38). For behavioral disturbance of pinnipeds in air, the longest distances to thresholds corresponded to the SEL_{24h} metric, with R_{max}= 9.3 km for the MK38. The addition of a second gun resulted in R_{max} = 15.6 km for the aggregate scenario with the M2 and the MK38.

An interesting feature is the increase in distance to the SEL_{24h} TTS for phocid carnivores in air, for the aggregate scenario with the C8 and the pistol (R_{max} = 96 m, Table 14), compared to the individual scenarios (R_{max} <10 m, Tables 7 and 8). This large increase is due to the addition of sound levels within two isolated sound areas in front of the weapons (see Figures 5 and 6). Individually, the levels near these areas are below 123 dB re 20 μPa^2·s but when added together, they exceed the 123 dB re 20 μPa^2·s threshold and result in the largest corresponding contour in Figure 12.

For underwater sound propagation, the longest distances to SEL_{24h} TTS thresholds (NMFS 2018) corresponded to the high-frequency cetaceans, with R_{max} = 20 m for the M2 and R_{max} = 28 m for the aggregate scenario with the M2 and the MK38. The 160 dB re 1 μPa SPL threshold for behavioural disturbance was never reached. In general, the MK38 resulted in the largest distances to underwater sound pressure levels. For underwater propagation, the SEL_{24h} PTS thresholds (NMFS 2018) were only reached for scenarios that include the M2 machine gun and high-frequency cetaceans, however, the threshold distances for such cases were all less than 10 m (R_{max}).

The modelling presented here accounted for firing of weapons from vessel platforms. Since military exercises could also be performed from Cyclone Helicopters at elevations 24-152 m toward on-water floating targets, the following points must be considered:

- For underwater sound propagation, the scenarios in this work are conservative assuming the maximum number of shots per day described in Table 6 are not exceeded. It has been shown (Chapman and Ward 1990) that the amount of sound energy that propagates into the water from an in-air source tends to decrease as the height of the source above the water increases. In addition, sound propagating from a helicopter-mounted weapon might undergo additional loss mechanisms such as air turbulence (which would be negligible for a weapon fired only a few meters above the water), thereby resulting in shorter distances to thresholds for underwater noise. If more shots per day are fired from a helicopter than modelled here, there is potential for the SEL-based threshold distances to be larger, e.g., if the increase in SEL due to more shots is larger than the decrease in per-shot SEL due to higher source altitude.
- For in-air propagation, additional modelling is required to quantify the impact of the platform height on sound propagation. Atmospheric properties (i.e., pressure, temperature, relative humidity) determine how sound propagates through the air, sometimes causing sound refraction towards the water (e.g., Figure C-2) at ranges that are strongly dependent on the source height.

Glossary

1/3-octave
One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band
Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave-band increases with increasing centre frequency.

90% sound pressure level (90% SPL)
The root-mean-square sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.

absorption
The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.

acoustic impedance
The ratio of the sound pressure in a medium to the rate of alternating flow of the medium through a specified surface due to the sound wave.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

audiogram
A graph of hearing threshold level (sound pressure levels) as a function of frequency, which describes the hearing sensitivity of an animal over its hearing range.

audiogram weighting
The process of applying an animal's audiogram to sound pressure levels to determine the sound level relative to the animal's hearing threshold (HT). Unit: dB re HT.

Auditory frequency weighting (auditory weighting function, frequency-weighting function)
The process of band-pass filtering sounds to reduce the importance of inaudible or less-audible frequencies for individual species or groups of species of aquatic mammals (ISO 2017). One example is M-weighting introduced by Southall et al. (2007) to describe "Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds".

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

boxcar averaging
A signal smoothing technique that returns the averages of consecutive segments of a specified width.

broadband sound level
The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measured frequency range.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

decade
Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 2006).

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

delphinid
Family of oceanic dolphins, or Delphinidae, composed of approximately thirty extant species, including dolphins, porpoises, and killer whales.

ensonified
Exposed to sound.

fast-average sound pressure level
The time-averaged sound pressure levels calculated over the duration of a pulse (e.g., 90%-energy time window), using the leaky time integrator from Plomp and Bouman (1959) and a time constant of 125 ms. Typically used only for pulsed sounds.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

hearing group
Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hearing threshold
The sound pressure level for any frequency of the hearing group that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for hearing high frequencies.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency (LF) cetacean
The functional cetacean hearing group that represents mysticetes (baleen whales) specialized for hearing low frequencies.

mean-square sound pressure spectral density
Distribution as a function of frequency of the mean-square sound pressure per unit bandwidth (usually 1 Hz) of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: $\mu Pa^2/Hz$.

mid-frequency (MF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for mid-frequency hearing.

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but they use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The skulls of toothed whales are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid
A common term used to describe members of the Otariidae, eared seals, commonly called sea lions and fur seals. Otariids are adapted to a semi-aquatic life; they use their large fore flippers for propulsion. Their ears distinguish them from phocids. Otariids are one of the three main groups in the superfamily Pinnipedia; the other two groups are phocids and walrus.

otariid pinnipeds in water (OW)
The functional pinniped hearing group that represents eared seals under water.

parabolic equation method
A computationally efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

phocid
A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.

phocid pinnipeds in water (PW)
The functional pinniped hearing group that represents true/earless seals under water.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

power spectrum density
Generic term, formally defined as power in W/Hz, but sometimes loosely used to refer to the spectral density of other parameters such as square pressure or time-integrated square pressure.

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: p.

received level (RL)
The sound level measured (or that would be measured) at a defined location.

rms
root-mean-square.

shear wave
A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 μPa^2·s. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound exposure spectral density
Distribution as a function of frequency of the time-integrated squared sound pressure per unit bandwidth of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: μPa^2·s/Hz.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 μPa) and the unit for SPL is dB re 1 μPa^2:

$$L_p = 10\log_{10}(p^2/p_0^2) = 20\log_{10}(p/p_0)$$

Unless otherwise stated, SPL refers to the root-mean-square (rms) pressure level. See also 90% sound pressure level and fast-average sound pressure level. Non-rectangular time window functions may be applied during calculation of the rms value, in which case the SPL unit should identify the window type.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 μPa·m (pressure level) or dB re 1 μPa^2·s·m (exposure level).

spectral density level
The decibel level (10·$\log_{10}$) of the spectral density of a given parameter such as SPL or SEL, for which the units are dB re 1 μPa^2/Hz and dB re 1 μPa^2·s/Hz, respectively.

spectrum
An acoustic signal represented in terms of its power, energy, mean-square sound pressure, or sound exposure distribution with frequency.

surface duct
The upper portion of a water column within which the sound speed profile gradient causes sound to refract upward and therefore reflect off the surface resulting in relatively long-range sound propagation with little loss.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also referred to as propagation loss.

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Appendix A. Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa underwater and p_0 = 20 µPa in air. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the American National Standard Institute and International Organization for Standardization definitions and symbols for sound metrics (ANSI 2013, e.g., ISO 2017), but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,pk}$; dB re 1 µPa or dB re 20 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{\mathrm{p,pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \tag{A-1}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The sound pressure level (SPL or L_p; dB re 1 µPa or dB re 20 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_{\mathrm{p}} = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right) \tag{A-2}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $g(t)$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,fast}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,boxcar\ 125ms}$. Another approach, historically used to evaluate SPL of impulsive signals underwater, defines $g(t)$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 µPa^2·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_{\mathrm{E}} = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right) \tag{A-3}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{\mathrm{E,N}} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \tag{A-4}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related numerically by the following expression, which depends only on the duration of the time window T:

$$L_{\mathrm{p}} = L_{\mathrm{E}} - 10\log_{10}(T) \tag{A-5}$$

$$L_{\mathrm{p90}} = L_{\mathrm{E}} - 10\log_{10}(T_{90}) - 0.458 \tag{A-6}$$

where the 0.458 dB factor accounts for the 10% of pulse SEL missing from the SPL(T_{90}) integration time window.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of M-weighted SEL (e.g., $L_{E,LFC,24h}$; see Appendix B.2.

A.1. One-third-octave-band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analyzing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into 1/3-octave-bands, which are approximately one-third of an octave (base 2) wide. Each octave represents a doubling in sound frequency. The centre frequency of the ith 1/3-octave-band, $f_c(i)$, is defined as:

$$f_{\mathrm{c}}(i) = 10^{\frac{i}{10}} \tag{A-7}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith 1/3-octave-band are defined as:

$$f_{\mathrm{lo},i} = 10^{\frac{-1}{20}} f_{\mathrm{c}}(i) \quad \text{and} \quad f_{\mathrm{hi},i} = 10^{\frac{1}{20}} f_{\mathrm{c}}(i) \tag{A-8}$$

The 1/3-octave-bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-1). The acoustic modelling spans from band 8 (f_c (8) = 6.3 Hz) to band 31 (f_c (31) = 1258 kHz) for in air modelling, and spans from band 8 (f_c (8) = 6.3 Hz) to band 43 (f_c (43) = 20 kHz) for in water modelling.

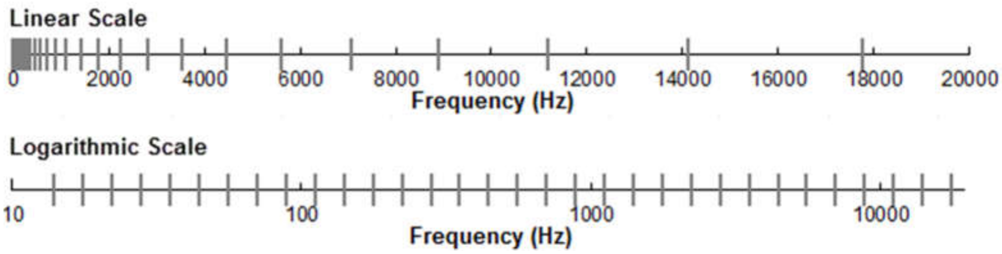


Figure A-1. One-third-octave frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{lo,i}$ and $f_{hi,i}$:

$$L_{\mathrm{p},i} = 10\log_{10} \int_{f_{\mathrm{lo},i}}^{f_{\mathrm{hi},i}} S(f)\,df \tag{A-9}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10\log_{10} \sum_{i} 10^{\frac{L_{p,i}}{10}} \tag{A-10}$$

Figure A-2 shows an example of how the 1/3-octave-band sound pressure levels compare to the sound pressure spectral density levels of an ambient noise signal. Because the 1/3-octave-bands are wider with increasing frequency, the 1/3-octave-band SPL is higher than the spectral levels, especially at higher frequencies. Acoustic modelling of 1/3-octave-bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

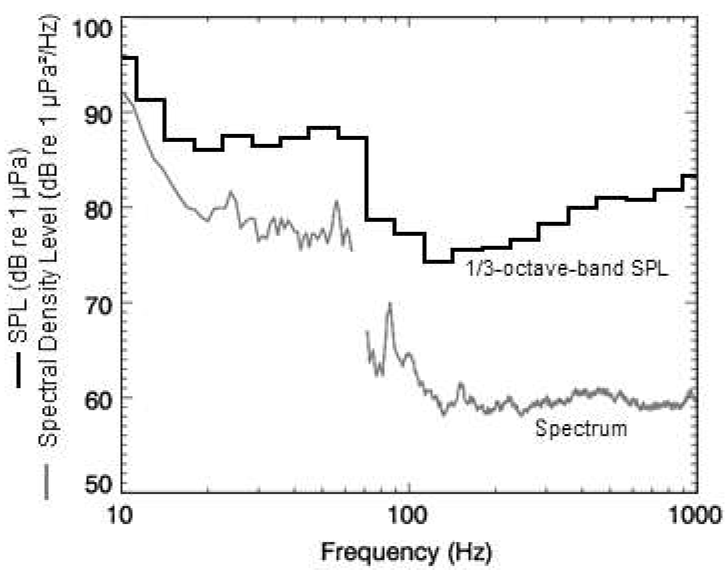


Figure A-2. Sound pressure spectral density levels and the corresponding 1/3-octave-band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

Appendix B. Impact Criteria

B.1. Marine Mammal Hearing Groups

Current data and predictions show that marine mammal species differ in their hearing capabilities, in their absolute hearing sensitivity as well as their frequency band of hearing (Richardson et al. 1995, Wartzok and Ketten 1999, Southall et al. 2007, Au and Hastings 2008). While hearing measurements are available for a small number of species based on captive animal studies, direct measurements of many odontocetes and all mysticetes do not exist. As a result, hearing ranges for many odontocetes are grouped with similar species, and predictions for mysticetes are based on other methods, including: anatomical studies and modeling (Houser et al. 2001, Parks et al. 2007, Tubelli et al. 2012, Cranford and Krysl 2015), vocalizations (see reviews in Richardson et al. 1995, Wartzok and Ketten 1999, Au and Hastings 2008), taxonomy, and behavioral responses to sound (Dahlheim and Ljungblad 1990, see review in Reichmuth et al. 2007). Southall et al. (2007) proposed dividing marine mammals into hearing groups. This division was updated in 2016 and 2018 by NOAA Fisheries using more recent best available science (NMFS 2016, 2018).

