Quantitative Assessment of Increased Potential for Marine Mammal-Vessel Interactions from the Trans Mountain Expansion Project

TRANS MOUNTAIN PIPELINE ULC
TRANS MOUNTAIN EXPANSION PROJECT

Stantec

Prepared for:

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1232-20258
April 27, 2015

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Executive Summary

This technical report was developed in response to National Energy Board (NEB) IR No. 4.72b (Filing ID A4K1E1) to assist in the risk assessment of marine mammal-ship strikes associated with development of the Trans Mountain Expansion Project. The model presented in this report was used to explore the potential for a whale-vessel encounter with the following marine mammal species at risk: blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physlaus*), sei whale (*Balaenoptera borealis*), humpback whale (*Megaptera novaeangliae*), North Pacific right whale (*Eubalaena japonica*), and killer whale (*Orcinus orca*). The mathematical model considered four traffic cases: (1) the Project case; (2) the baseline case; (3) the combined case (baseline + Project); and, (4) the future case.

The encounter risks calculated in this report were based on a set of biological assumptions that have been deemed scientifically reasonable for the survey area. However, there is insufficient scientific understanding of species-specific marine mammal behavioural responses to form predictions of actual collisions (i.e., strike occurrences) in the study area following an encounter. Out of the number of whales for which an encounter occurs, only a proportion of these will result in an actual collision. The use of a whale-vessel encounter probability as a proxy for determining the potential for a vessel strike is in keeping with the method applied by Lawson and Lesage (2013).

The Marine Regional Study Area (RSA) was divided into 2 km x 2 km grid cells, covering a 190 km x 190 km area of the Salish Sea. Based on 2012 AIS data, estimated baseline annual vessel density in the Marine RSA ranged from 0 to a maximum of 13,646 vessels per cell per year, with a median across the study area of 242 vessels. Median annual baseline vessel speeds in the Marine RSA were 11.92 knots, vessel length overall was 47.20 m, and beam size was 10.56 m. The addition of Project-related tankers was estimated to increase baseline median vessel density along the shipping route by approximately 9.4%, to have minimal effect on the median size of vessels, except within Burrard Inlet, and to decrease median vessel speeds along the shipping route by 1.6% from 14.7 to 14.5 knots.

Based on the results of the encounter risk model, for four of the five baleen whale species considered (blue, fin, sei, and North Pacific right whale), the overall probability of a Project-related vessel encountering a marine mammal is considered very low. While encounter risk is higher for humpback whales and killer whales compared to the other species (and regardless of the inclusion of Project vessels or not), this is to be expected given the higher predicted densities of these species in the study area.

Based on the assumptions presented in the report, a Project-related vessel was predicted to encounter a marine mammal along the shipping lanes once every 1,156 years for blue whales, once every 320 years for fin whales, once every 2,360 years for sei whales, and once every 2,153 years for North Pacific right whales. For the most likely species of baleen whale to be seen

in the Marine RSA (humpback whales), the Project-related return interval along the shipping lanes was predicted to be once every 334 days, and for killer whales, the only toothed whale assessed in this analysis, it was once every 6 days.

The overall combined probability of a vessel (baseline traffic or Project-related) encountering a marine mammal anywhere in the Marine RSA was predicted to be: once every 104 years for blue whales (change in encounter risk [ER] due to the increase in Project-related vessel traffic of 9.6%); once every 30 years for fin whales (change in ER of 9.7%); once every 223 years for sei whales (change in ER of 10.1%); once every 203 years for North Pacific right whales (change in ER of 10.1%); once every 20.3 days for humpback whales (change in ER due to Project of 5.7%); and once every 0.4 days for killer whales (change in ER due to Project of 6.1%). While the Project's influence along the shipping lanes is predicted to increase the change in encounter risk by 13.5 – 15.6%, when considered across the Marine RSA as a whole, the increase in Project-related vessels is predicted to result in an increased change in encounter risk of 5.7 – 10.1%.

While traffic in the Marine RSA is predicted to increase in the future, the anticipated increase in the number of Project-related vessels will stay the same. As a result, the Project's relative contribution to encounter risk will decrease over time. Since Project-related vessels will travel along the designated shipping lanes, the Project will have a larger relative effect when only vessel traffic along the shipping lanes is considered. The Project contribution to encounter risk along the shipping lanes was predicted to be 11.7 – 13.4% in 2018 (depending on the species considered), and 10.5 – 12.1% in 2030. Considered across the Marine RSA as a whole, the Project's contribution to encounter risk was predicted to be 5.1 – 8.7% in 2018, and this contribution is expected to drop to 4.5 – 7.8% by 2030.

The above return intervals only represent the frequency with which a Project-related vessel and marine mammal are expected to co-occur in the same place at the same time, assuming random ballistic trajectories of the whale. They do not factor in any behavioural responses of the whale (i.e., movement out of the area as the vessel approaches), nor any avoidance response (e.g., dives, bursts of speed, changes of course). Only a fraction of the above number of encounters will result in actual physical contact between a vessel and a whale; and if physical contact does occur, only a fraction of these incidents may result in fatal injuries. For the species examined for this report, publicly available behavioural or density data either do not exist or are not sufficient to predict levels of physical contact and fatalities.

This risk analysis is considered conservative because it does not consider behavioural responses of the whale to approaching vessels and thus encounter risks as presented overstate the risk for vessel strikes.

Abbreviations

AB	Alberta
AIS	automatic identification system
BC	British Columbia
CCG	Canadian Coast Guard
CI	confidence interval
ESA	Environmental and Socioeconomic Assessment
IMO	International Maritime Organization
IR	information request
LOA	length overall
Marine RSA	Marine Regional Study Area
MCTS	Marine Communications and Traffic Services
MEPS	Marine Exchange of Puget Sound
MMSI	Maritime Mobile Service Identity
NEB	National Energy Board
Project	Trans Mountain Expansion Project
SARA	*Species at Risk Act*
Stantec	Stantec Consulting Ltd.
TERMPOL	Technical Review Process of Marine Terminal Systems and Transshipment Sites
Trans Mountain	Trans Mountain Pipeline ULC
UTM	Universal Transverse Mercator
VTS	Vessel Traffic Services

1.0 INTRODUCTION

This technical report presents the results of a conceptual model developed to assist in the potential risk assessment of marine mammal-ship strikes associated with development of the Trans Mountain Expansion Project (the Project). The Project will result in an increase in marine transportation in the Marine Regional Study Area (Marine RSA), which is located in the Salish Sea, British Columbia, Canada. As requested in NEB IR No. 4.72b (Filing ID A4K1E1), this report considers those marine mammal species at risk that have "*a DFO Recovery Strategy that identifies marine shipping as a current threat to the recovery of the species*". These species are: the blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physlaus*), sei whale (*Balaenoptera borealis*), humpback whale (*Megaptera novaeangliae*), North Pacific right whale (*Eubalaena japonica*), and killer whale (*Orcinus orca*).

All vessels in transit through waters inhabited by various species of marine mammals could encounter an individual and accidentally strike a marine mammal its pathway. This may result in the marine mammal experiencing physical injury or direct or indirect mortality. Most injuries sustained by marine mammals from vessel strikes involve either blunt force trauma from impact on the bow of the vessel or lacerations from contact with propellers (Laist et al. 2001). As such, the terms collision and strike are often used interchangeably and refer to actual contact being made between a vessel and whale.

The model presented in this report is used to explore the potential for a whale-vessel encounter. The probability of encounter (encounter risk) is the probability that a whale and vessel share the same physical space at the same time. It factors in distribution and density of the whale species, and the proportion of time the animal is predicted to spend in the study area and in the surface waters where it would be within the draft of a vessel. The encounter risk does not account for behavioural responses of the whale, and thus does not predict whether actual contact between the whale and vessel is made. As a theoretical, worst case outcome, all encounters could result in a strike, although empirical evidence for even the most commonly struck species (e.g., North Atlantic Right whales of the east coast of the United States) indicate that actual values fall well below this maximum likelihood (Kite-Powell et al. 2007; Laist et al. 2001; Vanderlaan and Taggart 2007).

The encounter risks calculated in this report have been based on a set of biological assumptions within the survey area that have been deemed scientifically reasonable. However, there is currently insufficient scientific understanding of species-specific behavioural responses to form predictions of actual collisions (i.e., strike occurrences) for marine mammals in the study area following an encounter. Given the lack of information concerning both the mathematical risk of vessels of various classes striking different species of cetaceans, as well as the limited quantitative information concerning seasonal whale densities and habitat use for many of the marine mammal species being assessed, the model and analysis presented herein only supports calculation of potential encounter risk between vessels and the species considered in this report and not the risk of colliding with marine mammals. This approach is in keeping with the method applied in Fisheries and Oceans Canada's (DFO's) *A draft framework to quantify and cumulate risks of impacts from large development projects for marine mammal populations: A case study using shipping associated with the Mary River Iron Mine project* (Lawson and Lesage 2013). Out of the number of whales for which an encounter occurs, only a proportion of these will result in an actual collision. The use of a whale-vessel encounter probability as a proxy for determining the potential for a vessel strike has been used by other researchers examining and assessing strike risk for marine mammals (e.g., David et al. 2011; Lawson and Lesage 2013; Williams and O'Hara 2010).

The mathematical model used for the analysis presented in this document considers four traffic cases: (1) the baseline case; (2) the Project case; (3) the combined case (baseline + Project); and, (4) the future case. The Project case models potential encounter risk between marine mammals and vessels associated with the anticipated increase in Project-related marine transportation (*i.e.*, empty or laden Aframax tankers and associated escort tugs as applicable) in the Marine RSA. The baseline case examines the predicted encounter risk based on 2012 traffic levels, as determined from automatic identification system (AIS) traffic data in the Marine RSA, keeping in mind that small vessels are not required to be equipped with AIS. Encounter risks are considered both along the shipping lanes (i.e., where the Project-related vessels will have a higher proportional effect) and in the region overall. The combined case looks at the addition of Project-related traffic to the baseline case. The future case adds projected growth in traffic from 2012 to 2030 to the combined case.

This conceptual model is highly sensitive to its input parameters; for many of these, scientific understanding is limited or missing. For example, slight variations in the assumed percentage of time that an individual marine mammal is present within the Marine RSA have large implications for model outcomes. Detailed scientific support or documentation of the biological parameters necessary to form predictions of a higher resolution is not available. A sensitivity analysis has therefore been undertaken to identify the model parameters for which scientific uncertainty remains the highest (Appendix A).