Southall et al. (2019) published an updated set of criteria for onset of TTS and PTS in marine mammals. While the authors propose a new nomenclature and classification for the marine mammal functional hearing groups, the proposed thresholds and weighting functions for exposure to underwater sound do not differ in effect from those proposed by NOAA (2018). The new hearing groups proposed by Southall et al. (2019) have not yet been adopted by NOAA. The NOAA (2018) hearing groups used in this analysis are (Sills et al. 2014, NMFS 2018):

- Low-frequency (LF) cetaceans (mysticetes or baleen whales)
- Mid-frequency (MF) cetaceans (odontocetes: delphinids, beaked whales, sperm whales)
- High-frequency (HF) cetaceans (other odontocetes)
- Phocid pinnipeds in water (PW)
- Otariid pinnipeds in water (OW)

Hearing groups from Southall et al. (2019) for in-air thresholds used in this analysis are:

- Phocid carnivores in air (PCA)
- Other carnivores in air (OCA)

B.2. Marine Mammal Auditory Weighting Functions

The potential for anthropogenic sounds to impact marine mammals is largely dependent on whether the sound occurs at frequencies that an animal can hear well (Appendix B.1), unless the sound pressure level is so high that it can cause physical tissue damage regardless of frequency. Auditory (frequency) weighting functions reflect an animal's ability to hear a sound. Sound spectra are weighted at particular frequencies in a manner that reflects an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007). Auditory weighting functions have been proposed for marine mammals, specifically associated with thresholds for onset of TTS and PTS. They are expressed in metrics that consider what is known about marine mammal hearing (e.g., SEL) (Southall et al. 2007, Erbe et al. 2016, Finneran 2016). Table B-1 lists the auditory weighting parameters for the cetacean and pinniped hearing groups. Figure B-1 shows the marine mammal auditory weighting curves for underwater hearing sensitivity, and Figure B-2 the pinniped auditory weighting curves for in-air hearing sensitivity.

Table B-1. Parameters for cetacean auditory weighting functions recommended by NMFS (2018) and pinniped auditory weighting functions proposed by (Southall et al. 2019). Function parameters for pinnipeds differ between air and water.

Hearing group	*a*	*b*	f_{lo} (kHz)	f_{hi} (kHz)	*C* (dB)
Low-frequency (LF) cetaceans	1.0	2	0.2	19	0.13
Mid-frequency (MF) cetaceans	1.6	2	8.8	110	1.20
High-frequency (HF) cetaceans	1.8	2	12	140	1.36
Phocid pinnipeds in water (PW)	1	2	1.9	30	0.75
Otariid pinnipeds in water (OW)	2	2	0.94	25	0.64
Phocid carnivores in air (PCA)	2	2	0.75	8.3	1.5
Other carnivores in air (OCA)	1.4	2	2.0	20	1.39

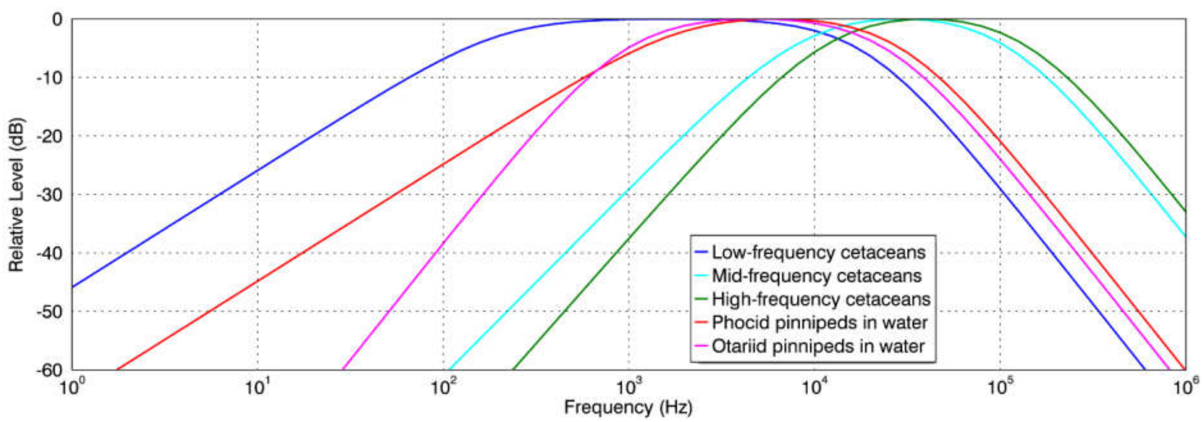


Figure B-1. Auditory weighting functions for underwater hearing sensitivity for functional marine mammal hearing groups as recommended by NMFS (2018).

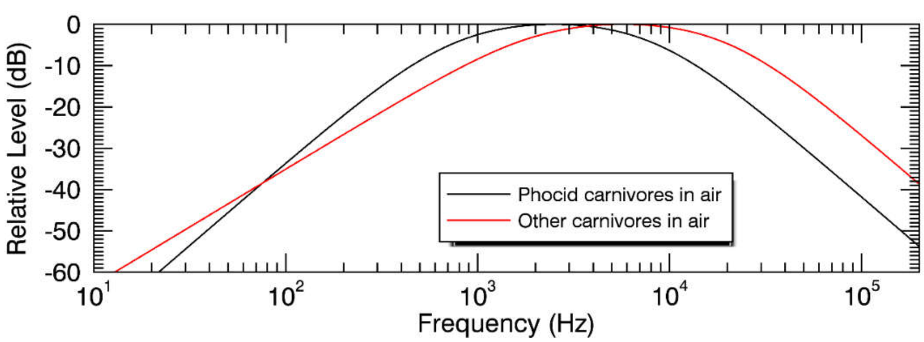


Figure B-2. Auditory weighting functions for in-air hearing sensitivity for pinnipeds hearing groups as recommended by Southall et al. (2019).

Marine mammal auditory weighting functions for all hearing groups published by Finneran (2016) are included in the NMFS (2018) Technical Guidance document for use in conjunction with corresponding SEL PTS onset acoustic criteria.

The application of marine mammal auditory weighting functions emphasizes the importance of making measurements and characterizing sound sources in terms of their overlap with biologically-important frequencies (e.g., frequencies used for environmental awareness, communication or the detection of predators or prey), and not only the frequencies of interest or concern for the completion of the sound-producing activity (i.e., context of sound source; NMFS 2018).

B.3. Injury Criteria

Historically, the NMFS SPL criteria for injury to marine mammals from acoustic exposure were set according to recommendations for cautionary estimates of sound levels leading to the onset of permanent hearing threshold shift (PTS). These criteria prescribed injury thresholds of 190 dB re 1 µPa SPL for pinnipeds and 180 dB re 1 µPa SPL for cetaceans, for all types of sound sources except tactical sonar and explosives. These injury thresholds were applied to individual noise pulses or instantaneous sound levels and did not consider the overall duration of the noise or its acoustic frequency distribution.

Criteria that do not account for exposure duration or noise spectra are generally insufficient on their own for assessing hearing injury. Human workplace noise assessment metrics consider the SPL as well as the duration of exposure and sound spectral characteristics. For example, the International Institute of Noise Control Engineering (I-INCE) and the Occupational Safety and Health Administration (OSHA) suggests thresholds in C-weighted peak pressure level and A-weighted time-average sound level (dB(A)[1] L_{eq}). They also suggest exchange rates that increase the allowable thresholds for each halving or doubling of exposure time. This approach assumes that hearing damage depends on the relative loudness perceived by the human ear, and that the ear might partially recover from past exposures, particularly if there are periods of quiet during the overall exposure.

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted “24h” refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted, whereas SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and pinnipeds in water (P_w) and in air (P_a). These weighting functions are referred to as M-weighting filters. SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of TTS in belugas by the amount of TTS required to produce PTS in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it infers a 3 dB exchange rate).

Wood et al. (2012) refined the Southall et al. (2007) thresholds, suggesting lower injury values for LF cetaceans and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 $\mu Pa^2 \cdot s$. Because no data were available for baleen whales, Wood et al. (2012) based their recommendations for LF cetaceans on results from MF cetacean studies. In particular, they referenced Finneran and Schlundt’s (2010) research, which found MF cetaceans were more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LF cetaceans of 192 dB re 1 $\mu Pa^2 \cdot s$.

Also in 2012, the US Navy recommended a different set of criteria for assessing Navy operations (Finneran and Jenkins 2012). Their analysis incorporated new dolphin equal-loudness contours[2] to update weighting functions and injury thresholds for LF, MF, and HF cetaceans. They recommended separating the pinniped group into otariids (eared seals) and phocids (earless seals) and assigning

[1] The “A” refers to a specific frequency-dependent filter shaped according to a human equal loudness contour.
[2] An equal-loudness contour is the measured sound pressure level (dB re 1 µPa for underwater sounds) over frequency, for which a listener perceives a constant loudness when exposed to pure tones.

adjusted frequency thresholds to the former based on several sensitivity studies (Schusterman et al. 1972, Moore and Schusterman 1987, Babushina et al. 1991, Kastak and Schusterman 1998, Kastelein et al. 2005, Mulsow and Reichmuth 2007, Mulsow et al. 2011a, Mulsow et al. 2011b).

Although a definitive approach is not yet apparent, there is consensus in the research community that an SEL-based method is preferable, either separately or in addition to an SPL-based approach, to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalized technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2018). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012).

Southall et al. (2007) reviewed the available data on TTS following exposure to in-air sound (impulses and non-pulses) in three pinniped species: harbor seals, *Phoca vitulina* (PCA), California sea lions, *Zalophus californianus* (OCA), and northern elephant seals, *Mirounga angustirostris* (OCA). In their updated version (Southall et al. 2019), the authors defined the functional hearing group audiograms for PCA and OCA based on a wider number of species (spotted seal, *Phoca largha*, ringed seal, *Pusa hispida*, Steller sea lion, *Eumetopias jubatus*, polar bear *Ursus maritimus*, and sea otter, *Enhydra lutris*) while no other species had been tested for onset of TTS. Table B-2 provides the recommended thresholds.

Table B-2. Peak pressure level (PK; dB re 1 µPa) and sound exposure level (SEL; dB re 1 µPa^2·s underwater and dB re 20 µPa^2·s in air) thresholds for injury (PTS onset) for marine mammals for impulsive sources, as proposed by NMFS (2018) and Southall et al. (2019).