1.1 BACKGROUND

Trans Mountain Pipeline ULC (Trans Mountain) is proposing to expand the Trans Mountain pipeline system between Strathcona County AB and Burnaby BC. The proposed expansion will increase the amount of vessel traffic transiting to and from the Westridge Marine Terminal. While Trans Mountain does not own or operate the vessels calling at the Westridge Marine Terminal, it is responsible for ensuring the safety of the terminal operations. Further details on the Project and anticipated increases in Project-related marine vessel traffic are available in Volume 8A of the Application (Filing ID A3S4X3). The record also contains a considerable amount of information regarding the issue of vessels striking marine mammals. In particular, this information is contained in the following documents:

- Application:
  - Section 4.3.13 – Accidents and Malfunctions; Volume 8A; Filing ID A3S4Y3 (Sections 4.3.13.3.1 – Incident Types; subheading: Strike of a Marine Mammal; and 4.3.13.5.4 – Physical Injury or Mortality of a Marine Mammal Due to a Vessel Strike)
- NEB IRs:
  - Response to NEB IR No. 2.065c; Filing ID A3Z4T9
  - Response to NEB IR No. 4.09a,b,c; Filing ID A4K4W3
  - Response to NEB IR No. 4.72a, b.2; Filing ID A4K4W3
  - Response to NEB IR No. 4.73a,b; Filing ID A4K4W3
- Intervenor IRs:
  - Response to Tsawwassen FN IR No. 1.16; Filing ID A3Y3U7
  - Response to GoC DFO IR No. 2.083; Filing ID A4H6A5
  - Response to GoC DFO IR No. 2.084; Filing ID A4H6A5
  - Response to GoC DFO IR No. 2.085; Filing ID A4H6A5
  - Response to GoC DFO IR No. 2.086; Filing ID A4H6A5
  - Response to PIPEUP Network TERMPOL IR No. II.biia; Filing ID A4J7T7

In response to a National Energy Board (NEB) information request (NEB IR No. 4.72b [Filing ID A4K1E1]), forming part of the environmental and socio-economic assessment (ESA) for the Project, Trans Mountain requested that Stantec Consulting Ltd. (Stantec) undertake a quantitative modelling study (i.e., this report) to characterize how the anticipated increase in Project-related marine vessel traffic may affect the encounter risk for marine mammals in the Marine RSA, as well as the relative change in this rate over baseline levels.

1.2 OBJECTIVES

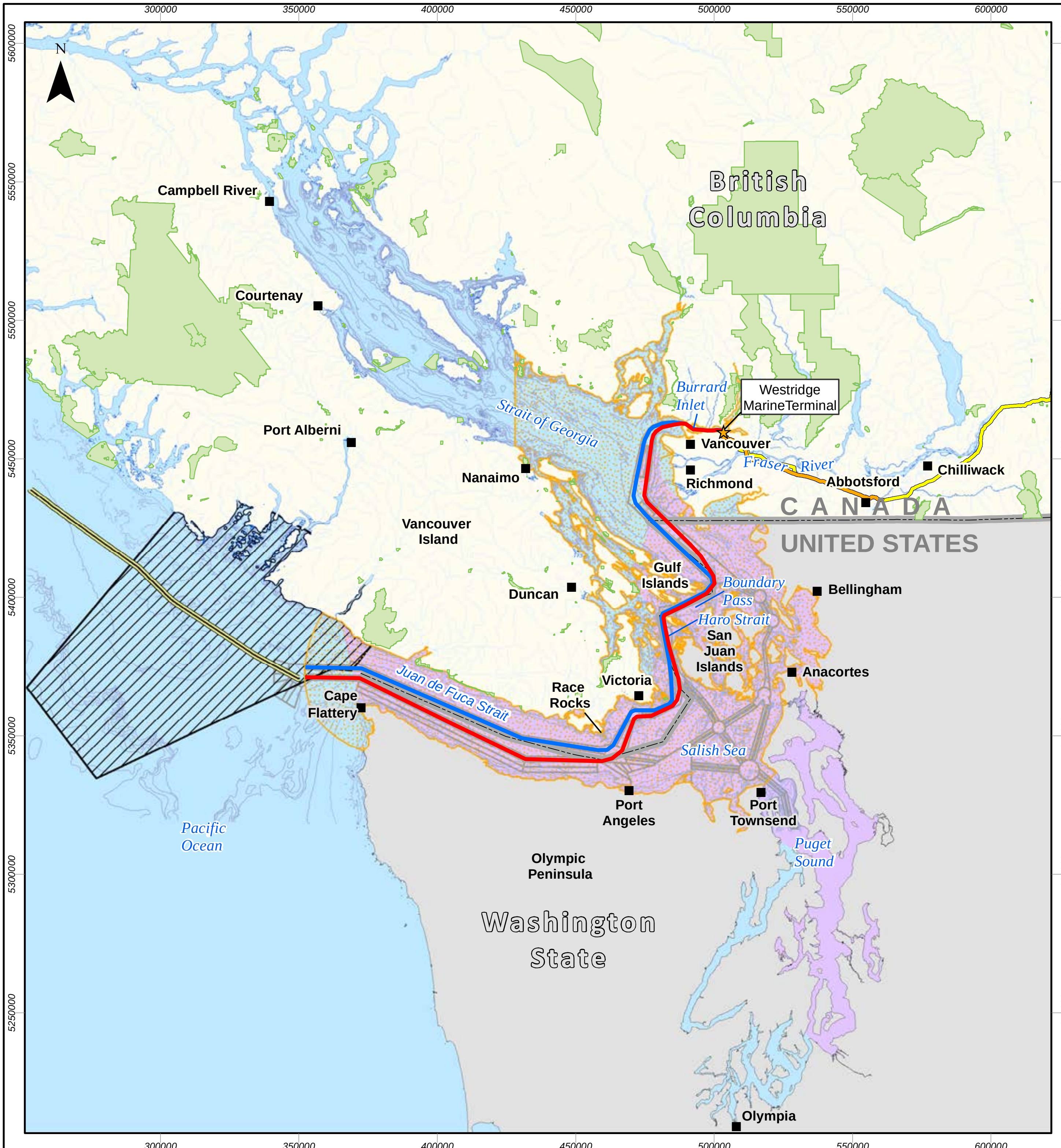
The purpose of this report is to assess the potential risk of Project-related vessel strikes to marine mammals within the Marine RSA. Modelling was used to:

- Calculate the probability of encounter for various marine mammal species at risk (i.e., those with a Recovery Strategy under the federal *Species at Risk Act* [*SARA*]), under the following four vessel traffic scenarios:
  - Baseline (2012) marine traffic alone (Baseline case)
  - Anticipated Project marine vessel traffic alone (Project case)
  - Anticipated Project + baseline (2012) marine traffic (Combined case)
  - Anticipated Project + baseline (2012) + future (2018, 2020, 2025, 2030) projected marine traffic levels (Future case)
- Consider the increase in risk posed by the anticipated increase in Project-related vessels relative to baseline (2012) traffic levels

1.3 STUDY AREA

The Marine RSA is comprised of a large portion of the Salish Sea, including the inland marine waters of the southern Strait of Georgia and Juan de Fuca Strait and their connecting channels, passes and straits (Figure 1). The Marine RSA is generally centered on the IMO-designated marine shipping lanes, which extend from the Westridge Marine Terminal through Burrard Inlet, south through the southern part of the Strait of Georgia, the Gulf Islands and Haro Strait, westward past Victoria and through Juan de Fuca Strait out to the 12 nautical mile limit of Canada's territorial sea. The western boundary of the Marine RSA extends further out to sea than the western boundary of the Salish Sea. The northern boundary of the Marine RSA is limited to the southern portion of the Strait of Georgia.

The study area for this analysis is defined as a 190 km x 190 km square, which is bounded by the Westridge Marine Terminal, and by the northeastern and southwestern-most extents of the Marine RSA, thus encompassing all proposed Project-related vessel routes through the Marine RSA. A grid was overlaid on this study area, breaking it down into cells of 2 km by 2 km (Figure 2).



★ Westridge Marine Terminal
■ Town / City
Marine Vessel Inbound Shipping Lane
Marine Vessel Outbound Shipping Lane
International Border
Canadian 12 Nautical Mile Territorial Boundary
Bathymetry
Watercourse
Existing Trans Mountain Pipeline
Trans Mountain Expansion Proposed Pipeline Corridor
Waterbody
Provincial Park
Traffic Separation Scheme
Land of British Columbia
Land of Washington State
Marine RSA (Transportation)
Humpback Whale Critical Habitat
Southern Resident Killer Whale Critical Habitat

SCALE: 1:2,000,000

0 10 20 30 40 km

ALL LOCATIONS APPROXIMATE

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MAP NUMBER		PAGE
10494_FIG_01		SHEET 1 OF 1
DATE Apr 2015	REF. 7894	REVISION 0
SCALE 1:2,000,000	PAGE SIZE 8.5x11	DISCIPLINE SD
DRAWN SS	CHECKED DP	DESIGN SD

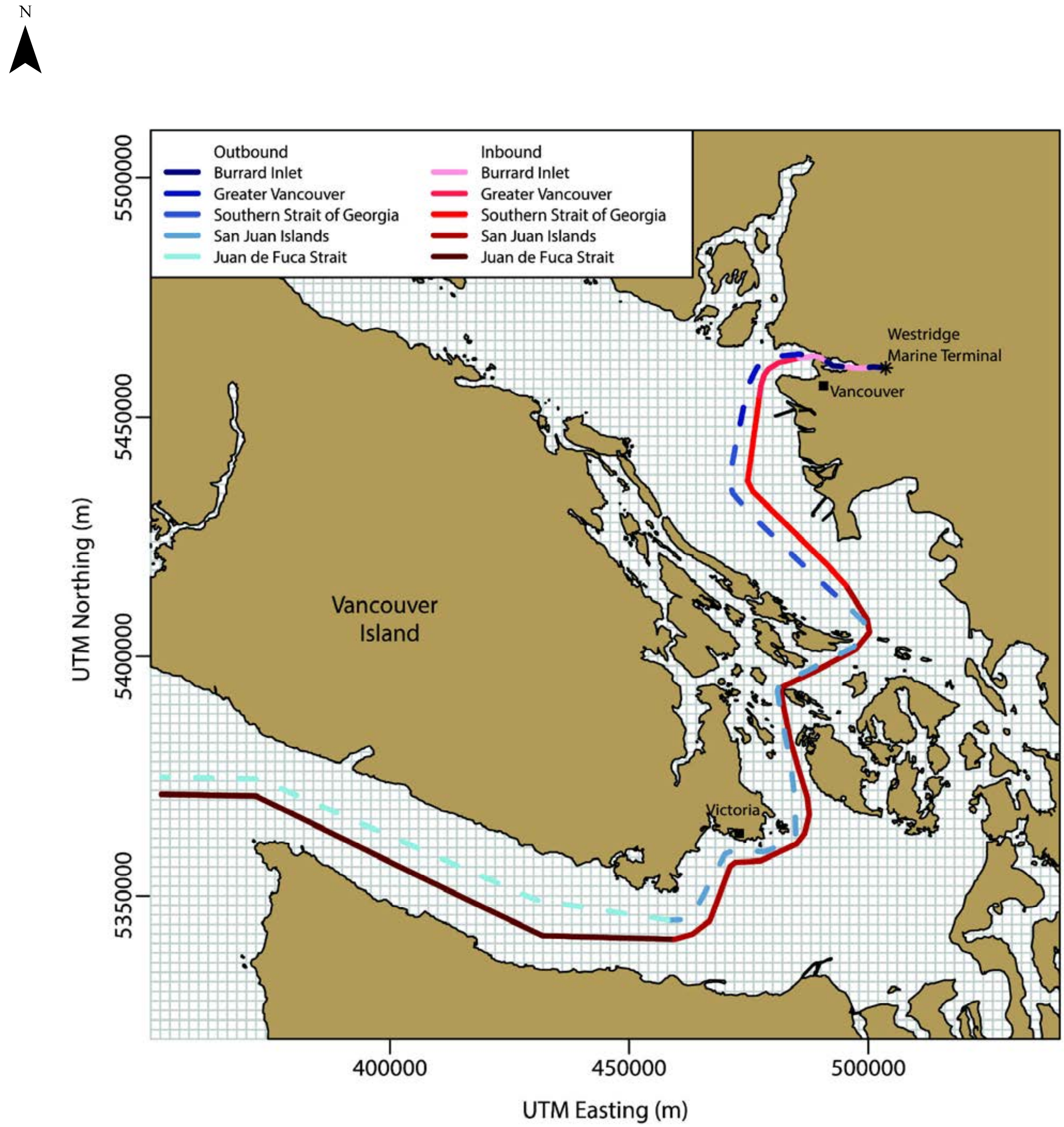
Projection: UTM Zone 10N; Marine Vessel Inbound Shipping Lane: Moffatt & Nichol, 2013a; Marine Vessel Outbound Shipping Lane: Moffatt & Nichol, 2013b; International Border: British Columbia Ministry of Energy and Mines, 2013; Canadian 12 Nautical Mile Territorial Boundary and Traffic Separation Scheme: Canadian Hydrographic Service, 2013; Bathymetry: Canadian Hydrographic Service, 2011; Watercourse: National Hydro Network, 2007; Existing Pipeline: Kinder Morgan Canada, 2012; Trans Mountain Expansion Proposed Pipeline Corridor: Universal Pegasus International, 2013; Provincial Park: BC MFLNRO, 2008a; Land of British Columbia: National Topographic Data Base, 2007; Land of Washington State: Washington State Department of Ecology, 1994; Humpback Whale Critical Habitat: DFO, 2013b; Critical Habitat for Southern Resident Killer Whale: DFO, 2011.

Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

FIGURE: 1

MARINE REGIONAL STUDY AREA

TRANS MOUNTAIN EXPANSION PROJECT



Stantec

The study area for this report covers a 190 km x 190 km square divided into 2 km x 2 km grid cells. This area includes the Marine RSA and the IMO-designated shipping lanes that will be transited by Project-related vessels both inbound (red lines) and outbound (blue lines). The shipping routes have been divided into five segments based on the major anticipated changes in maximum vessel speeds. Starting at the Westridge Marine Terminal and travelling outbound, these are as follows: Burrard Inlet: 6 kts; Greater Vancouver: 10 kts; Southern Strait of Georgia:12 kts; San Juan Islands: 10 kts; and Juan de Fuca Strait: 12.5 kts outbound (14.5 kts inbound).

TRANS MOUNTAIN

FIGURE: 2

MAP NUMBER		PAGE
10494_FIG_02		SHEET 1 OF 1
DATE Apr 2015	REF. 7894	REVISION 0
SCALE N.T.S.	PAGE SIZE 8.5x11	DISCIPLINE SD
DRAWN RA	CHECKED AA	DESIGN AA

Figures were produced by Dr. Robert Ahrens in R statistical software (R Core Development Team 2006) using the PBSmapping package (Schnute et al. 2015) and maptools (Bivand et al. 2015).

Bivand, R., N. Lewin-Koh, E. Pebesma, E. Archer, A. Baddeley, H.-J. Bibiko, S. Brey, J. Callahan, G. Carrillo, S. Dray, D. Forrest, M. Friendly, P. Giraudoux, D. Golicher, V. Gómez Rubio, P. Hausmann, K.O. Hufthammer, T. Jagger, S. Luque, D. MacQueen, A. Niccolai, E. Pebesma, O. Perpiñán Lamigueiro, T. Short, G. Snow, B. Stabler, M. Stokely and R. Turner. (2015). maptools: Tools for Reading and Handling Spatial Objects (Version 0.8-34) [R Statistical software].

R Core Development Team. (2006). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Schnute, J.T., N. Boers, R. Haigh, C. Grandin, D. Chabot, A. Johnson, P. Wessel, F. Antonio, N.J. Lewin-Koh and R. Bivand. (2015). PBSmapping: Mapping Fisheries Data and Spatial Analysis Tools (Version 2.68.68) [R Statistical Software].

Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

TECHNICAL REPORT STUDY AREA SHOWING GRID CELLS AND SPEED SEGMENTS OF THE SHIPPING ROUTE

TRANS MOUNTAIN EXPANSION PROJECT

1.4 SCOPE

1.4.1 Marine Mammals

As requested in NEB IR No. 4.72b (Filing ID A4K1E1), this report considers those marine mammal species at risk that have "*a DFO Recovery Strategy that identifies marine shipping as a current threat to the recovery of the species*". Table 1 lists the *SARA*-listed endangered or threatened marine mammal species that may occur in the Marine RSA and for which there exists a recovery strategy identifying marine shipping as a threat. Marine mammal species of special concern require the development of management plans (not recovery strategies) (*SARA* Section 65), and thus no marine mammals of special concern were considered in this study.

Table 1 Marine Mammal Species Considered in the Vessel Strike Risk Assessment

Common Name	Scientific Name	*SARA* Schedule 1 Status
Blue whale	*Balaenoptera musculus*	Endangered
Fin whale	*Balaenoptera physlaus*	Threatened
Sei whale	*Balaenoptera borealis*	Endangered
Humpback whale	*Megaptera novaeangliae*	Threatened
North Pacific right whale	*Eubalaena japonica*	Endangered
Killer whale[1]	*Orcinus orca*	Endangered (southern residents) Threatened (northern residents, transients, and offshores)

Notes:

[1] There are four ecotypes of killer whales that may occur in the Marine RSA. Morphometric and behavioural parameters (i.e., length, width, swim speeds) do not differ sufficiently between ecotypes for the model to predict differences between these populations. The only parameter that varies sufficiently to affect model outcomes is animal density, which varies by ecotype. Densities in the Marine RSA are predicted to be highest for southern residents and therefore densities for this ecotype were applied in the model to predict strike risk for "killer whales" generically. This method is believed to conservatively represent potential strike risk for all four populations (i.e., strike risk to northern residents, offshores, and transients should be less than that for southern residents based purely on numbers and time spent within the study area). See also Section 2.3.4.

1.4.1.1 Predicted Occurrence of Marine Mammals in the Marine RSA

Although whale sighting information is available for much of the Marine RSA (e.g., Barlow et al. 2011), most of these data were collected opportunistically (i.e., during other activities such as whale watching or fishing)(e.g., Hauser et al. 2006), or with the intention of identifying, watching, or researching species present in the area, but not necessarily determining actual densities. Collection of data that can be used for density information requires a detailed study design and an accounting of survey effort (Buckland et al. 2001). Density predictions can be calculated using a variety of methods including distance sampling (e.g., Williams and Thomas 2007) and kernel density (e.g., Hauser et al. 2007), to name a few. Seasonal density information can be used to predict encounter probability between marine mammals and vessels (e.g., Williams and O'Hara 2010). With the exceptions noted below, such a quantitative seasonal accounting of densities is not publicly available for many of the marine mammal species considered, nor for the entire Marine RSA; such information would greatly improve the applicability and spatial resolution of the encounter model. Biological parameters used in the analysis are discussed in Section 2.3.

1.4.1.2 Density Data for Marine Mammal Species Considered

Available density data for marine mammal species in British Columbia and in the Marine RSA is limited. Hauser et al. (2007) used commercial whale watching data to predict normalized kernel densities for southern resident killer whales. The predictions used data from May to September from 1996 to 2001 and were limited to the southeast portion of the Marine RSA.

The one publically available systematic multi-species marine mammal density survey in the Marine RSA was a line transect survey conducted in the summer of 2004 by Raincoast Conservation Foundation (Best and Halpin 2011; Williams and Thomas 2007). This survey program entailed 24 transects, covering a linear distance of 479 km, over an area of 8,186 km^2 in the Canadian waters of the southern Strait of Georgia and Juan de Fuca Strait. While the survey produced density estimates for minke whales, harbour porpoise, Dall’s porpoise, Pacific white-sided dolphin, and harbour seal, none of the species listed in Table 1 were observed in the Marine RSA over the course of the survey.

Other modeled distributions and habitat-based whale occurrence studies, such as those predicted by Dalla Rosa et al. (2012) and Gregr and Trites (2001) are also valuable for informing assignment of species densities, spatial distributions, and habitat use when, given the lack of actual quantitative metrics, such parameters need to be selected through professional judgement.

1.4.1.3 British Columbia (BC) Cetacean Sightings Network Data

The BC Cetacean Sightings Network (BC CSN) is a network of over 3,600 observers across BC that voluntarily records and reports any sightings of cetaceans in BC waters. This network includes whale watching operators, lighthouse keepers, charter boat operators, tugboat captains, BC Ferries personnel, researchers, government employees, recreational boaters and coastal residents. Data obtained from the BC CSN are collected opportunistically with limited knowledge of the temporal or spatial distribution of observer effort; as a result, absence of sightings at any location does not demonstrate absence of cetaceans. However, a vast amount of information on cetacean species presence has been gathered by this network over the past four decades (British Columbia Cetacean Sightings Network 2013). Sightings of marine mammals in the Marine RSA based on these opportunistic records are presented in Figures 4.7 – 4.14 of the Marine Resources – Marine Transportation Technical Report (Volume 8B, Technical Report 8B-1, Stantec Consulting Ltd. December 2013, Filing ID A3S4J5).

Between 1975 and 2013 (the year access to the dataset was requested by the Project), no observations of blue whales, sei whales, or North Pacific right whales were reported to the BC CSN within the Marine RSA (British Columbia Cetacean Sightings Network 2013). There was one recorded blue whale sighting on the continental shelf, 50 km from the western-most edge of the RSA (no date, estimated group size: 18-22 individuals). It was not possible from the data provided to determine the reliability of this record; though the group size seems quite high (blue whales are often solitary or seen in pairs (Calambokidis and Barlow 2004); larger feeding aggregations have been reported (e.g., Schoenherr 1991)).