Functional hearing group	Impulsive source	
	PK	Weighted SEL_{24h}
Low-frequency cetaceans (LF)	219	183
Mid-frequency cetaceans (MF)	230	185
High-frequency cetaceans (HF)	202	155
Phocid carnivores in water (PCW)	218	185
Otariid pinnipeds in water (OCW)	232	203
Phocid carnivores in air (PCA)	144	138
Other carnivores in air (OCA)	167	161

B.4. Behavioral Response Criteria

Numerous studies on marine mammal behavioral responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioral reactions. However, it is recognized that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012). Because of the complexity and variability of marine mammal behavioral responses to acoustic exposure, NMFS has not yet released technical guidance on behavior thresholds for use in calculating exposures to animals.

For impulsive sounds, NMFS is currently using an unweighted SPL of 160 dB re 1 µPa as the behavioral response threshold for all cetacean species (NMFS and NOAA 2005). As of 2016, NMFS applies these disturbance thresholds as a default but makes exceptions on a species-specific and sub-population specific basis where warranted. This criterion was derived from the High Energy Seismic Survey (HESS) Review Process (1999) report which, in turn, was based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1983, Malme et al. 1984). The HESS team recognized that behavioral responses to sound may occur at lower levels, but substantial responses were only likely to occur above a SPL of 140 dB re 1 µPa. An extensive review of behavioral responses to sound was undertaken by Southall et al. (2007, their Appendix B). Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but a lack of convergence in the data prevented them from suggesting explicit dose-response functions. Absence of controls, precise measurements, appropriate metrics, and context dependency of responses (including the activity state of the animal) all contribute to variability.

As discussed in Finneran et al. (2017) the received level of sound may not always be the best predictor of a marine mammal's behavioral reaction to a sound exposure. The context, including the animal's behavioral state, animal's previous experience with the sound, sound source speed and heading (either toward or away), and sound source distance, can all affect an animal's reaction (Wartzok et al. 2003, Southall et al. 2007). Ellison et al. (2012) proposed dividing behavioral reactions into level-based responses and context-based responses. At higher amplitudes, a level-based response relates the received sound level to the probability of a behavioral response that is probably caused by auditory masking or annoyance (Ellison et al. (2012)). At lower amplitudes, sound can cue the presence, proximity, and approach of a sound source and stimulate a context-based response based on factors other than received sound level (e.g., the animal's previous experience, sound source-animal separation distance, or behavioral state).

Appendix C. Modelling Methodology and Parameters

This appendix provides details of the underwater and in-air models for sound propagation, and describes the input environmental parameters used for acoustic modelling.

C.1. Underwater Noise Propagation from In-air Sources

Underwater sound propagation due to an in-air source was modelled in this work using the normal mode theory as presented by Chapman et al. (1990). In their derivation, Chapman treated the air-water interface using the appropriate sound reflection and transmission coefficient (rather than making the usual assumption of a pressure release), and showed that a source located *H* m above the water produces an underwater sound field at range r and depth z given by the normal mode summation:

$$p(r,z) = -\pi \sum_n [e^{i\gamma_n h}/\gamma_n \varphi_n'(0)] \varphi_n(z)\, H_o^{(1)}(k_n r) \quad \text{(C-1)}$$

were $\varphi_n(z)$ and k_n are the *n*th normal mode and horizontal wavenumbers for the water column, respectively; $\varphi_n'(0)$ is the derivative of the *n*th normal mode function with respect to depth, evaluated at the air-water interface; $H_o^{(1)}$ is the Hankel function of the first kind; and γ_n is the vertical wavenumber. These functions can be computed by any of the available normal-mode solvers, which account for a depth-dependent water sound speed profile. Equation (C-1) shows that an in-air source is equivalent to having the nth mode excited by the term within square brackets.

Figure C-1 shows examples of the normal mode solutions for the OPAREA WH waveguide. Underwater modelling was conducted assuming a flat bathymetry with a 45 m water depth (i.e., the water depth at the source location). Although bathymetric effects play a role in acoustic propagation, the modelling results obtained under this constant bathymetry assumption are accurate at the short ranges to relevant thresholds presented in this work.

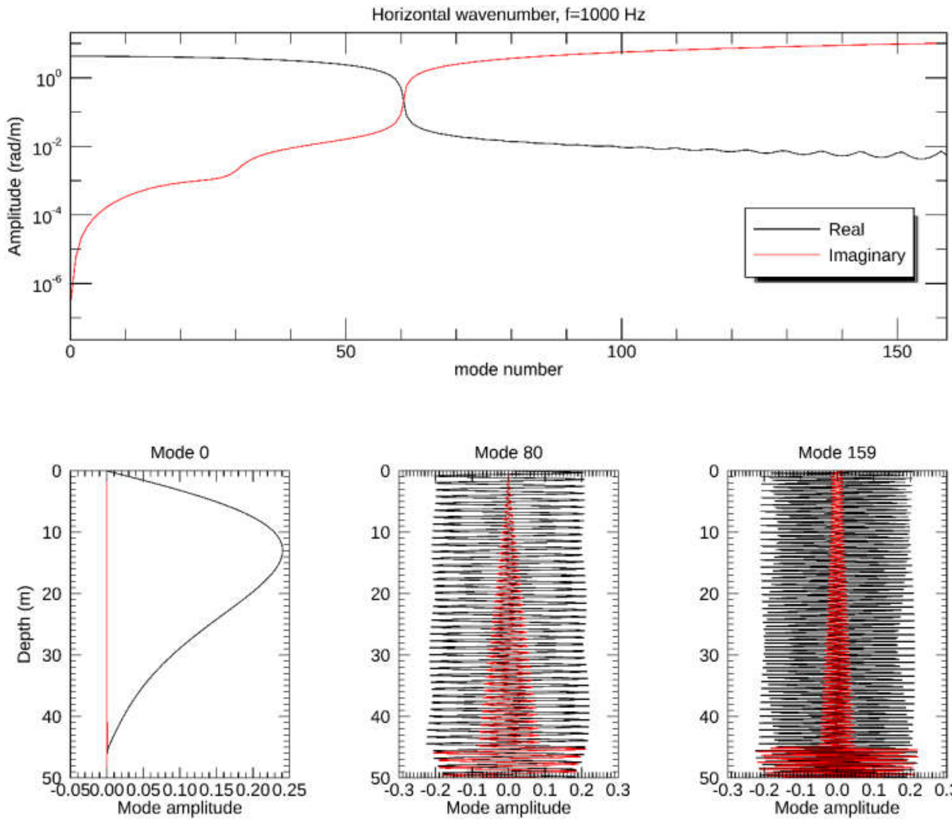


Figure C-1. Examples of normal mode functions and horizontal wavenumbers at 1 kHz, used in modelling transmission loss at OPAREA Whiskey Hotel (WH).

C.2. In-air Noise Propagation with Impulse Noise Propagation Model (INPM)

C.2.1. Transmission Loss Estimation

INPM uses a split-step Padé solution (Collins 1993) for the parabolic form of the wave equation to determine frequency-dependent transmission losses as a function of range away from a point source. The split-step Padé solution is computationally faster than the finite-difference solution of the Parabolic Equation (PE) by approximately two orders of magnitude and is more accurate than the split-step Fourier solution for wide angle propagation. This approach is also superior to standard ray tracing models that can yield unrealistically large received sound level values due to caustics, which are computationally intensive to remove (Salomons 2001). The model uses a two-dimensional (2-D) implementation of the PE method that accounts for diffraction, air turbulence, and sound interaction with the terrain.

INPM can output the complete sound level field in range and height along a radial from the source. This can be rendered as an image plot (Figure C-2), which presents an example of noise propagation for the MK38, using the march atmospheric profile selected as the most conservative for this modelling.

INPM has been verified by comparing model outputs against a set of benchmarks available in the open literature. The model shows nearly perfect agreement to the published results (Racca et al. 2006).

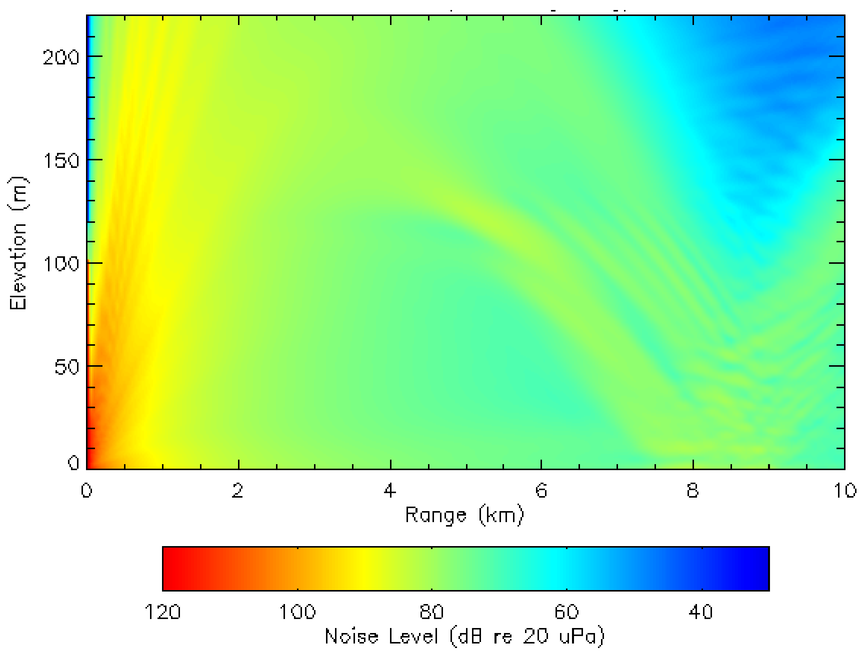


Figure C-2. Example of in-air received sound level vertical radial plot from Impulse Noise Propagation Model (INPM), corresponding to the MK38 with the atmospheric profile for March.

C.2.2. Frequency-dependent Source Level Model

To obtain the frequency-dependent source levels required to estimate the broadband noise generated by small calibre arms, INPM uses the Gun Firing Noise Source level (GUNSL) module (Hannay et al. 1999). GUNSL estimates source levels per 1/3-octave-band according to the weapon's calibre, azimuth direction of shooting, and declination angle from the horizontal line.

This module uses the traditional formula known as Patter's equation (Pater and Shea 1981) to estimate the directionality from the muzzle blast for a weapon of given calibre. However, Patter's formulae produce broadband peak pressure levels that are inadequate for estimating the energy levels per frequency band considered by the INPM transmission loss module. The frequency distribution of the signal was therefore derived from pressure history measurements performed at the Defence and Civil Institute of Environmental Medicine (DCIEM) for different types of weapons, suitably interpolated in the frequency domain to provide spectral estimates for other gun sizes. Specifically, the spectra for two primary gun types, a 102 mm Howitzer and a 0.5" machine gun, were used to derive an expression for source level as a function of calibre and frequency band.

Measured spectra for the two gun types were taken from a DCIEM report by Mario Mongrain (1991). The measured spectra were backpropagated to the source position by performing high-resolution runs of the PE propagation model, thus removing any effects from ground interaction that were present in the measured data. The source level interpolation is based on the intercept and slope of the function: $10 \log E = A + B \log(\text{calibre})$. This represents a variation of linear energy of the form: $E = C * \text{calibre}^D$, where $C = 10^B$ and $D = B/10$. Patter's formula for peak pressure versus calibre suggests a broadband value for D of approximately 2.8. The 1/3-octave values here range from 0.9 to 3.9, with lower frequencies having higher coefficients. The coefficient is approximately 2.8 at 80 Hz. Since energy in decibels is required, we calculated values for A and B for each frequency band and stored these results in a table for use within the GUNSL module. Having computed the spectrally distributed source levels the subroutine applies to each band the Patter formula for directivity, which causes a maximum difference of 14.3 dB between the forward (0-degree offset from muzzle direction) and reverse directions. The module output consists of either 1/3 or 1-octave source levels for the specified frequency band.

C.3. Estimating In-air Peak Levels

INPM accurately estimates the sound exposure levels at a given range and azimuth from a weapon. However, its current implementation does not provide solutions in the time domain from which the PK levels can be extracted. Because of this, PK levels in this investigation were estimated by applying the modified ideal scaling model proposed by Fansler (1997).