Over the same 38-year time period there were four opportunistic sighting records of fin whales in the Marine RSA. Three of these were in Juan de Fuca Strait: one off Sooke in August 2005, another off Race Rocks in December of that year, and a third was next to the outbound shipping route northwest of Cape Flattery in December 2011. The fourth record was a very rare sighting of a fin whale off Nanaimo in September 2012. There were an additional three BC CSN records of fin whales in southern BC, all of them to the west of the mouth of Juan de Fuca Strait: two sightings on the continental shelf in 1991 and 1997 (at distances of 43 and 52 km, respectively, from the western edge of the Marine RSA); and a sighting of three fin whales off Tofino in 2009 (British Columbia Cetacean Sightings Network 2013).

The BC CSN dataset also contains a vast number of killer whale sightings as the Marine RSA contains 100% of the critical habitat for southern resident killer whales (as well as fairly regular sightings of transients off Race Rocks, although the dataset does not distinguish between ecotypes)(Figure 1). Sightings occur year-round, with highest concentrations in the summer, when there is a very active commercial whale watching community that focusses on daily sightings of southern resident killer whales (days without a killer whale sighting somewhere in the Marine RSA are rare during the summer peak period).

While sightings of humpback whales are far less common, and densities lower than killer whales in the Marine RSA, there are still a large number of records of this species in the Marine RSA. Although there is the occasional sighting in all months of the year, the peak sighting period is in late summer/early fall (August and September), as this species is migratory and travels to the warm waters of Mexico and Hawaii to breed during the winter months (Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2011). Sightings are scattered throughout the Strait of Georgia, Gulf and San Juan Islands, and Juan de Fuca Strait, with most opportunistic sightings made near Race Rocks off Victoria (Figure 1). Designated critical habitat for this species occurs over the continental shelf, with large aggregations observed over Swiftsure Bank (Fisheries and Oceans Canada 2013a); the easternmost edge of critical habitat overlaps with the western-most extent of the Marine RSA (Figure 1).

1.4.1.4 Fisheries and Oceans Canada's Marine Mammal Incident Database

Based on data obtained from DFO's Marine Mammal Incident Database (1973 to October 2012), there were eight records of vessel strikes with toothed whales that were confirmed or deemed likely to have occurred in BC: one involved a Dall's porpoise calf; one involved a harbour porpoise calf; and six involved killer whales (maximum vessel size reported for a killer whale strike was a ferry in the Strait of Georgia). The most commonly struck species in BC, as reported to the BC Marine Mammal Response Network, is the humpback whale (Fisheries and Oceans Canada 2013a). It is important to note that data obtained from the BC Marine Mammal Incident Database is collected by voluntary reporting of dead and distressed animals. It is unknown to what extent all incidents are reported, and as a result, absence of incidents at any location does not demonstrate absence of a threat in the report's timeframe. Despite these uncertainties, and the fact that vessel strike events are likely under-reported, the species' of marine mammal at highest relative risk of a vessel strike in the Marine RSA are most likely humpback whales and to a lesser degree fin whales (due to their lower expected densities), along with other less frequently-observed species of baleen whales. The BC Marine Mammal Incident Database (up to October 2012) includes 19 records of humpback whale strike events, all of which occurred in BC between 2004 and 2011. Most of these involved vessels less than 75 m in length, although larger vessels are also the least likely to detect and, therefore, report a strike event. Other records of baleen whale strike events include four records of grey whales, one fin whale, and three unidentified whales.

1.4.2 Vessels

1.4.2.1 Baseline (2012) Vessel Traffic in the Marine RSA

To assess encounter risk based on baseline traffic levels in the Marine RSA, the 2012 AIS vessel traffic data was obtained from the Marine Exchange of Puget Sound (MEPS). The 2012 data was selected so that vessel traffic information presented in this analysis would be generally comparable to analyses presented in TERMPOL 3.2 (Volume 8C, Technical Report 8C-2, Moffatt & Nichol November 2013, Filing IDs A3S4R7 and A3S4R8). Summary traffic statistics presented in this report are not expected to align completely with values presented in TERMPOL 3.2 as a result of the different means of filtering the data and averaging of values within grid cells for this analysis. AIS data obtained from MEPS only contain tracks of vessels carrying AIS equipment; however, under law, not all vessels are required to be fitted with AIS. The federal Navigation Safety Regulations, which came into force on May 10, 2005, state: "Every ship, other than a fishing vessel, of 500 tons or more that is not engaged on an international voyage shall be fitted with an AIS" (Navigation Safety Regulations, SOR/2005-134).

1.4.2.2 Anticipated Increase in Project-related Vessel Traffic

Currently, in a typical month, five tankers are loaded at the Westridge Marine Terminal. The maximum size of tankers (Aframax class) served at the terminal will not change as part of the Project. The expanded system will be capable of serving a total of 34 Aframax class vessels per month, with actual demand driven by market conditions. Tankers are escorted by escort tugs, in varying numbers and configurations depending on the location along the marine shipping route. In addition to tanker traffic, the terminal typically loads two to three barges with oil per month and receives one or two barges of jet fuel per month for shipment on a separate pipeline system that serves Vancouver International Airport. Barge activity is not expected to change as a result of the expansion.

The anticipated increase in Project-related vessels is therefore assumed to be 29 Aframax-class tanker calls per month (i.e., 58 monthly transits through the Marine RSA) as well as the associated escort tugs, while they accompany (tethered or not) the tankers. The Aframax standard dimensions used for the model were a length overall (LOA) of 243.8 m and a beam of 42 m (Aframax Characteristics, Filing ID A3S5J6). The *Seaspan Raven* was used as the assumed representative tug, with an LOA of 28.2 m and a beam of 12.6 m (Seaspan ULC 2009).

2.0 METHODS

The statistical likelihood of a vessel strike causing serious or fatal injury to a marine mammal depends on three factors: the probability of encounter; the probability of a strike occurring; and the probability that strike results in severe or fatal injuries.

The probability of encounter is the probability (per cell and per vessel transit) that a whale and vessel occupy the same physical space at the same time. This is dependent on the distribution and density of the whale species and their presence along the route that vessels are travelling. In this model, probability of encounter also accounts for the proportion of time a whale spends in the surface waters where it would be within the draft of a vessel. Encounter risk (ER) additionally factors in the proportion of time the whale is predicted to be present in the study area over the course of the year, as well as the number of vessel transits Encounter risk does not, however, account for behavioural responses of the whale, such attraction to or avoidance of the vessel, nor does it account for potential hydrodynamic forces of the vessel pulling a whale in towards the hull (Knowlton et al. 1995; Knowlton et al. 1998; Silber et al. 2010). Encounter risk is calculated assuming that whale trajectory is random with respect to vessel movement and simply evaluates the potential for overlap between the two in space and time.

The probability of a strike occurring is the probability, given a whale and vessel occur in the same location, that a strike actually occurs (i.e., any potential avoidance response by either the whale or vessel is unsuccessful and actual contact between the two occurs). This is primarily a function of vessel size and speed; however, there is uncertainty regarding species-specific risk of collision. Many species of marine mammal have been shown to actively avoid vessels, whereas some are often drawn to vessels and may even interact with them of their own accord (e.g., killer whales or other dolphins bow riding). With the exception of North Atlantic right whales, for which some predictive probabilities of strike have been developed (Kite-Powell et al. 2007), the mathematical relationship leading to collisions has not been determined, and it is expected that species-specific responses to vessels heavily modify and influence strike risk.

The probability of a lethal strike is the probability, given that a strike occurs, that the resulting injuries are severe enough to be fatal to the whale. Vanderlaan and Taggart (2007) have calculated such probabilities for large whale species, and shown that these probabilities are in large part a function of vessel class and speed.

While the relationship between vessel speed and lethality has been reasonably well defined for baleen whales, the probability of a strike occurring has not been determined for any species other than North Atlantic right whale (Kite-Powell et al. 2007). The ability and success rate of avoidance maneuvers by most species, and the generalized circumstances that lead to actual contact are simply not known for the vast majority of whale species. Differences of morphology and behaviour do not support extrapolation of the North Atlantic right whale results to the species considered in this report. As a result, and in keeping with the approach taken by others (e.g., David et al. 2011; Lawson and Lesage 2013; Williams and O'Hara 2010) only probabilities of encounter are calculated in this report. Out of the number of whales for which an encounter occurs, some unknown number of these encounters may result in an actual collision.

While the model and remainder of this report thus focus on the risk of encounter, Section 4.3 provides a brief discussion of the potential for broader extrapolations to strike risk.

The remainder of this section is divided into three subsections as follows:

- Section 2.1 outlines the mathematical equations used in the probability of encounter calculations (see Table 2 for symbols used in the equations). All model calculations were performed in R statistical software (R Core Development Team 2006) using the PBS mapping package (Schnute et al. 2015) and maptools (Bivand et al. 2015).
- Section 2.2 identifies the specifications that were used as model input parameters for all four vessel traffic cases defined above.
- Section 2.3 identifies the biological parameters used in the model and their source references. A description of the generalized method for how parameters were selected is provided, and potential errors, assumptions and uncertainties inherent in the selection and use of these parameters is discussed. A detailed per-species accounting of this process was outside the scope of this report.

Table 2 Model Symbols

Symbol	Description
a	Area length (m)
v_l	Vessel length (m)
v_w	Vessel beam (m)
v_s	Average vessel speed (m/s)
t_v	Time required for a vessel to transit a 2 km x 2 km cell (s)
N	Number of times a vessel transits a 2 km x 2 km cell within a year
w_l	Assigned species-specific whale length (m)
w_w	Assigned species-specific whale width (m)
w_s	Assigned species-specific whale speed (m/s)
w_d	Assigned species-specific whale density (m^{-2})
v	Average relative speed between vessel and whale (m/s)
D	Transect width (m)
p_e	Probability of encounter (probability an individual vessel encounters an individual whale per cell, per vessel transit)
ER	Annual whale-vessel encounter risk (calculated per cell and summed across area of interest)
RI	Return interval (the average length of time in years between encounters)
p_{sw}	Annual proportion of time whale spends within the surface waters
p_y	Annual proportion of time whale is within the area of interest
p_T	Annual probability of encounter over areas of interest

2.1 PROBABILITY AND RISK OF ENCOUNTER

Whale-vessel encounter probability is calculated assuming random ballistic trajectories, as in the ideal gas model, for an individual whale and vessel and with a Maxwell-Boltzmann distribution of whale and vessel speeds (see review in Hutchinson and Waser (2007)). This encounter probability formulation is slightly different from that presented in Vanderlaan and Taggart (2007) that utilized an encounter model based on the trapping of random walk particles. The canonical form of both models is similar (i.e., encounters are assumed to be Poisson distributed), but the ballistic trajectory model does not require the estimation of the number of unique points encountered during the random walk, which is itself probabilistic in nature and difficult to assess.

A number of assumptions are made to when calculating the probability of encounter, given the uncertainties of whale behaviour:

- For an encounter to occur, whales must be present in the surface waters where they would be vulnerable to ship strike. Percent time spent at the surface has been assigned conservatively for each species based on literature, but this value may be quite variable and this particular parameter has a large influence over the final model outputs (see Section 4.2 for a discussion of parameter sensitivity).
- Whale movement is assumed random with respect to vessel movement.
- Whales are assumed not to avoid or engage vessels or detect vessels from a distance and alter behaviour. While this assumption is known to be false, it should generally over-predict actual encounters, as species that are drawn to vessels (e.g., dolphins bow-riding) are rarely struck during the course of these activities, and species that detect and avoid vessels remove themselves from the potential for an encounter.
- Vessels within a 2 km by 2 km cell are assumed to travel 2 km in a straight line.

Encounter probabilities are calculated on a 'per cell basis', with each vessel transiting within a 2 km x 2 km area. Individual vessel track lengths were not calculated. Instead, for each Project-related vessel or vessel with an AIS-identified position within a cell, time taken to transit the cell was estimated assuming the vessel travels 2 km within it (i.e., a = 2,000 m; Equation 1).

$$(1) \qquad t_v = a/v_s$$

The transect width (D) within each cell is assumed to be a function of the vessel (i.e., Aframax tanker) beam plus the width of accompanying vessels (i.e., escort tugs) and the mean expected width of the whale (w_w; see Section 2.4.1) assuming the whale has a random orientation to the vessel (Equation 2). Vessel beam (v_w) varies along the shipping route according to escort tug configuration. In locations where one or two escort tugs are present, v_w is the tanker width plus the width of each tug (see Section 2.2.1 for a description of tug configuration). When three tugs are present in Burrard Inlet, v_w included the width of only two tugs, as it was assumed that all four vessels were not aligned side-by-side. In the model, v_w is not changed based on whether the tug(s) were tethered or not.

$$(2) \qquad D = v_w + w_w + 0.5(w_l - w_w)$$

Assuming whale speed (see Section 2.4.2) and vessel velocity follow a Maxwell-Boltzmann distribution, the average relative velocity can be estimated using Equation 3.

$$(3) \qquad v = \sqrt{v_s^2 + w_s^2}$$

Encounter probability (p_e, per vessel, per cell) can be estimated as a function of the time needed to transit a 2 km x 2 km area, the transect width, whale density (see Section 2.4.3), mean relative velocity, and the proportion of time a whale spends in the surface waters where it would be within the draft of a vessel (Section 2.4.5), (Equation 4).

$$(4) \qquad p_e = \left(1 - exp(-vDw_d t_v)\right)p_{sw}$$

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The expected annual encounter risk (*ER*) in a given cell can be calculated using Equation 5. This accounts for the average proportion of a year whales are expected (Section 2.4.4) in the study area or speed segment (Section 2.2.1) that contains the cell of interest, as well as the annual number of vessel transits of the area (Sections 2.2.1 for Project-related vessels, 2.2.2 for baseline, and 2.2.3 for future traffic).

$$(5) \qquad ER = p_e N p_y$$

Annual probabilities of encounter by cell (Equation 5) are then summed across the area of interest to predict the probability that a vessel encounters a whale (i.e., occurs in the same place at the same time) in a given year. This is done separately for Project related-vessels alone, baseline traffic, combined Project-related and baseline vessel traffic, and future vessel traffic, and looking at both the shipping lanes alone, and the entire Marine RSA. The return interval (RI) is the length of time between predicted encounters and its calculation is simply the inverse of the encounter risk.

$$(6) \qquad p_T = 1 - e^{-ER}$$

The annual probability of encountering a whale including all areas of interest can be calculated using Equation 6. For low ER (<0.2) p_T is similar to ER and for higher ERs p_T asymptotically approaches 1 with ERs > 6 resulting in p_Ts near 1.

2.2 VESSEL TRAFFIC

2.2.1 Project-Related Vessels

2.2.1.1 Speed Segments along the Marine Shipping Lanes

The inbound and outbound shipping lanes were divided into five segments based on the major anticipated changes in maximum Project-related vessel speeds (see Figure 2). Starting at the Westridge Marine Terminal, the assumed speed profile and tanker configuration of Project-related vessels, based on existing established practice for tankers is the following for outbound transits:

- Speed Segment 1 – Burrard Inlet
  - 6 knots (1 knot = 1.852 km/h)
  - 3 tethered tugs
- Speed Segment 2 – Greater Vancouver
  - 10 knots
  - 1 tethered tug
- Speed Segment 3 – Southern Strait of Georgia
  - 12 knots
  - 1 untethered tug

- Speed Segment 4 – San Juan Islands
  - 10 knots
  - 1 tethered tug
- Speed Segment 5 – Juan de Fuca Strait
  - 12.5 knots (14.5 knots inbound)
  - 1 untethered tug

For inbound transits, there are no accompanying tugs on the route until First Narrows, when two tethered tugs will escort inbound tankers to the Westridge Marine Terminal. The division into segments does not line up exactly between inbound and outbound lanes (see Figure 2); however speeds in each segment are the same inbound and outbound (with the exception of Juan de Fuca Strait, where speeds are 12.5 knots outbound and 14. 5 knots outbound).

2.2.2 Baseline Traffic

2.2.2.1 Automatic Identification System Data

The MEPS database of vessel traffic was used to calculate vessel density, mean annual speed, mean annual LOA, and mean annual beam at a spatial resolution of 2 km by 2 km within the study area for 2012. AIS data for 2012 was filtered to remove all points outside of the study area and those occurring on land. Vessels were uniquely identifiable based on the numbering identification system applied by the Maritime Mobile Service Identity (MMSI) or International Maritime Organization (IMO); locations without a unique ship vessel number were excluded from the dataset. The calculations used each uniquely identifiable vessel within each cell that showed a positive recorded speed for each hour, thus excluding stationary vessels (e.g., vessels at anchor that were not transiting through the area). This approach is similar to that taken by (Williams and O'Hara 2010). Multiple records for a cell were included if the time differential between AIS reports was greater than six hours and a vessel's velocity was greater than 1.0 knots.

2.2.2.2 Baseline Vessel Statistics

The annual density of vessels transiting any 2 km x 2 km area grid cell was calculated from individual daily AIS data points. AIS data is reported every 2-10 seconds when a vessel is underway and every three minutes when a vessel is stationary. Vessel speeds less than 1.0 knot were excluded from the analysis, as the vessel was assumed to be stationary. For each vessel on a given day the unique number of cells transited was determined by locating each AIS data point within a 2 km x 2 km grid. These instances were assumed to represent a separate transit of a cell. Daily transits of each cell were tallied across the year along with the mean vessel speed, beam, and LOA. Mean vessel speed per cell was averaged over all transits. The speed of each transit was calculated as the 75th percentile of vessel speed calculated for each day, as recommended by David et al. (2011). Vessel speed was calculated as the straight-line distance between AIS points over the time between reported points Vessel speeds greater than 60 knots were also excluded as they were assumed to be errors in the AIS data (The maximum speed reported below this was 41.75 knots). AIS data is reported every 2-10 seconds when a vessel is underway and every three minutes when a vessel is stationary. Other than the above filters, all vessels included in the MEPS 2012 AIS database were included in the analysis. Variability in the estimated impact of the anticipated increase in Project-related vessels on area-specific average speed, LOA, and beam within each cell of the route was estimated from 10,000 bootstraps (i.e., 10,000 random draws) assuming a lognormal distribution and estimated area-specific mean and standard deviations in speed, LOA, and beam for each cell.

2.2.3 Future Traffic

Future vessel traffic was calculated based on the estimated percent increase in traffic by vessel class to 2018, 2020, 2025 and 2030, details of which are presented in Section 6 of TERMPOL 3.2 (Volume 8C, Technical Report 8C-2, Moffatt & Nichol November 2013, Filing IDs A3S4R7 and A3S4R8). Percent increase in each time block was calculated as the vessel category weighted average yearly percent change in traffic (see Table 3). For each time block, the change in vessel category composition was estimated based on the percent change in each category over the previous time block. The first time period represents this change as compared to the combined baseline + Project related traffic

Table 3 Annual Growth Factors (%) Used to Escalate Traffic from 2012 to 2030

Vessel Type	2012-2018	2018 - 2020	2020 - 2025	2025 - 2030
Cargo/Carrier	1	1	1	1
Tug	1	1	1	1
Service	1	1	1	1
Passenger	1	1	1	1
Tanker (not Trans Mountain tanker)	4	2	2	2
Fishing	0	0	0	0
Ferry	0	0	1	1
Unknown	1	1	1	1
Other	1	1	1	1

Source: Section 6 of TERMPOL 3.2 (Volume 8C, Technical Report 8C-2, Moffatt & Nichol November 2013, Filing IDs A3S4R7 and A3S4R8).

2.2.4 Vessel Assumptions

The 2012 AIS values (annual vessel density, and median annual speed, LOA, and beam) are assumed to represent baseline vessel traffic in the study area.

Anticipated Project-related vessel speeds and positions, while consistent with existing Aframax vessels travelling to and from the Westridge Marine Terminal, are only approximate for a number of reasons:

- The actual course and speeds followed may deviate a few hundred meters to either side of the theoretical course line, as pilots adjust heading and speed to suit prevailing weather conditions, presence of other vessel traffic, etc.
- Transitions from one course and speed to another are modeled as instantaneous occurrences, whereas in reality the vessel will follow a smooth gradual curve as it makes the course change and increases or decreases speed.
- The assigned speeds do not take into account tidal currents which can speed up or slow down the vessel’s speed over the ground.

2.3 BIOLOGICAL ASSUMPTIONS, UNCERTAINTIES, AND POTENTIAL SOURCES OF ERROR

Numerous biological assumptions and generalizations were made to facilitate development of the model; these are based on expert opinion and a review of relevant literature. Without the availability of quantitative whale density and distribution information, reasonable assumptions concerning plausible whale densities have been made. Although a greater understanding of particulars such as whale distribution and behavioural response would improve the model, the assumptions made herein are scientifically reasonable and appropriate for the stated objectives.

To assess the degree to which these assumptions may have influenced model outcomes, a sensitivity analysis was performed. Sensitivity of encounter risk and return interval (i.e., the average length of time in years between encounters) was assessed by increasing and decreasing (by 20% each) the combined species-specific biological parameters of whale length, whale width, and whale speed. This analysis was also performed separately for the proportion of time a whale spends in the surface waters, the average proportion of a year whales are expected in the study area, and the assumed whale densities.