Fansler proposed applying a collection of empirical models based on fitting curves to measured data. The data were obtained from weapons with calibre ranging from 7.62 to 105 mm, at multiple ranges (up to ~40 m) and azimuths from the weapon.

In this report, the peak pressure (in units of Pa) was obtained as:

$$\mathrm{p}_{pk} = 10^5 \left(0.11 \frac{l(\emptyset)}{r} + 0.0061 \left(\frac{l(\emptyset)}{r}\right)^2\right), \tag{C-2}$$

where r is the range from the weapon and l is a scaled length defined as:

$$l(\emptyset) = \left(0.78 \cos\emptyset + \sqrt{1 - 0.78^2 (\sin\emptyset)^2}\right) K\,, \tag{C-3}$$

where Ø is the azimuth from the line-of-fire and K is a constant that depends on the energy of the weapon propellant, a quantity that is difficult to determine experimentally. Instead of attempting to estimate the constant K, in this modelling we used the PK levels measured at r = 1 m and $\emptyset = 0^{\circ}$ to obtain the parameter $l(0)$ from Eq.(C-4) and then $K = l(0)/1.78$. Next, peak levels were calculated at all ranges of interest and azimuths by using:

$$l(\emptyset) = \left(0.78 \cos\emptyset + \sqrt{1 - 0.78^2 (\sin\emptyset)^2}\right) \frac{l(0)}{1.78}. \tag{C-4}$$

For this modelling, RNC/USCG provided PK levels for each weapon as listed in Table C-1. Because the empirical model is based on a curve obtained by fitting data at close range from the weapon muzzle, JASCO included an additional range-dependent loss mechanism, based on the attenuation coefficient for the air. For the March atmospheric temperature and relative humidity near the air-water interface (6 °C and 78%, respectively, Figure C-6), the air attenuation coefficient is 1, 1.9, and 3.7 dB/km at frequencies 250 Hz, 500 Hz, and 1 kHz, respectively (Harris 1991). In this work, the average attenuation coefficient of 2.2 dB/km was applied to the peak levels estimated from Eq.(C-2).

Table C-1. Peak sound pressure levels at 1 m range and along the line-of-fire for the small-calibre weapons.

Weapon	$L_{p,0\text{-}pk}$ (dB re 20 µPa)
Pt	154
C8	162
M240	164
M2	164
MK38	180

C.4. Estimating Ranges to Threshold Levels

For underwater modelling, sound level contours were calculated based on the sound fields predicted by the propagation model, sampled by taking the maximum value over all modelled depths above the seafloor for each location in the modelled region. For in-air modelling, sound levels were estimated at a height of 20 cm above the water, which is representative of the position of the ears of swimming pinnipeds. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: (1) R_{max}, the maximum range to the given sound level over all azimuths, and (2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure C-3).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure C-3a. In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In contrast, in strongly radially asymmetric cases such as shown in Figure C-3b, $R_{95\%}$ neglects to account for substantial protrusions in the footprint. In such cases, R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features that affect propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

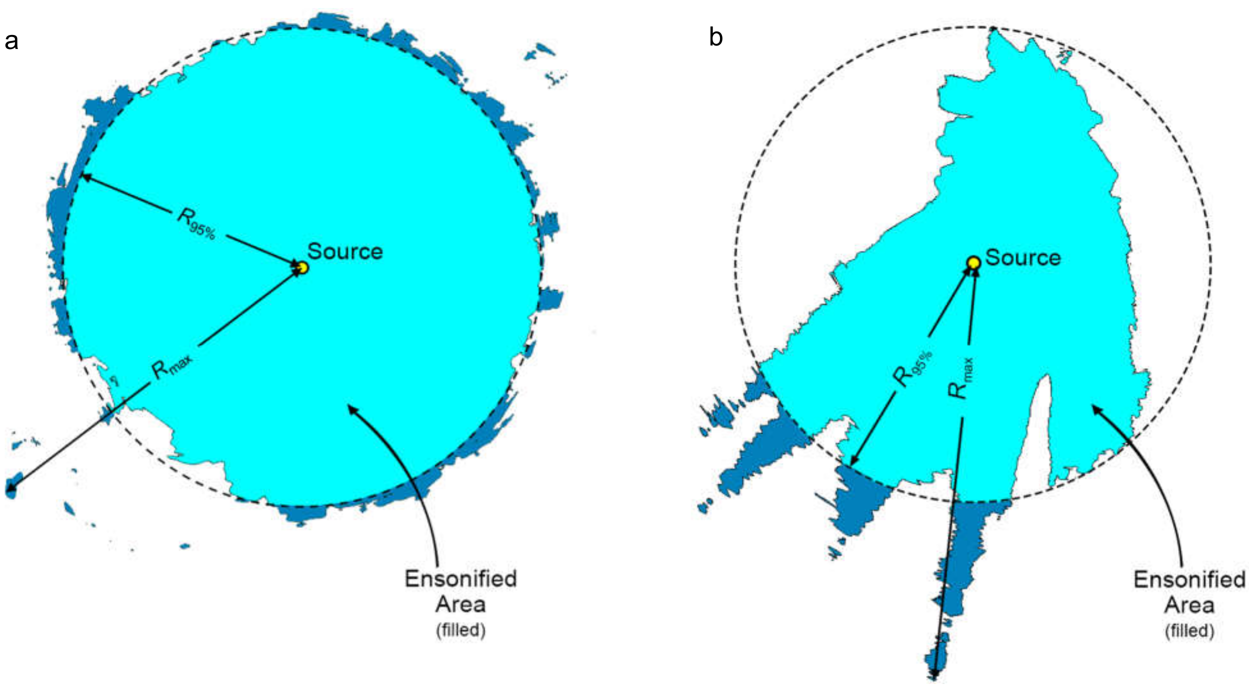
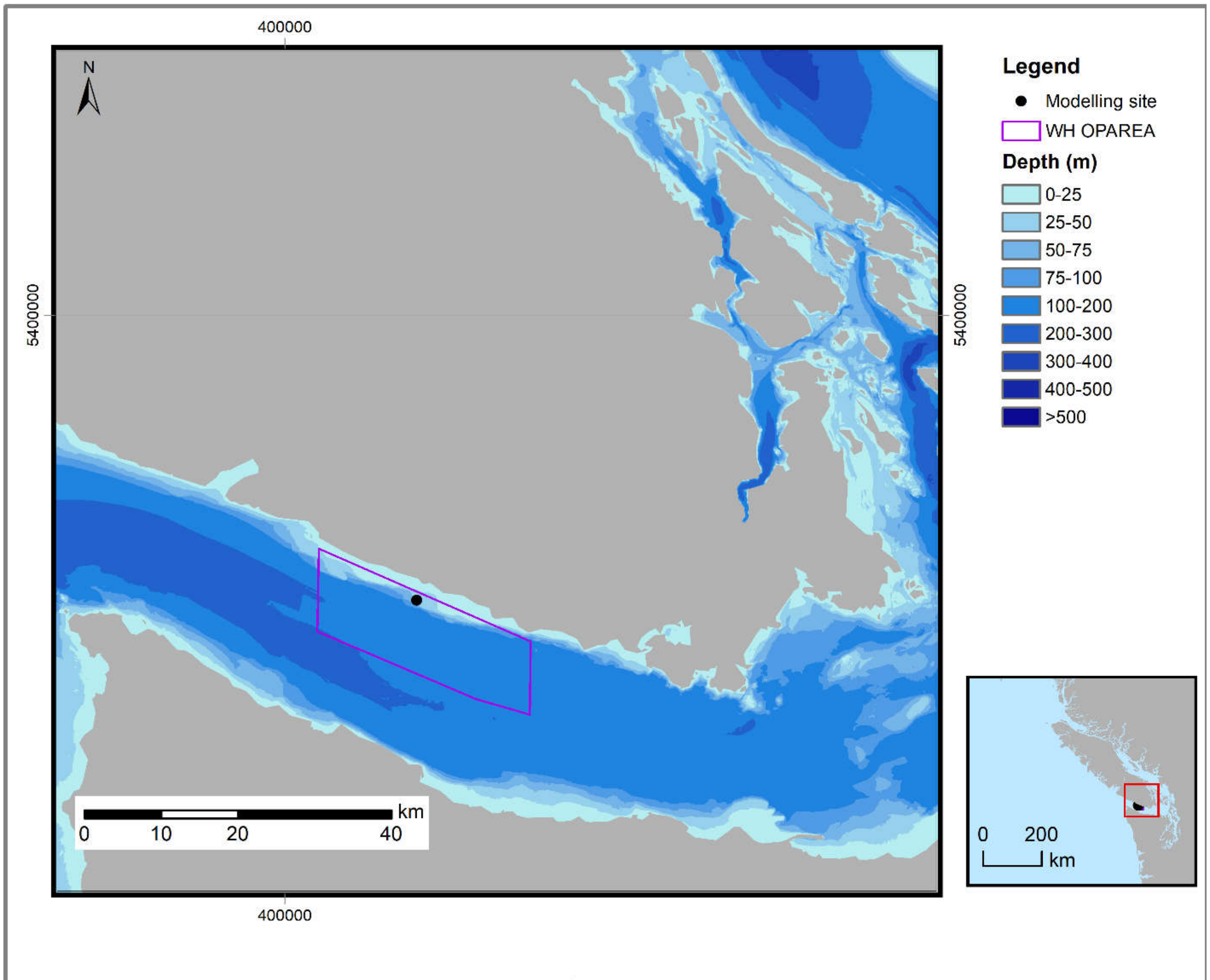


Figure C-3. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two contrasting scenarios: (a) a largely radially symmetric sound level contour with small protrusions, for which $R_{95\%}$ best represents the ensonified area; and (b) a strongly asymmetric sound level contour with long protrusions, for which R_{max} best represents the ensonified areas in some directions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the ensonified areas beyond $R_{95\%}$ that determine R_{max}.

C.5. Environmental Parameters

C.5.1. Bathymetry

Bathymetry data with a resolution of 1/3 to 1 arc-second (10 × 10 m to 30 × 30 m) were obtained from NOAA National Centre for Environmental Information (2018) for the OPAREA WH. The data were adjusted to the mean high water and re-gridded onto a UTM coordinate projection Zone 10 N (Figure C-4) with a regular grid spacing of 20 × 20 m.



OPAREA WH: Bathymetry	Datum: WGS 1984 Projection: UTM Zone 10N	JASCO APPLIED SCIENCES
MARPAC area	Created October 2019	

Figure C-4. OPAREA WH bathymetry gridded onto Universal Transverse Mercator (UTM) coordinate projection (Zone 10 N).

C.5.2. Water Sound Speed Profiles

The sound speed profile for OPAREA WH was derived from temperature and salinity profiles from the US Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the US Navy's Master Oceanographic Observational Data Set (MOODS). The temperature-salinity profiles were converted to sound speed profiles according to the equations of Coppens (1981).

Monthly mean sound speed profiles were derived from the GDEM temperature and salinity vs. depth. The January (Figure C-5) exhibits the more pronounced surface duct, and therefore was identified as the most conservative profile (i.e., the one which results in larger ranges of sound propagation) for this modelling.

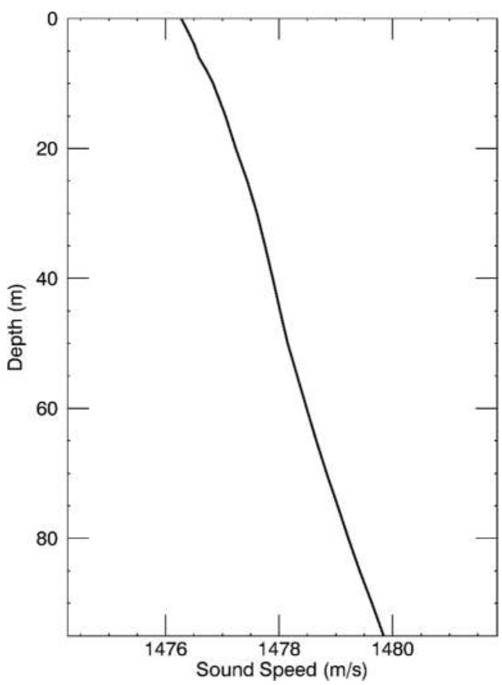


Figure C-5. January sound speed profile used for the modelling at OPAREA WH.