The following sections provide a brief description of the rationale behind selection of values for the biological parameters applied in the encounter model, as well as the associated assumptions and generalizations. A search of the scientific literature was conducted to identify the necessary parameters (e.g., whale breadth, swim speed, density) required by the model. Biological parameters applied in the encounter model are Table 4 (Section 2.3.6). Only those papers from which a parameter was ultimately selected for use are cited, and these are provided as footnotes to Table 4.

2.3.1 Whale Body Sizes

Body lengths of individual whale species vary substantially and also vary according to sex, maturity, health, regional differences, and reproductive state (e.g., pregnant or lactating females). Female baleen whales are generally larger than males (e.g., Gregr 2000), while the opposite is true of killer whales (the only toothed whale species considered in this study)(Fisheries and Oceans Canada 2011). A reliable 'upper average' measurement was generally selected (i.e., large but not maximum recorded individuals; we used female baleen whales and male toothed whales). Where available, parameters from the North Pacific were selected over those from populations elsewhere in the world. Maximum measurements were not selected as there is likely some upward bias since many length reports are the result of whaling records; mean lengths of commercially-hunted whales declined over time as larger individuals were removed from the population (Gregr et al. 2000). Current size averages are therefore likely lower than they were historically.

The following provides an example of the variation in size information available in the literature, and generalizes the process taken in selecting model parameters. The maximum reported length of a blue whale worldwide is 33.6 m, although the longest scientifically-validated measurement is 29.9 m (Rice 1978). Blue whales in the northern hemisphere are generally smaller than those in the southern hemisphere (Gregr et al. 2006) and the largest recorded individual in the northern hemisphere was a 28.1 m female reported from whaling catches in Davis Strait in the North Atlantic (Sears and Perrin 2009). Woodward et al. (2006) derived morphometric parameters (including for body length and maximum body diameter) for blue, humpback, and right whales "based on the definition of the average whale for each species". These values (presented Table 4) were selected for use in the model. Relative to some of the other input parameters, the model was relatively insensitive to changes in body size (See Section 4.2 and Appendix A).

2.3.2 Whale Swim Speeds

Maximum recorded swim speeds vary substantially between species, with the North Pacific right whale being the slowest at approximately 3 knots (Hain et al. 2013), and blue whales the fastest, at 20 kn burst speed McCarthy 1946 *in* Kermack (1947)). Burst speeds are generally not sustainable for more than 10 minutes or so, and are generally associated with predation events (whether avoidance or attack). Burst speeds are not used in the model explicitly but are included in Table 4 for consideration of species-specific potential for strike avoidance. The concept of an 'average' swim speed also depends heavily on context, as whales tend to have very different average swim speeds during feeding than while they are covering large distances during migration. For example, a single blue whale identified off Haida Gwaii, BC in June 1997 was re-sighted in the Santa Barbara Channel, California 28 days later. This represents a minimum travel distance of 2,500 km and a minimum average swimming speed of 2 kn (Sears and Calambokidis 2002). However, while swim speeds may generally fall in the range of 1.6 - 3.2 kn while blue whales are feeding, they can travel at speeds of 2.7 – 16 kn, and when being chased or hunted, can reach burst speeds of up to 20 kn McCarthy 1946 *in* Kermack (1947). For the model, slower travel/faster feeding speeds were selected; thus the blue whale was assigned an 'average' speed of 3 kn.

2.3.3 Whale Densities

A comprehensive spatial dataset allowing the estimation of mean annual whale density is not available for the study area. A number of previous studies in British Columbia have provided sightings data and relative abundance information (e.g., Ford et al. 2010a; Gregr et al. 2006) or density estimates for parts of the coast (e.g., Best and Halpin 2011; Williams and Thomas 2007). These studies however, are either not comprehensive of the study area, they report densities in a manner that does not facilitate the estimation of a per-area-density, or they did not contain observations of the species of interest. To evaluate annual whale encounter risk, densities were assigned based on the general criteria outlined below.

The potential of seeing a blue, sei, fin, or North Pacific right whale in the study area is considered generally unlikely. For these four species:

- There were no sightings during the surveys reported on in Best and Halpin (2011) in this region.
- There were less than four sightings in 38 years of opportunistic BC Cetacean Sightings Network (BC CSN) data in the Marine RSA (0 sightings each for blue, sei, and right whales; four sightings of fin whales) (British Columbia Cetacean Sightings Network 2013).
- Whaling records do not suggest that these species are likely to occur in this area or that they occurred here historically (although large numbers of catches were recorded off the continental shelf and effort by whaling vessels is unknown in the Marine RSA (Gregr et al. 2000; Nichol et al. 2002)).
- Expert opinion suggests that sightings of such animals in the study area would overall, be a rare occurrence. For example, on June 9, 2013, for the first time in over 60 years, a North Pacific right whale was spotted in BC waters – off the coast of Haida Gwaii. A second whale was seen off the entrance to Juan de Fuca Strait in October of the same year (Pynn 2013). According to DFO "Sightings of these whales are extremely rare – there are only six records of the species in Canadian waters over the past century, and all were killed by whalers; the last in 1951. Fewer than 50 individuals are thought to currently exist in the eastern North Pacific Ocean" (Fisheries and Oceans Canada 2013b).

It is not possible to evaluate encounter probabilities or risk for a zero density (i.e., in all likelihood the average annual probability of encounter for these species is 0). However, there remains some small possibility that on occasion one of these predominantly offshore species enters the westward reaches of the Marine RSA; there have been, for example, calls of blue whales recorded off Swiftsure Bank (Ford et al. 2010b), and on Oct 25, 2013 there was a sighting of a North Pacific right whale (the second in BC in 60 years) in the waters off the entrance to Juan de Fuca Strait (Pynn 2013). To evaluate possible non-zero annual whale encounter risk along the shipping routes for these species, a density was assigned based on the occurrence of a single individual of each species in Speed Segment 5 (i.e., from Race Rocks out to the western edge of the Marine RSA). This segment, and area, was selected due to the primarily offshore distribution of these species in southern BC waters (Nichol and Ford 2012). See Section 2.3.4 below for a description of how proportion of time in this area was assigned.

Despite the fact that Best and Halpin (2011) reported 0 densities for humpback whales and killer whales (i.e., these species were not observed during this particular survey), these species are known to occur in the Marine RSA on a far more regular basis than those species discussed above. For these two species, uniform density of whales is assumed across the entire grid, with the exception of Speed Segment 1 (Burrard Inlet), where it was assigned a value of 0 based on low predicted occurrence. The assumption of uniform density is known to be false, as these species are highly social and show highly aggregated distributions; however, without actual density survey information, the spatial and temporal resolution of available information was insufficient to undertake a more detailed approach.

Southern resident killer whales were used as a proxy to calculate encounter risk for all four ecotypes of killer whales (see Section 2.3.4 below for further details). Killer whale densities were therefore assigned assuming that the entire population of southern resident killer whales (i.e., 79 individuals as of Dec 31, 2014 (Center for Whale Research 2014)) was present within their critical habitat (i.e., 9,024 km^2; Figure 1), within which killer whales are expected to be present in the highest densities.

While the BC CSN data includes numerous opportunistic sightings of humpback whales in the study area over the course of the last four decades, the majority of the Marine RSA is generally not recognized as a humpback whale hotspot, although the western extent just overlaps with the eastern-most extent of humpback whale critical habitat (Figure 1)(Fisheries and Oceans Canada 2013a). As such, and since actual humpback whale density values for the Marine RSA do not exist, this species was assigned a density according to the lowest density observed for humpback whales during the surveys reported on in Best and Halpin (2011) elsewhere in BC ((Williams and Thomas 2007) did not observe any humpback whales during their summer 2004 survey in this area) This value corresponds to roughly 10 whales distributed across the majority of the Marine RSA (with the exception of Burrard Inlet, which was assigned a 0 density due to low predicted occurrence). Use of higher densities (for all species) was also tested in the model (e.g., using the highest densities reported on in Best and Halpin (2011) from other parts of BC), but these values produced unrealistically high encounter rates (i.e., suggesting that given the very large amount of vessel traffic [including whale watching operations] that these species should be seen on a far more frequent and regular basis than they are). The sensitivity of the model to the assigned densities is discussed in Section 4.2 and results are presented in Appendix A.

2.3.4 Time Spent in the Study Area

Consistent with the above discussion concerning the low likelihood of occurrence and lack of sighting records for blue, sei, and North Pacific right whales in the Marine RSA, instead of assigning these species a zero occurrence, they were assigned a predicted occurrence within the study area of one day every 10 years for sei and right whales, and one day every five years for blue whales. Blue whales were assigned a more frequent time spent in the study area, compared to sei and right whales, as a result of recorded calls at Swiftsure Bank (Ford et al. 2010b). All of these are assumed occurrences only, as there is no published information available on the potential seasonal presence of these species in the Marine RSA. Since there were four recorded instances of fin whales in the Marine RSA over 38 years (opportunistic data, no accounting of spatial or temporal effort)(British Columbia Cetacean Sightings Network 2013), this species was assigned a predicted occurrence of 1 day/year. While four sightings of fin whales over 38 years might have been represented by an assumed density of one every 9.5 years, at such low numbers, and in the less-populated western extent of the study area, this species may go unobserved/unreported. As such, a more conservative value of 1 day/year was used to acknowledge that though there have been very few sightings, fin whales have been seen in the study area (unlike the previous 3 species). Use of higher proportions of time in the study area were also tested in the model (for all four species), but these produced unrealistically high encounter rates (i.e., suggesting that these four species that are considered rare in the Marine RSA should in fact be seen on a frequent and regular basis given the very large amount of vessel traffic [including whale watching vessels] in the study area). The sensitivity of the model to the assigned 'time spent in the study area' is discussed in Section 4.2 and results are presented in Appendix 1.

Southern resident killer whales were used as a proxy to calculate encounter risk for all four ecotypes of killer whales. The Marine RSA overlaps the entire known Canadian critical habitat of this population (which is made up of three pods: J, K, and L). Based on a dataset maintained by the Whale Museum going back to 1976, J Pod spends some of its time in the Marine RSA, on average, during every month of the year (Osborne 1999; Osborne et al. 2001). The L and K pods are less common in March and April, although they are commonly observed in the Marine RSA every other month of the year (The Whale Museum 2013). Southern residents are therefore expected to be present in the Marine RSA in higher densities and for a larger portion of the year than the other three ecotypes (transients, offshores, and northern residents), which are present on a less predictable basis (COSEWIC 2009). Encounter risk is therefore likely to be highest for southern residents (i.e., a given vessel is more likely to encounter a southern resident killer whale than a transient, offshore or northern resident) Killer whales were predicted to be present eight and a half months of the year, based on the weighted average of J pod (n=26) being present all year, and L and K pods (n=34 and 19, respectively) each being present a full 7 months of the year (based on numbers from the Center for Whale Research as of Dec 31, 2014 (Center for Whale Research 2014)).