C.5.3. Geoacoustic Profiles

Seabed geoacoustic parameters for the OPAREA WH (West Strait of Juan de Fuca) were obtained using a combination of geoacoustic inversion results from transmission loss (TL) measurements and a review of the scientific literature (Wladichuk et al. 2014). Underwater acoustic propagation was modelled using the seabed profile described in Table C-2.

Table C-2. Geoacoustic properties for underwater acoustic modelling at OPAREA WH (West Strait of Juan de Fuca). Within each depth range, each parameter varies linearly within the stated range. The compressional wave is the primary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–50.0	Sand	1.94	1713–1763	0.90	500	3.4
>50.0	Bedrock	2.20	2275	0.10		

C.5.4. In-air Acoustic Environment

This section describes the terrain topography, terrain impedance, and atmospheric profiles which are input to INPM for this study.

First, since the military exercises occur at sea, terrain topography is assumed to be flat with elevation of 0 m. Second, the relationship between the acoustic impedance of the ground and that of the atmosphere will dictate the ratio between the amount of sound energy that is reflected into the atmosphere and the amount of sound energy that is absorbed into the ground. A single parameter describes this acoustic impedance: flow resistivity (Delany and Bazley 1970), which corresponds to 2000 kNs/m^4 for water surfaces.

Third, the atmospheric profiles used in this investigation were calculated from twice-daily weather balloon launches from Quillayute, WA, USA during 2019. Quillayute is approximately 61 km southwest of the OPAREA WH modelling location. Upper-atmospheric parameters are regionalized and therefore are representative of the upper atmospheric parameters in OPAREA WH. For each month, Quillayute data consists of elevation-dependent profiles of pressure, temperature, and dew point. Relative humidity was then calculated from temperature and dew point using the equation from Alduchov and Eskridge (1996). All the data were averaged in 50 m bins, interpolated from 0 and 3 km, and smoothed using a moving average. Pressure, temperature, dew point, and relative humidity at elevations less than 50 m were assumed to be constant because the lowest measurements at Quillayute were made at 50 m. Broadband levels for the MK38 machine gun were estimated using INPM along the shooting direction using the smooth atmospheric profiles representative of each month. The March profile (Figure C-6) yielded the most conservative results and was used to obtain all results presented in this study.

Wind velocity, unlike the other atmospheric profile parameters used in INPM, is a vector quantity. INPM uses a scalar wind speed profile that is the wind velocity projected along the modelled sound propagation radial. We used a wind velocity of zero in our model so as not to bias the sound propagation in any direction, given that there are no prevailing winds at this location.

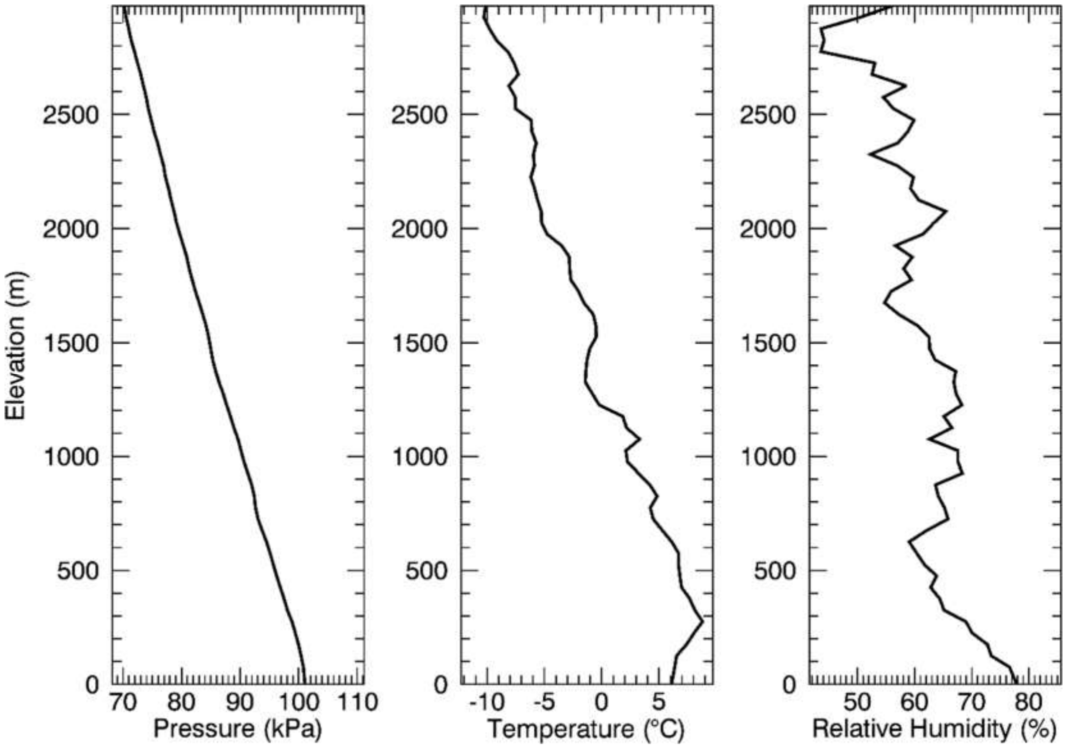


Figure C-6. Atmospheric pressure, temperature, and relative humidity March profiles used to model sound propagation from weapon firing.

Appendix D. Scenario Matrix and Client Confirmed Project Assumptions

Version Control for Scenario Matrix and Project Assumptions
Document Number: 00572
Version: 2.0
Version Date: 2016

Project Number:	P001454
Project Name:	DND Task 5: Small arms acoustic modelling
Project Manager:	Melanie Austin
Alternate PM:	
Modeller(s):	Jorge Quijano
Senior Reviewer:	Melanie Austin, Graham Warner

Changes tracking

Date	Information Type	High-level description
29-Jul-19	Created by Jorge Q.	Most entries are to be confirmed by the client
28-Aug-19	Weapon detailed description	Added details about the weapons and location provided by the client. Added 2 additional weapons.
3-Oct-19	More detailed info on weapons	Added more details about weapons source levels, model, and assumptions approved by the client

Project: P001454-003 Evaluation of Small Arms Munitions in OPAREA Whiskey Hotel (WH)
Modelling scenario: Small Calibre Firearms Modelling of underwater noise in OPAREA Whiskey Hotel (WH)

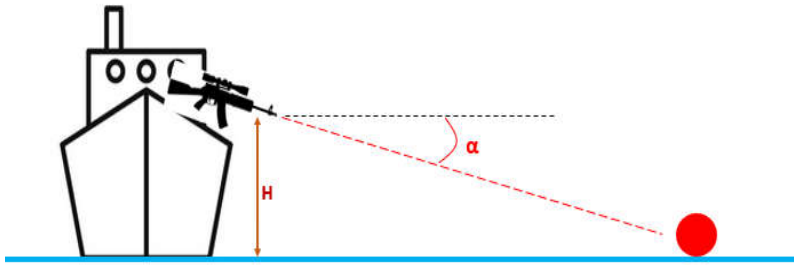
Time of year	Weapon properties (see "ShootingGeometry" tab for more details)													Environmental Parameter		
	Weapon	Calibre	Lat.	Long.	Height H above waterline (m)*	Gun azimuthal direction (°)	Gun elevation angle α (°)*	Gun elevation angle for underwater modelling (°)	Max. firing rate (rounds per min.)	# of bullets/ burst	# of bursts/ day	Total max. # of bullets/day	Source level (peak)	Sound speed profile	Seabed geoacoustics	Bathymetry
Year round: most conservative parameters TBD by JASCO	General service pistol (RCN)	9 mm	48° 24.78 471' N	124° 7.1326 0' W	12.525 (top part) to 12.6 (flight deck)	295	11 to 28	49	single shots	5 bullets/mag 2 mags/person	90 (based on per mag)	450 (based on CRR for NBP shoots)	151-154 dB re 20 uPa at 1 m	Most conservative choice	Same as WH site modelled in tasks 1-2, see Geoacoustics tab	NOAA bathymetry used in tasks 1-2, see ShootingGeometry tab
	C8 automatic rifle (RCN)	5.56 mm			12.525 (top part) to 12.6 (flight deck)		11 to 28	49	single shots	10 bullets/mag 2 mags/person	180 (based on per mag)	1800 (based on CRR for NBP shoots)	162 dB re 20 uPa at 1m			
	M240 (USCG)	7.62 mm			1.5 (USCG)		0 to 15	62	1100	3-5 warning 9-15 disabling	50-75 warning 50-75 disabling	800-1200 (JASCO will model 1200)	162 dB re 20 uPa at ~1.2 m (M240)			
	Browning M2 heavy machine gun (USCG)	0.5 calibre			10.0 or 3.0 (USCG)		0 to 20	57	635	3-5 warning 9-15 disabling	50-75 warning 50-75 disabling	800-1200 (JASCO will model 1200)	164 dB re 20 uPa at 1m			
	MK38 machine gun (USCG)	25 mm			10		0 to 20	57	180	3-5 warning 9-15 disabling	28	440	174 dB re 20 uPa at 2 m			

* See Shooting Geometry tab

red: parameters proposed by JASCO, to be confirmed by the client

purple: JASCO will determine which angle and height results in longest distances to thresholds, and only report modelling with those conservative parameters

JASCO modelling assumptions:	DND RESPONSE
• JASCO will **only model azimuth 295°**; the extent of sound in the 115° azimuth is expected to be the same.	**Understood and accepted**
• M2 0.5 calibre: From RCN, at 635 rounds/min, each 10 s burst would be 106 rounds. However, from USCG, they will have bursts of 200 rounds. To be conservative, JASCO will model 4 bursts/day, each burst consisting of 200 rounds, **for a daily total of 800 rounds**.	**Understood and accepted**
The location proposed by USCG is within the 3-mile radius from Point-no-point (MARPACORD 3350-1). For this reason, the **modelling location proposed by JASCO needs to be approved.**	**Accepted**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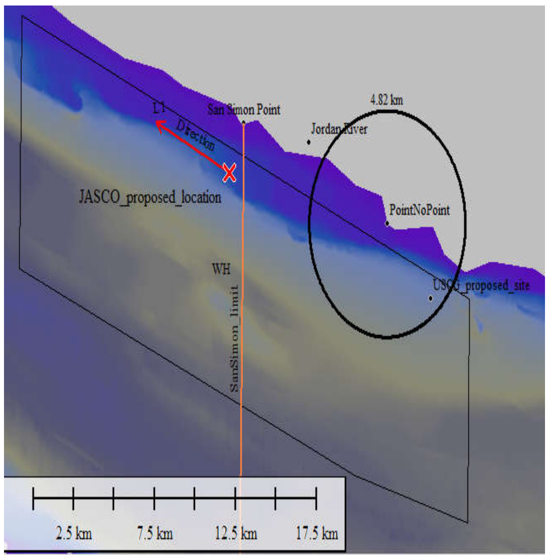
L1
Direction
San Simon Point
Jordan River
4.82 km
PointNoPoint
JASCO_proposed_location
WH
SanSimon_limit
USCG_proposed_site
2.5 km
7.5 km
12.5 km
17.5 km

United States Navy
Fact File

25mm - MK38 -
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MK 38 - 25 MM MACHINE GUN SYSTEM

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Description
The MK 38 is a 25 mm machine gun system (MGS) installed for ship self-defense to counter Fast Attack Crafts and Fast Inshore Attack Crafts.

Background
The MK 38 MOD 0 25 mm MGS replaced the MK 16 20 mm gun system and was then upgraded to a MK 38 MOD 1 MGS. A total of 387 MK 38 MOD 1 MGSs were procured and deployed in the U.S. Navy and U.S. Coast Guard. In 2003, the CNO directed the Navy to pursue a simple, stabilized, remote controlled, low cost solution for outfitting near-term deployers to counter small boat threats. In response, the Navy began fielding the MK 38 MOD 2 MGS in 2005. Due to the success of the MK 38 MOD 2 MGS, the program scope was expanded in July 2012 to add several ship classes and to develop a modification to the system. This modification is known as the MK 38 MOD 3 MGS, which is a technical refresh of the MK 38 MOD 2 MGS. The first MK 38 MOD 3 MGS is to be fielded in FY17. As of 2018, 341 MK 38 MOD 2 and MOD 3 systems have been delivered. The total number of systems within the Program of Record is 501.

Installed aboard CG, CVN, DDG, LSD, LHD, LHA, LCC, MK VI, PC, OSV, AS and USCG FRC class ships and planned for installation aboard USCG OPC and WMEC class cutters, the MK 38 MGS is a low cost, stabilized self-defense weapon system that dramatically improves ships' self-defense capabilities.

Point Of Contact
Office of Corporate Communication
Naval Sea Systems Command (OOD)
Washington, D.C. 20376

General Characteristics
Primary Function: 25 mm single barrel, air cooled, semi- and full-automatic, remotely and manually trained and elevated main machine gun system.
Optional Secondary Function:7.62mm single-barrel, air-cooled, automatic, remotely trained and elevated coaxial machine gun system.
Contractor: Contractor MOD 2/3: BAE Systems Minneapolis, Minnesota; Rafael, Haifa, Israel.
Date Deployed: 2005; 341 systems installed as of December 2018.
Range: 2500 yards (effective range)
Type Fire: 25 mm: Single shot or Burst Mode; Maximum 180 rounds per minute automatic. **7.62 mm:** 500 rounds per minute automatic.
Caliber: 25 mm (1 inch).
Guidance System: Mod 2/3: Stabilized, remotely operated, electro-optical sensor, fire control system, and auto-tracking.
Platforms: The MK 38 MGS is intended for installation and operation on board the U.S. Navy AS, CG, CVN, DDG, LCC, LHA, LHD, LPD, LSD, OSV, PC class ships, MK VI Patrol Boats, and U.S. Coast Guard FRC, OPC, and WMEC 270' class ships.

Browning M2 0.5 calibre Heavy Machine Gun: http://www.army-armee.forces.gc.ca/en/weapons/m2-browning-machine-gun.page

Browning M2 .50-Cal. Heavy Machine Gun

Description | Specifications | Ammo

Description

The Browning M2 .50-calibre heavy machine gun is belt fed, recoil operated, heavy barrel, and air-cooled. The standard ammunition is C44 armour piercing tracer which is fired from a disintegrating link belt, fed from the right or left and operated and fired electrically or mechanically.

This flexible weapon can be adapted to a variety of combat vehicles and ground mounts. It may be mounted on vehicles or on a tripod for ground operations, or dismounted to provide supporting fire.

Photo Gallery

Browning M2 .50-Cal. Heavy Machine Gun

Description | Specifications | Ammo

Specifications

- Weight: 38 kg
- Sustained rate of fire: 40 rounds per minute
- Maximum rate of fire: 635 rounds per minute
- Maximum range of fire: 1850 m
- Effective range of fire against armour: 600 m

7.62mm - M240 machine gun https://fnamerica.com/products/machine-guns/fn-m240b/

9mm–Sig Sauer P225 handgun https://www.sigsauer.com/products/firearms/pistols/p225/

Colt Canada C8

5.56mm – C8 assault rifle http://www.military-today.com/firearms/c8.htm

The Canadian C8 carbine is equivalent to the US Colt M4

Country of origin	Canada
Entered service	1994
Caliber	5.56x45 mm NATO
Weight (unloaded)	~ 2.5 kg
Length	~ 840 mm
Length (with folded stock)	~ 760 mm
Barrel length	368 mm
Muzzle velocity	840 m/s
Cyclic rate of fire	700 - 950 rpm
Practical rate of fire	40 - 100 rpm
Magazine capacity	30 rounds
Sighting range	600 m
Range of effective fire	~ 360 m

The Canadian C8 carbine was revealed in 1983. It is a modified license-produced version of the US Colt Model 723 (M4) carbine. Technical data package was provided by Colt to the Canadian Government. However Canadian Diemaco reviewed the design and made numerous changes to this weapon, before it entered production. These changes include materials and manufacturing processes. Improvements are similar to those of the C7 assault rifle. The C8 can be seen as a compact version of the C7 for the troops that do not need a full-size assault rifle, such as vehicle drivers, artillery crews, airborne troops and special operation units. The C8 carbine was adopted in 1994. Currently it is used by the Canadian armed forces. Also this weapon has been exported to the United Kingdom, where it is used by special forces and military police. In 2005 Diemaco was acquired by Colt Defense and became known as Colt Canada Corporation.

EXPAND IMAGE

The geoacoustics below were used to model sonar acoustic propagation for site WH for tasks 1-2.

Table C-5. Geoacoustic properties for MARPAC source location WH (West Strait of Juan de Fuca). Within each depth range, each parameter varies linearly within the stated range. The compressional wave is the primary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–50.0	Sand	1.94	1713–1763	0.90	500	3.4
>50.0	Bedrock	2.20	2275	0.10		

ANNEX C

Quantitative Analysis - Number of Individuals Potentially Affected Based on Density Estimates

Table C-1: Number of Pinnipeds Potentially Exposed to In-air Noise from Small Arms Munitions at Received Levels in Exceedance of Weighted Sound Exposure Level (SEL_{24h}) TTS and PTS Thresholds (Southall et al. 2019)

Source	Species (functional hearing group)	Threshold (dB re 20 μPa²·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		TTS	PTS	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Pt	ES (PCA)	123	138	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019
Pt	HS (PCA)	123	138	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Pt	SSL (OCA)	146	161	0	0	0	0	0	0	0	0
Pt	CSL (OCA)	146	161	0	0	0	0	0	0	0	0
C8	ES (PCA)	123	138	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019
C8	HS (PCA)	123	138	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
C8	SSL (OCA)	146	161	0	0	0	0	0	0	0	0
C8	CSL (OCA)	146	161	0	0	0	0	0	0	0	0
M240	ES (PCA)	123	138	0.00004	0.00004	0.00004	0.00004	0.0000019	0.0000019	0.0000019	0.0000019
M240	HS (PCA)	123	138	0.021	0.021	0.021	0.021	0.001	0.001	0.001	0.001
M240	SSL (OCA)	146	161	0	0	0	0	0	0	0	0
M240	CSL (OCA)	146	161	0	0	0	0	0	0	0	0
M2	ES (PCA)	123	138	0.00017	0.00017	0.00017	0.00017	0.0000075	0.0000075	0.0000075	0.0000075
M2	HS (PCA)	123	138	0.088	0.088	0.088	0.088	0.004	0.004	0.004	0.004
M2	SSL (OCA)	146	161	0.00029	0.00029	0.00029	0.00029	0	0	0	0
M2	CSL (OCA)	146	161	0.00021	0.00021	0.00021	0.00021	0	0	0	0
MK38	ES (PCA)	123	138	0.00019	0.00019	0.00019	0.00019	0.0000019	0.0000019	0.0000019	0.0000019

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Functional Hearing Groups: PCA =Phocid carnivores in Air, OCA = Other marine carnivores in air, Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Source	Species (functional hearing group)	Threshold (dB re 20 μPa^2·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		TTS	PTS	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
MK38	HS (PCA)	123	138	0.098	0.098	0.098	0.098	0.001	0.001	0.001	0.001
MK38	SSL (OCA)	146	161	0.00029	0.00029	0.00029	0.00029	0	0	0	0
MK38	CSL (OCA)	146	161	0.00021	0.00021	0.00021	0.00021	0	0	0	0
M2 & M240	ES (PCA)	123	138	0.00019	0.00019	0.00019	0.00019	0.0000091	0.0000091	0.0000091	0.0000091
M2 & M240	HS (PCA)	123	138	0.098	0.098	0.098	0.098	0.0048	0.0048	0.0048	0.0048
M2 & M240	SSL (OCA)	146	161	0.00014	0.00014	0.00014	0.00014	0	0	0	0
M2 & M240	CSL (OCA)	146	161	0.0001	0.0001	0.0001	0.0001	0	0	0	0
M2 & MK38	ES (PCA)	123	138	0.00032	0.00032	0.00032	0.00032	0.00001	0.00001	0.00001	0.00001
M2 & MK38	HS (PCA)	123	138	0.17	0.17	0.17	0.17	0.0053	0.0053	0.0053	0.0053
M2 & MK38	SSL (OCA)	146	161	0.00029	0.00029	0.00029	0.00029	0	0	0	0
M2 & MK38	CSL (OCA)	146	161	0.00021	0.00021	0.00021	0.00021	0	0	0	0
C8 & Pt	ES (PCA)	123	138	0.000034	0.000034	0.000034	0.000034	0.0000019	0.0000019	0.0000019	0.0000019
C8 & Pt	HS (PCA)	123	138	0.018	0.018	0.018	0.018	0.00998	0.00998	0.00998	0.00998
C8 & Pt	SSL (OCA)	146	161	0	0	0	0	0	0	0	0
C8 & Pt	CSL (OCA)	146	161	0	0	0	0	0	0	0	0

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Functional Hearing Groups: PCA =Phocid carnivores in Air, OCA = Other marine carnivores in air, Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Table C-2: Number of Pinnipeds Potentially Exposed to In-air Noise from Small Arms Munitions at Received Levels in Exceedance of Peak Sound Pressure Level (SPL_{peak}) TTS and PTS Thresholds (Southall et al. 2019)

Source	Species (functional hearing group)	Threshold (dB re 20 µPa)		TTS (Number of Animals)				PTS (Number of Animals)			
		TTS	PTS	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Pt	ES (PCA)	138	144	0.0000019	0.0000019	0.0000019	0.0000019	0.00000047	0.00000047	0.00000047	0.00000047
Pt	HS (PCA)	138	144	0.001	0.001	0.001	0.001	0.00025	0.00025	0.00025	0.00025
Pt	SSL (OCA)	161	167	0	0	0	0	0	0	0	0
Pt	CSL (OCA)	161	167	0	0	0	0	0	0	0	0
C8	ES (PCA)	138	144	0.0000061	0.0000061	0.0000061	0.0000061	0.0000019	0.0000019	0.0000019	0.0000019
C8	HS (PCA)	138	144	0.0032	0.0032	0.0032	0.0032	0.001	0.001	0.001	0.001
C8	SSL (OCA)	161	167	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029
C8	CSL (OCA)	161	167	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
M240	ES (PCA)	138	144	0.0000083	0.0000083	0.0000083	0.0000083	0.0000023	0.0000023	0.0000023	0.0000023
M240	HS (PCA)	138	144	0.0044	0.0044	0.0044	0.0044	0.0012	0.0012	0.0012	0.0012
M240	SSL (OCA)	161	167	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029
M240	CSL (OCA)	161	167	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
M2	ES (PCA)	138	144	0.0000091	0.0000091	0.0000091	0.0000091	0.0000027	0.0000027	0.0000027	0.0000027
M2	HS (PCA)	138	144	0.0048	0.0048	0.0048	0.0048	0.0014	0.0014	0.0014	0.0014
M2	SSL (OCA)	161	167	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029
M2	CSL (OCA)	161	167	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
MK38	ES (PCA)	138	144	0.00029	0.00029	0.00029	0.00029	0.000077	0.000077	0.000077	0.000077