According to BC CSN records, humpback whales have been observed in the Marine RSA in all months of the year (British Columbia Cetacean Sightings Network 2013); however, numbers vary substantially seasonally, which is to be expected of a migratory species such as this (COSEWIC 2011). As a result, humpback whales were assigned a proportion of time in the study area of 0.17 (i.e., two months of the year) based on the largest concentration of sightings from the BC CSN data (British Columbia Cetacean Sightings Network 2013)).The model assigns the average whale density parameter equally across the proportion of time present (i.e., the model artificially smooths all data over the year and study area, and does not account for seasonal variations in whale or vessel density).

2.3.5 Time at the Surface

The biological parameter of 'time spent at the surface' is more complex than simply using values of 'surfacing time/intervals' reported in the literature for different whale species. The value must also include time spent during shallow dives. For an encounter to occur, a whale must be within the water column at depths shallow enough to encounter the hull or propellers of a vessel. Project-related Aframax tankers will have a maximum draft of 14.8 m; this means that marine mammals swimming or diving underwater at depths of less than 15 m, may not be visible at the surface, but may still be struck by the hull of the vessel or the propellers. There is also some indication that whales may be 'pulled in' towards the vessel (Knowlton et al. 1995; Knowlton et al. 1998; Silber et al. 2010).

Reporting on surfacing time/intervals can be done fairly easily through simple field observations; however, reporting on dive depth generally requires that an animal be tagged with a depth recorder. The difference between the two metrics can be substantial. Lagerquist et al. (2000) reported that four satellite-tagged blue whales in Central California spent >94% of their time submerged (i.e., leaving them 'available' for a strike only an apparent 6% of their time); however, the one whale with a depth recorder spent 78% of its time at depths ≤16 m, and thus within the range of a potential collision with a tanker hull.

Even within a given species, generalizations on time available at the surface (i.e., taken within this report to mean the top 15 m of the water column or so) are further complicated by differences between individuals, sexes, maturity, region, the season and, likely of greatest importance, activity state. Substantial variability is expected between whales depending on whether they are undertaking migration, resting, foraging, avoiding predators, engaging in social or mating activity etc. (e.g., Alves et al. 2010; Baird et al. 2003; Dolphin 1987; Goldbogen et al. 2008; Goldbogen et al. 2006; Winn et al. 1995). Since sightings of a number of the study species are rare or non-existent in the Marine RSA (i.e., blue, fin, sei, right whale), it is also difficult to assign a predicted activity state as studies of these animals in this area are entirely lacking.

For this model, efforts were made to select reasonable values for the 'time at surface' parameter based on literature (sometimes of single individuals) observed elsewhere; however, it is noted that, as for the values assigned to density and percent time in the study area, this parameter has a large influence on the output results. The % change in encounter risk scales linearly with % changes to any of these three parameters (see Section 4.2; sensitivity values are presented in Appendix A).

2.3.6 Biological Parameters used in the Encounter Risk Model

Table 4 lists the biological parameters applied in the encounter model as well as the sources for the assigned values.

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Table 4 Biological Parameters used in the Encounter Risk Model

Marine Mammal Species	Body Diameter (m)	Body Length (m)	Normal Swim Speed (knots)	Fastest Swim Speed (knots)	Assigned Densities (and associated speed segment)	Percentage of Time at Surface (<15 m depth)	Assigned Proportion of Year within Marine RSA
Blue whale	3.9[a]	24.7[a]	3[b]	20[c]	0.0004[d] (1b in segment 5 only)	78[e]	0.00055[d] (1 day/5 years)
Fin whale	2.8[f]	22.5[g]	6[g]	14[c]	0.0004[d] (1e in segment 5 only)	55[h]	0.0027[d] (1 day/year)
Sei whale	2.2[f]	15.8[i]	3[j]	13[j]	0.0004[d] (1g in segment 5 only)	85[k]	0.00027[d] (1 day/10 years)
North Pacific right whale	3.3[a]	15.0[a]	1[l]	3[l]	0.0004[d] (1 in segment 5 only)	95[m]	0.00027[d] (1 day/10 years)
Humpback whale	3.2[a]	13.5[a]	2[n]	6[o]	0.0012[p] (across all segments but 1)	46[q]	0.17[d] (2 months/year)
Killer whale	1.0[r]	9.0[s]	3[t]	11[r]	0.0088[u] (across all segments but 1)	97[v]	0.70[u] (8.4 months/year)

Notes:

There are four ecotypes of killer whales with the potential to occur in the Marine RSA. The southern resident was selected to conservatively represent potential encounter risk for all four populations

See subsections 2.3.1 – 2.3.5 above for a description of values represented in the above table and method of selection.

Swim speeds are represented in knots for ease of comparability with vessel speeds discussed in other sections of the report. Burst speeds were not used in the model but are supplied for reference.

Sources:

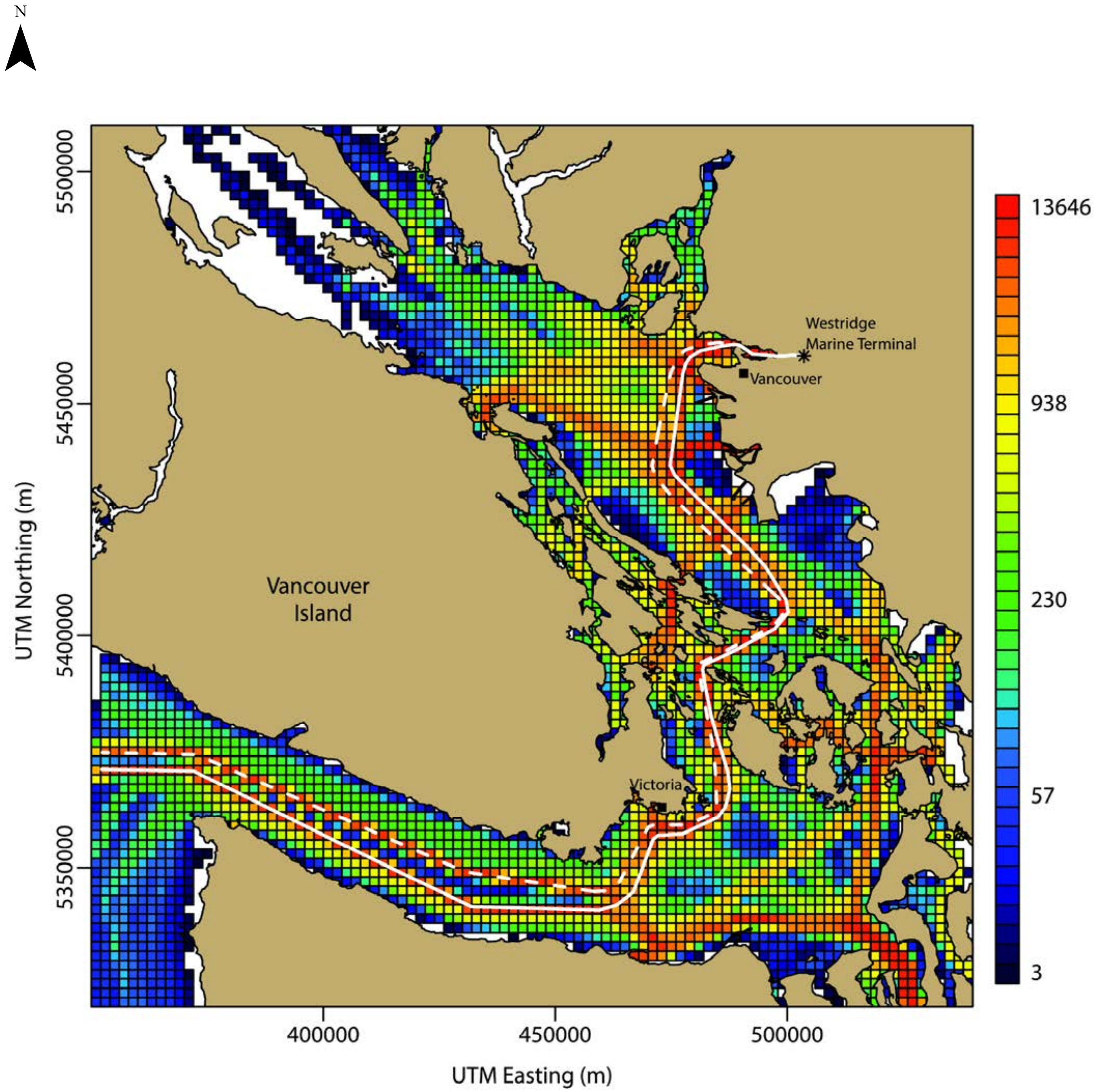
[a]: Woodward et al. (2006); [b]: Sears and Perrin (2009); [c]: McCarthy 1946 in Kermack (1947); [d]: Assigned parameters. See explanation in Sections 2.3.3, and 2.3.4; [e]: Lagerquist et al. (2000) [f]: derived from upper average girth (8.8 m for fin and 7.0 m for sei)(Víkingsson et al. 1988), assuming girth roughly approximates a circle; [g]: Aguilar (2009); [h]: Goldbogen et al. (2008); [i]: Best and Lockyer (2002) [j]: records were not located for sei whales and therefore values were based on the morphologically very similar Bryde's whale (*Balaenoptera edeni/brydei*) in Kato and Perrin (2009); [k]: Alves et al. (2010); value for Bryde's whale (see j); [l]: based on North Atlantic right whales (Hain et al. 2013); [m]: Winn et al. (1995) [n]: Noad and Cato (2007); [o]: Bauer (1986) in Gabriele et al. (1996); [p]: (Best and Halpin 2011); [q]: Goldbogen et al. (2006); [r]: Fish (1998); [s]: Ford (2009) [t]: Williams and Noren (2009); [u]: Center for Whale Research (2014); [v]: Baird et al. (2003)

3.0 RESULTS

3.1 BASELINE VESSEL TRAFFIC

3.1.1 Vessel Densities

Analysis of the AIS data for 2012 clearly indicates a wide range in vessel densities within the Marine RSA as measured per 2 km by 2 km cell. Estimated baseline annual vessel density ranges from 0 to a maximum of 13,646 vessels per cell per year, with a median across the study area of 242 vessels (95% confidence interval [CI]: 4 – 4,416). Areas of higher density traffic, indicating shipping lanes and primary shipping routes, are distinct in Figure 3.



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Estimated baseline annual vessel densities per 2 km by 2 km cell are based on AIS traffic data for 2012. The white lines indicate the IMO-designated shipping lanes that Project-related tankers will transit inbound (solid line) and outbound (dashed). White areas within the grid indicate no AIS traffic data.