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Functional Hearing Groups: PCA =Phocid carnivores in Air, OCA = Other marine carnivores in air, Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Source	Species (functional hearing group)	Threshold (dB re 20 µPa)		TTS (Number of Animals)				PTS (Number of Animals)			
		TTS	PTS	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
MK38	HS (PCA)	138	144	0.15	0.15	0.15	0.15	0.041	0.041	0.041	0.041
MK38	SSL (OCA)	161	167	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029
MK38	CSL (OCA)	161	167	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
M2 & M240	ES (PCA)	138	144	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
M2 & M240	HS (PCA)	138	144	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
M2 & M240	SSL (OCA)	161	167	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
M2 & M240	CSL (OCA)	161	167	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
M2 & MK38	ES (PCA)	138	144	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
M2 & MK38	HS (PCA)	138	144	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
M2 & MK38	SSL (OCA)	161	167	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
M2 & MK38	CSL (OCA)	161	167	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C8 & Pt	ES (PCA)	138	144	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C8 & Pt	HS (PCA)	138	144	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C8 & Pt	SSL (OCA)	161	167	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C8 & Pt	CSL (OCA)	161	167	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Functional Hearing Groups: PCA =Phocid carnivores in Air, OCA = Other marine carnivores in air, Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Table C-3: Number of Pinnipeds Potentially Exposed to In-Air Noise from Small Arms Munitions at Received Levels in Exceedance of SEL_{24h} and SPL_{peak} PTS (M_{pa} weighted) (Southall et al. 2007)

Source	Species	Number of Animals (SEL_{24h} 144 dB re 20 µPa2·s)				Number of Animals (SPL_{peak} 149 dB re 20 µPa)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Pt	ES	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019
Pt	HS	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Pt	SSL	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029
Pt	CSL	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
C8	ES	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019	0.0000019
C8	HS	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
C8	SSL	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029
C8	CSL	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
M240	ES	0.0000023	0.0000023	0.0000023	0.0000023	0.0000019	0.0000019	0.0000019	0.0000019
M240	HS	0.0012	0.0012	0.0012	0.0012	0.001	0.001	0.001	0.001
M240	SSL	0.00036	0.00036	0.00036	0.00036	0.00029	0.00029	0.00029	0.00029
M240	CSL	0.00026	0.00026	0.00026	0.00026	0.00021	0.00021	0.00021	0.00021
M2	ES	0.000016	0.000016	0.000016	0.000016	0.00000092	0.00000092	0.00000092	0.00000092
M2	HS	0.0084	0.0084	0.0084	0.0084	0.00049	0.00049	0.00049	0.00049
M2	SSL	0.0025	0.0025	0.0025	0.0025	0.00014	0.00014	0.00014	0.00014
M2	CSL	0.0018	0.0018	0.0018	0.0018	0.0001	0.0001	0.0001	0.0001
MK38	ES	0.0000075	0.0000075	0.0000075	0.0000075	0.000024	0.000024	0.000024	0.000024
MK38	HS	0.004	0.004	0.004	0.004	0.013	0.013	0.013	0.013

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion.

Source	Species	Number of Animals (SEL_{24h} 144 dB re 20 µPa2·s)				Number of Animals (SPL_{peak} 149 dB re 20 µPa)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
MK38	SSL	0.0012	0.0012	0.0012	0.0012	0.0038	0.0038	0.0038	0.0038
MK38	CSL	0.00085	0.00085	0.00085	0.00085	0.0028	0.0028	0.0028	0.0028
M2 & M240	ES	0.000018	0.000018	0.000018	0.000018	n/a	n/a	n/a	n/a
M2 & M240	HS	0.0096	0.0096	0.0096	0.0096	n/a	n/a	n/a	n/a
M2 & M240	SSL	0.0028	0.0028	0.0028	0.0028	n/a	n/a	n/a	n/a
M2 & M240	CSL	0.002	0.002	0.002	0.002	n/a	n/a	n/a	n/a
M2 & MK38	ES	0.000029	0.000029	0.000029	0.000029	n/a	n/a	n/a	n/a
M2 & MK38	HS	0.015	0.015	0.015	0.015	n/a	n/a	n/a	n/a
M2 & MK38	SSL	0.0045	0.0045	0.0045	0.0045	n/a	n/a	n/a	n/a
M2 & MK38	CSL	0.0032	0.0032	0.0032	0.0032	n/a	n/a	n/a	n/a
C8 & Pt	ES	0.0000019	0.0000019	0.0000019	0.0000019	n/a	n/a	n/a	n/a
C8 & Pt	HS	0.000998	0.000998	0.000998	0.000998	n/a	n/a	n/a	n/a
C8 & Pt	SSL	0.000294	0.000294	0.000294	0.000294	n/a	n/a	n/a	n/a
C8 & Pt	CSL	0.000212	0.000212	0.000212	0.000212	n/a	n/a	n/a	n/a

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion.

Table C-4: Number of Pinnipeds Potentially Exposed to In-Air Noise from Small Arms Munitions at Received Levels in Exceedance of SEL_{24h} and SPL_{peak} Behavioural thresholds (Southall et al. 2007)

Source	Species	Number of Animals (SEL_{24h} 100 dB re 20 µPa2·s)				Number of Animals (SPL_{peak} 109 dB re 20 µPa)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Pt	ES	0.014	0.014	0.014	0.014	0.00078	0.00078	0.00078	0.00078
Pt	HS	7.3	7.3	7.3	7.3	0.42	0.42	0.42	0.42
Pt	SSL	2.2	2.2	2.2	2.2	0.12	0.12	0.12	0.12
Pt	CSL	1.6	1.6	1.6	1.6	0.088	0.088	0.088	0.088
C8	ES	0.011	0.011	0.011	0.011	0.0034	0.0034	0.0034	0.0034
C8	HS	5.7	5.7	5.7	5.7	1.8	1.8	1.8	1.8
C8	SSL	1.7	1.7	1.7	1.7	0.54	0.54	0.54	0.54
C8	CSL	1.2	1.2	1.2	1.2	0.39	0.39	0.39	0.39
M240	ES	0.025	0.025	0.025	0.025	0.0047	0.0047	0.0047	0.0047
M240	HS	13	13	13	13	2.5	2.5	2.5	2.5
M240	SSL	3.8	3.8	3.8	3.8	0.73	0.73	0.73	0.73
M240	CSL	2.8	2.8	2.8	2.8	0.53	0.53	0.53	0.53
M2	ES	0.2	0.2	0.2	0.2	0.0051	0.0051	0.0051	0.0051
M2	HS	106	106	106	106	2.7	2.7	2.7	2.7
M2	SSL	31	31	31	31	0.79	0.79	0.79	0.79
M2	CSL	23	23	23	23	0.57	0.57	0.57	0.57
MK38	ES	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
MK38	HS	222	222	222	222	222	222	222	222

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion.

Source	Species	Number of Animals (SEL_{24h} 100 dB re 20 µPa2·s)				Number of Animals (SPL_{peak} 109 dB re 20 µPa)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
MK38	SSL	65	65	65	65	65	65	65	65
MK38	CSL	47	47	47	47	47	47	47	47
M2 & M240	ES	0.25	0.25	0.25	0.25	n/a	n/a	n/a	n/a
M2 & M240	HS	134	134	134	134	n/a	n/a	n/a	n/a
M2 & M240	SSL	39	39	39	39	n/a	n/a	n/a	n/a
M2 & M240	CSL	29	29	29	29	n/a	n/a	n/a	n/a
M2 & MK38	ES	0.62	0.62	0.62	0.62	n/a	n/a	n/a	n/a
M2 & MK38	HS	331	331	331	331	n/a	n/a	n/a	n/a
M2 & MK38	SSL	97	97	97	97	n/a	n/a	n/a	n/a
M2 & MK38	CSL	70	70	70	70	n/a	n/a	n/a	n/a
C8 & Pt	ES	0.20	0.20	0.20	0.20	n/a	n/a	n/a	n/a
C8 & Pt	HS	10.82	10.82	10.82	10.82	n/a	n/a	n/a	n/a
C8 & Pt	SSL	3.2	3.2	3.2	3.2	n/a	n/a	n/a	n/a
C8 & Pt	CSL	2.3	2.3	2.3	2.3	n/a	n/a	n/a	n/a

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion.

Table C-5: Number of Marine Mammals Potentially Exposed to Underwater Noise from Small Arms Munitions at Received Levels in Exceedance of Weighted SEL_{24h} TTS and PTS Thresholds (NMFS 2018)

Source	Species (hearing group)	Threshold (dB re 1 µPa²·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		TTS	PTS	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Pt	HW (LFC)	168	183	0	0	0	n/a	0	0	0	0
Pt	GW (LFC)	168	183	0	0	0	0	0	0	0	0
Pt	MW (LFC)	168	183	0	0	0	0	0	0	0	0
Pt	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
Pt	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0
Pt	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
Pt	HP (HFC)	140	155	0.00066	0.00066	0.00066	0.00066	0	0	0	0
Pt	DP (HFC)	140	155	0.00017	0.00017	0.00017	0.00017	0	0	0	0
Pt	ES (PW)	170	185	0	0	0	0	0	0	0	0
Pt	HS (PW)	170	185	0	0	0	0	0	0	0	0
Pt	SSL (OW)	188	203	0	0	0	0	0	0	0	0
Pt	CSL (OW)	188	203	0	0	0	0	0	0	0	0
C8	HW (LFC)	168	183	0	0	0	n/a	0	0	0	0
C8	GW (LFC)	168	183	0	0	0	0	0	0	0	0
C8	MW (LFC)	168	183	0	0	0	0	0	0	0	0
C8	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
C8	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: HW=Humpback whale, GW= Gray whale, MW=Minke whale, SRKW=Southern resident killer whale, TKW=Transient killer whale, PWSD=Pacific white-sided dolphin, HP=Harbour porpoise, DP=Dall's porpoise, ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Source	Species (hearing group)	Threshold (dB re 1 μPa²·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		TTS	PTS	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
C8	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
C8	HP (HFC)	140	155	0.00066	0.00066	0.00066	0.00066	0	0	0	0
C8	DP (HFC)	140	155	0.00017	0.00017	0.00017	0.00017	0	0	0	0
C8	ES (PW)	170	185	0	0	0	0	0	0	0	0
C8	HS (PW)	170	185	0	0	0	0	0	0	0	0
C8	SSL (OW)	188	203	0	0	0	0	0	0	0	0
C8	CSL (OW)	188	203	0	0	0	0	0	0	0	0
M240	HW (LFC)	168	183	6.3E-09	4.4E-08	1.1E-05	n/a	0	0	0	n/a
M240	GW (LFC)	168	183	1.6E-06	1.6E-06	4.4E-08	4.4E-08	0	0	0	0
M240	MW (LFC)	168	183	0.00000628	0.00000628	0.00000628	0.00000628	0	0	0	0
M240	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
M240	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0
M240	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
M240	HP (HFC)	140	155	0.00066	0.00066	0.00066	0.00066	0	0	0	0
M240	DP (HFC	140	155	0.00017	0.00017	0.00017	0.00017	0	0	0	0
M240	ES (PW)	170	185	0	0	0	0	0	0	0	0
M240	HS (PW)	170	185	0	0	0	0	0	0	0	0
M240	SSL (OW)	188	203	0	0	0	0	0	0	0	0

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: HW=Humpback whale, GW= Gray whale, MW=Minke whale, SRKW=Southern resident killer whale, TKW=Transient killer whale, PWSD=Pacific white-sided dolphin, HP=Harbour porpoise, DP=Dall's porpoise, ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Source	Species (hearing group)	Threshold (dB re 1 µPa²·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		TTS	PTS	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
M240	CSL (OW)	188	203	0	0	0	0	0	0	0	0
M2	HW (LFC)	168	183	6.3E-09	4.4E-08	1.1E-05	n/a	0	0	0	n/a
M2	GW (LFC)	168	183	1.6E-06	1.6E-06	4.4E-08	4.4E-08	0	0	0	0
M2	MW (LFC)	168	183	0.00000628	0.00000628	0.00000628	0.00000628	0	0	0	0
M2	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
M2	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0
M2	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
M2	HP (HFC)	140	155	0.0013	0.0013	0.0013	0.0013	0.00066	0.00066	0.00066	0.00066
M2	DP (HFC)	140	155	0.00034	0.00034	0.00034	0.00034	0.00017	0.00017	0.00017	0.00017
M2	ES (PW)	170	185	0.000001884	0.000001884	0.000001884	0.000001884	0	0	0	0
M2	HS (PW)	170	185	0.001	0.001	0.001	0.001	0	0	0	0
M2	SSL (OW)	188	203	0	0	0	0	0	0	0	0
M2	CSL (OW)	188	203	0	0	0	0	0	0	0	0
MK38	HW (LFC)	168	183	6.3E-09	4.4E-08	1.1E-05	n/a	0	0	0	n/a
MK38	GW (LFC)	168	183	1.6E-06	1.6E-06	4.4E-08	4.4E-08	0	0	0	0
MK38	MW (LFC)	168	183	0.00000628	0.00000628	0.00000628	0.00000628	0	0	0	0
MK38	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
MK38	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: HW=Humpback whale, GW= Gray whale, MW=Minke whale, SRKW=Southern resident killer whale, TKW=Transient killer whale, PWSD=Pacific white-sided dolphin, HP=Harbour porpoise, DP=Dall's porpoise, ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Source	Species (hearing group)	Threshold (dB re 1 µPa²·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring
MK38	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
MK38	HP (HFC)	140	155	0.0008	0.0008	0.0008	0.0008	0	0	0	0
MK38	DP (HFC)	140	155	0.00021	0.00021	0.00021	0.00021	0	0	0	0
MK38	ES (PW)	170	185	0.000001884	0.000001884	0.000001884	0.000001884	0	0	0	0
MK38	HS (PW)	170	185	0.001	0.001	0.001	0.001	0	0	0	0
MK38	SSL (OW)	188	203	0	0	0	0	0	0	0	0
MK38	CSL (OW)	188	203	0	0	0	0	0	0	0	0
M2/M240	HW (LFC)	168	183	6.3E-09	4.4E-08	1.1E-05	n/a	0	0	0	n/a
M2/M240	GW (LFC)	168	183	1.6E-06	1.6E-06	4.4E-08	4.4E-08	0	0	0	0
M2/M240	MW (LFC)	168	183	0.00000628	0.00000628	0.00000628	0.00000628	0	0	0	0
M2/M240	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
M2/M240	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0
M2/M240	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
M2/M240	HP (HFC)	140	155	0.0015	0.0015	0.0015	0.0015	0.00066	0.00066	0.00066	0.00066
M2/M240	DP (HFC)	140	155	0.00039	0.00039	0.00039	0.00039	0.00017	0.00017	0.00017	0.00017
M2/M240	ES (PW)	170	185	0.000001884	0.000001884	0.000001884	0.000001884	0	0	0	0
M2/M240	HS (PW)	170	185	0.001	0.001	0.001	0.001	0	0	0	0
M2/M240	SSL (OW)	188	203	0	0	0	0	0	0	0	0

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: HW=Humpback whale, GW= Gray whale, MW=Minke whale, SRKW=Southern resident killer whale, TKW=Transient killer whale, PWSD=Pacific white-sided dolphin, HP=Harbour porpoise, DP=Dall's porpoise, ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Source	Species (hearing group)	Threshold (dB re 1 µPa²·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring
M2/M240	CSL (OW)	188	203	0	0	0	0	0	0	0	0
M2/MK38	HW (LFC)	168	183	6.3E-09	4.4E-08	1.1E-05	n/a	0	0	0	n/a
M2/MK38	GW (LFC)	168	183	1.6E-06	1.6E-06	4.4E-08	4.4E-08	0	0	0	0
M2/MK38	MW (LFC)	168	183	0.00000628	0.00000628	0.00000628	0.00000628	0	0	0	0
M2/MK38	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
M2/MK38	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0
M2/MK38	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
M2/MK38	HP (HFC)	140	155	0.0024	0.0024	0.0024	0.0024	0.00066	0.00066	0.00066	0.00066
M2/MK38	DP (HFC)	140	155	0.00063	0.00063	0.00063	0.00063	0.00017	0.00017	0.00017	0.00017
M2/MK38	ES (PW)	170	185	0.000001884	0.000001884	0.000001884	0.000001884	0	0	0	0
M2/MK38	HS (PW)	170	185	0.001	0.001	0.001	0.001	0	0	0	0
M2/MK38	SSL (OW)	188	203	0	0	0	0	0	0	0	0
M2/MK38	CSL (OW)	188	203	0	0	0	0	0	0	0	0
C8/Pt	HW (LFC)	168	183	6.3E-09	4.4E-08	1.1E-05	n/a	0	0	0	n/a
C8/Pt	GW (LFC)	168	183	1.6E-06	1.6E-06	4.4E-08	4.4E-08	0	0	0	0
C8/Pt	MW (LFC)	168	183	0.00000628	0.00000628	0.00000628	0.00000628	0	0	0	0
C8/Pt	SRKW (MFC)	170	185	0	0	0	0	0	0	0	0
C8/Pt	TKW (MFC)	1709	185	0	0	0	0	0	0	0	0

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: HW=Humpback whale, GW= Gray whale, MW=Minke whale, SRKW=Southern resident killer whale, TKW=Transient killer whale, PWSD=Pacific white-sided dolphin, HP=Harbour porpoise, DP=Dall's porpoise, ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

Source	Species (hearing group)	Threshold (dB re 1 µPa²·s)		TTS (Number of Animals)				PTS (Number of Animals)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring
C8/Pt	PWSD (MFC)	1709	185	0	0	0	0	0	0	0	0
C8/Pt	HP (HFC)	140	155	0.00066	0.00066	0.00066	0.00066	0	0	0	0
C8/Pt	DP (HFC)	140	155	0.00017	0.00017	0.00017	0.00017	0	0	0	0
C8/Pt	ES (PW)	170	185	0	0	0	0	0	0	0	0
C8/Pt	HS (PW)	170	185	0	0	0	0	0	0	0	0
C8/Pt	SSL (OW)	188	203	0	0	0	0	0	0	0	0
C8/Pt	CSL (OW)	188	203	0	0	0	0	0	0	0	0

Notes: Pt = general service pistol, C8 = automatic rifle, M240 = M240 machine gun, M2 = Browning M2 heavy machine gun, MK38 = MK38 machine gun. N/A = Not applicable, peak thresholds do not apply to aggregate scenarios. Species: HW=Humpback whale, GW= Gray whale, MW=Minke whale, SRKW=Southern resident killer whale, TKW=Transient killer whale, PWSD=Pacific white-sided dolphin, HP=Harbour porpoise, DP=Dall's porpoise, ES=Northern elephant seal, HS=harbour seal, SSL=Steller sea lion, CSL=California sea lion

ANNEX D

Literature Review - Dive Durations for Marine Mammal Species in OPAREA WH

Table D-1: Reported Marine Mammal Dive Durations in MARPAC OPAREA WH

Species	Recorded Dive Time	Reference
Humpback whale	Dives tended to be short (57.4% were less than 2.8 min in duration) and shallow (84.6% were to depths of less than 60 m)	Dolphin 1987
Humpback whale	Migrating humpbacks were recorded to undergo dives of approximately 6 min with maximum values around 13 min	Kavanagh et al. 2017
Humpback whale and fin whale	During a tagging study near Kodiak Island, Alaska, dive times ranged from 5 to 7 min with SD of 0.4 to 1.8	Witteveen et al. 2015
Grey whale	Mean dive times during foraging were 2.24 min and ranged from 8 seconds to 11 min	Stelle et al. 2008
Blue whale	Average duration of true dives (dives >I min) ranged from 4.2 to 7.2 min	Lagerquist et al. 2000
Transient killer whale	Dive times have been recorded in the range of 1 to 13 min	Morton 1990
Resident killer whale	Dive times have been recorded in the range of 0.8 to 4.1 min with median dives of 2.4 to 3.6 min depending on behaviour	Morton 1990 Wright et al. 2017
Sperm whale	Dives lasted from 18 min to 1 h and 13 min, averaging 33 and 41 min on different days	Watkins et al. 1993
Harbour porpoise	Dive information collected from free-ranging harbour porpoise indicated that most dives were less than 2 min and max dive times were < 321 sec. Longer deeper dives were most common at night.	Westgate et al. 1995
Harbour seal	Dive times were generally a few minutes long with the longest dive recorded being 31 min	Ries et al. 2011

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ANNEX E

Additional Sensitive Areas and Timing Windows for Marine Mammals in Strait of Juan de Fuca

Fisheries and Oceans Canada (DFO) has defined Important Areas (IAs) that should be considered when determining the timing of small arms munition training in MARPAC OPAREA WH for the purposes of protecting marine mammals from in-air and underwater noise. A summary of these areas and the timing of expected peak abundances is presented in Table E-1, with an overview provided below.

DFOs IAs were identified by a panel of experts using the Delphic method[1] to support Phase 1 of DFO's process for defining Ecologically and Biologically Significant Areas (EBSAs) for the Pacific marine ecoregions (Levesque and Jamieson 2015). Marine mammal IAs were selected based on the following information 1) research survey data, 2) opportunistic marine mammal sightings recorded by the BC Cetacean Sightings Network (BCCSN), which is a partnership between the Vancouver Aquarium and DFO, and 3) historical whaling data (held by DFO). Phase II (Jamieson and Levesque 2014) and III (in-progress) of the process will result in the identification of EBSAs (Phase II) and the development of management strategies within those EBSAs (Phase III). Once Phase III is completed, management strategies within these areas should be reviewed for compliance with the current proposed mitigation measures.

IAs were used instead of EBSAs for the purposes of this evaluation as they are derived for individual marine mammal species. Species-specific IAs are more relevant than EBSAs for the purpose of informing management initiatives related to underwater noise as the effects of noise on marine mammals varies amongst species (e.g., thresholds vary for different functional marine mammal hearing groups). Some IAs are seasonal (e.g., winter haul-outs) and others are year-round for resident species (harbour porpoise).

Grey whale IAs along the west coast of Vancouver Island were designed to protect the migration route and known foraging locations for this species (Levesque and Jamieson 2015). Although most individuals travel through the IAs to more northerly feeding locations, some individuals (mainly juveniles) remain during the summer months to feed within these defined IAs off Vancouver Island. Other migratory-based IAs have been established based on the timing of peak densities of grey whales along the coast of Vancouver Island during their spring and fall migratory windows (Levesque and Jamieson 2015). The northwest corner of MARPAC OPAREA WH overlaps with a portion of the grey whale IA along the west coast of Vancouver Island (Figure 4 – Appendix A). Operators should therefore consider limiting training activities within this portion of the IA from mid-February to April, and from mid-September to early December.

Harbour porpoise are present in MARPAC OPAREA WH year-round. However, a greater influx of harbour porpoise is observed in this area during the summer months of April to October with larger numbers of adults and calves observed in the IAs during this time (Hall 2004; A. Hall, pers. comm. in Levesque and Jamieson 2015). Operators should consider limiting small arms activities within the IAs from April to October.

[1] structured communication technique using a panel of experts often answering a series of questions

Table E-1: Additional Sensitive Areas for Marine Mammals – Strait of Juan de Fuca

Designations	Legislation	Current DND or Legislated Restrictions	Additional Recommended Restrictions
Important Areas for harbour porpoise	None	None	Avoid/limit gunnery activities from April to October.
Important Areas for grey whale	None	None	Avoid/limit gunnery activities in portions of OPAREA WH that overlap with grey whale IA along west coast of Vancouver Island during migration and peak density period from mid-February to April and again mid-September to December.

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