TRANS MOUNTAIN

FIGURE: 3

ESTIMATED BASELINE 2012 VESSEL DENSITIES (IN # PER 2 KM X 2 KM CELL) IN THE MARINE RSA

TRANS MOUNTAIN EXPANSION PROJECT

MAP NUMBER		PAGE
10494_FIG_03		SHEET 1 OF 1
DATE Apr 2015	REF. 7894	REVISION 0
SCALE N.T.S.	PAGE SIZE 8.5x11	DISCIPLINE SD
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Bivand, R., N. Lewin-Koh, E. Pebesma, E. Archer, A. Baddeley, H.-J. Bibiko, S. Brey, J. Callahan, G. Carrillo, S. Dray, D. Forrest, M. Friendly, P. Giraudoux, D. Golicher, V. Gómez Rubio, P. Hausmann, K.O. Hufthammer, T. Jagger, S. Luque, D. MacQueen, A. Niccolai, E. Pebesma, O. Perpiñán Lamigueiro, T. Short, G. Snow, B. Stabler, M. Stokely and R. Turner. (2015). maptools: Tools for Reading and Handling Spatial Objects (Version 0.8-34) [R Statistical software].

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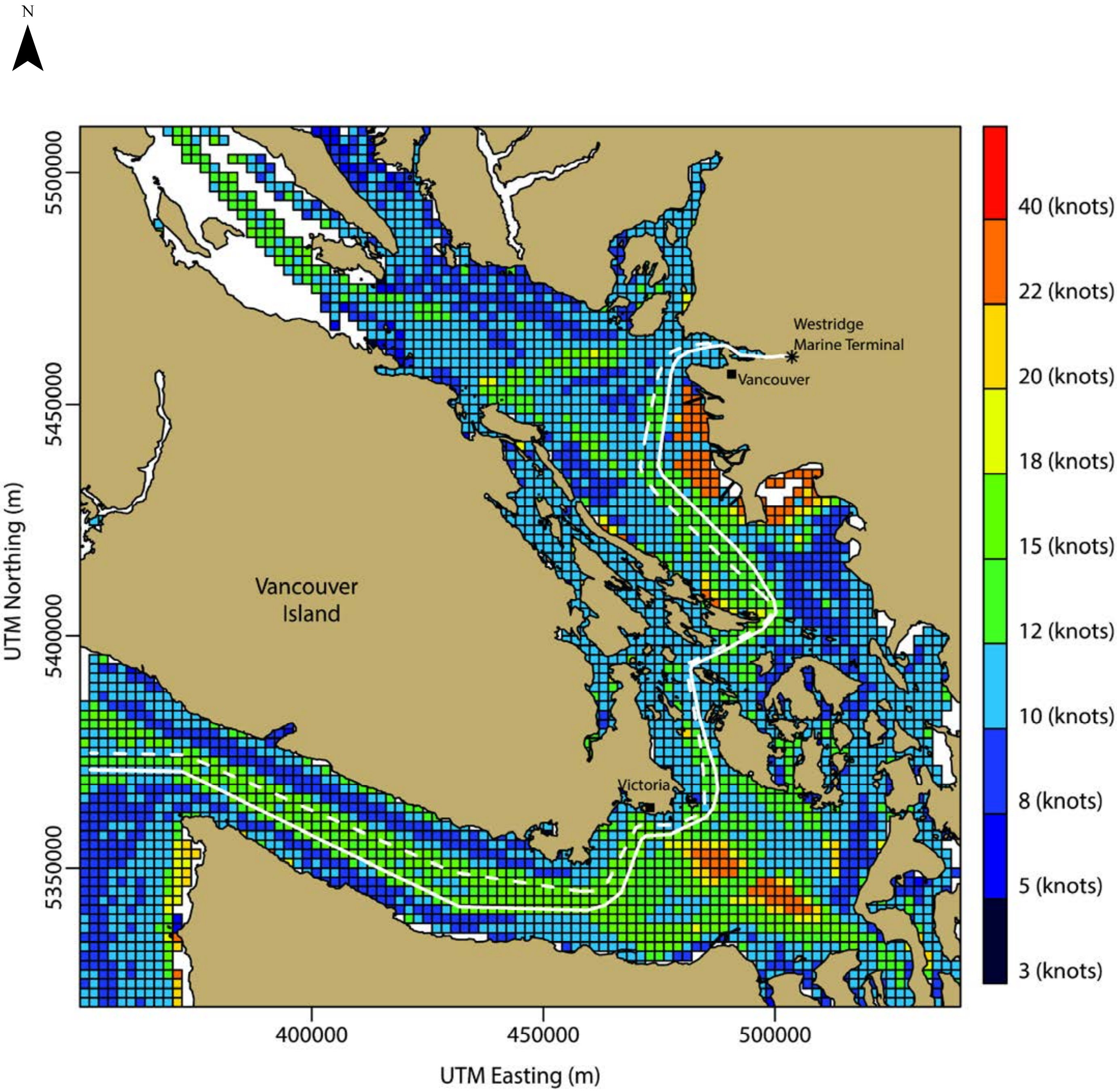
Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

3.1.2 Vessel Speeds

Median annual baseline vessel speeds in the Marine RSA were 11.92 knots (95% CI: 7.82 –22.97). Vessel speeds were highest off Richmond and along the ferry route connecting Victoria and Port Townsend in the US (Figure 4). The maximum vessel speed reported in the AIS data (below the assumed error truncation value of 60 knots) was 41.75 knots.



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Estimated baseline mean annual vessel speeds (in knots) per 2 km by 2 km cell are based on AIS traffic data for 2012. The white lines indicate the IMO-designated shipping lanes that Project related tankers will transit inbound (solid line) and outbound (dashed). White areas within the grid indicate no AIS traffic data.

TRANS MOUNTAIN

FIGURE: 4

ESTIMATED BASELINE MEAN 2012 VESSEL SPEEDS (IN KNOTS) PER 2 KM X 2 KM CELL IN THE MARINE RSA

MAP NUMBER		PAGE
10494_FIG_04		SHEET 1 OF 1
DATE Apr 2015	REF. 7894	REVISION 0
SCALE N.T.S.	PAGE SIZE 8.5x11	DISCIPLINE SD
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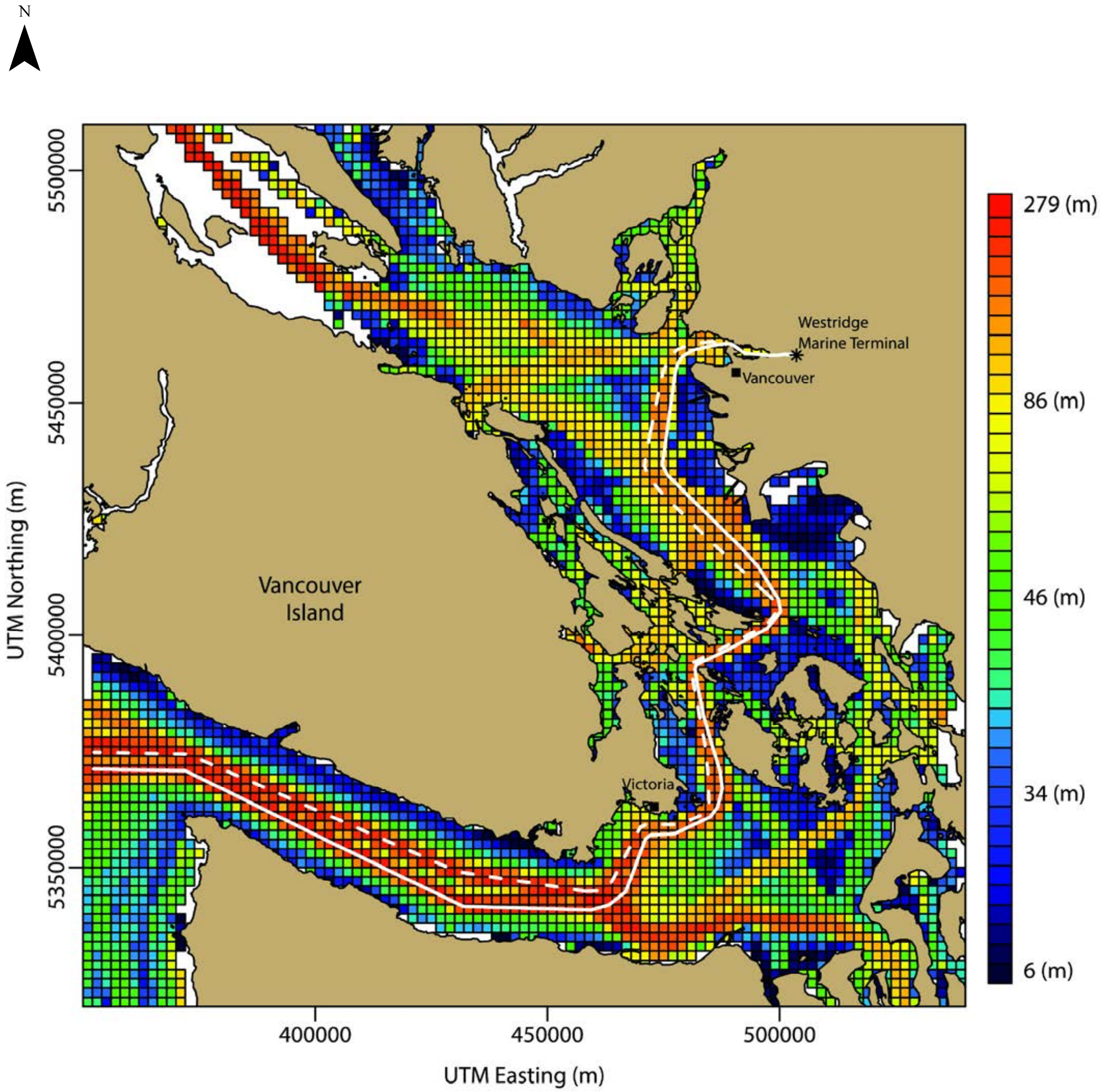
TRANS MOUNTAIN EXPANSION PROJECT

3.1.3 Vessel Length Overall

Median vessel LOA in the Marine RSA was 47.20 m (95% CI: 18.01-213.16), with a maximum recorded size of 279.17 m. The longest vessels were recorded along the shipping route in Juan de Fuca Strait (Figure 5).



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Estimated baseline mean annual vessel LOAs (in m) per 2 km by 2 km cell are based on AIS traffic data for 2012. The white lines indicate the IMO-designated shipping lanes that Project related tankers will transit inbound (solid line) and outbound (dashed). White areas within the grid indicate no AIS traffic data.

TRANS MOUNTAIN

FIGURE: 5

MAP NUMBER		PAGE
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DATE Apr 2015	REF. 7894	REVISION 0
SCALE N.T.S.	PAGE SIZE 8.5x11	DISCIPLINE SD
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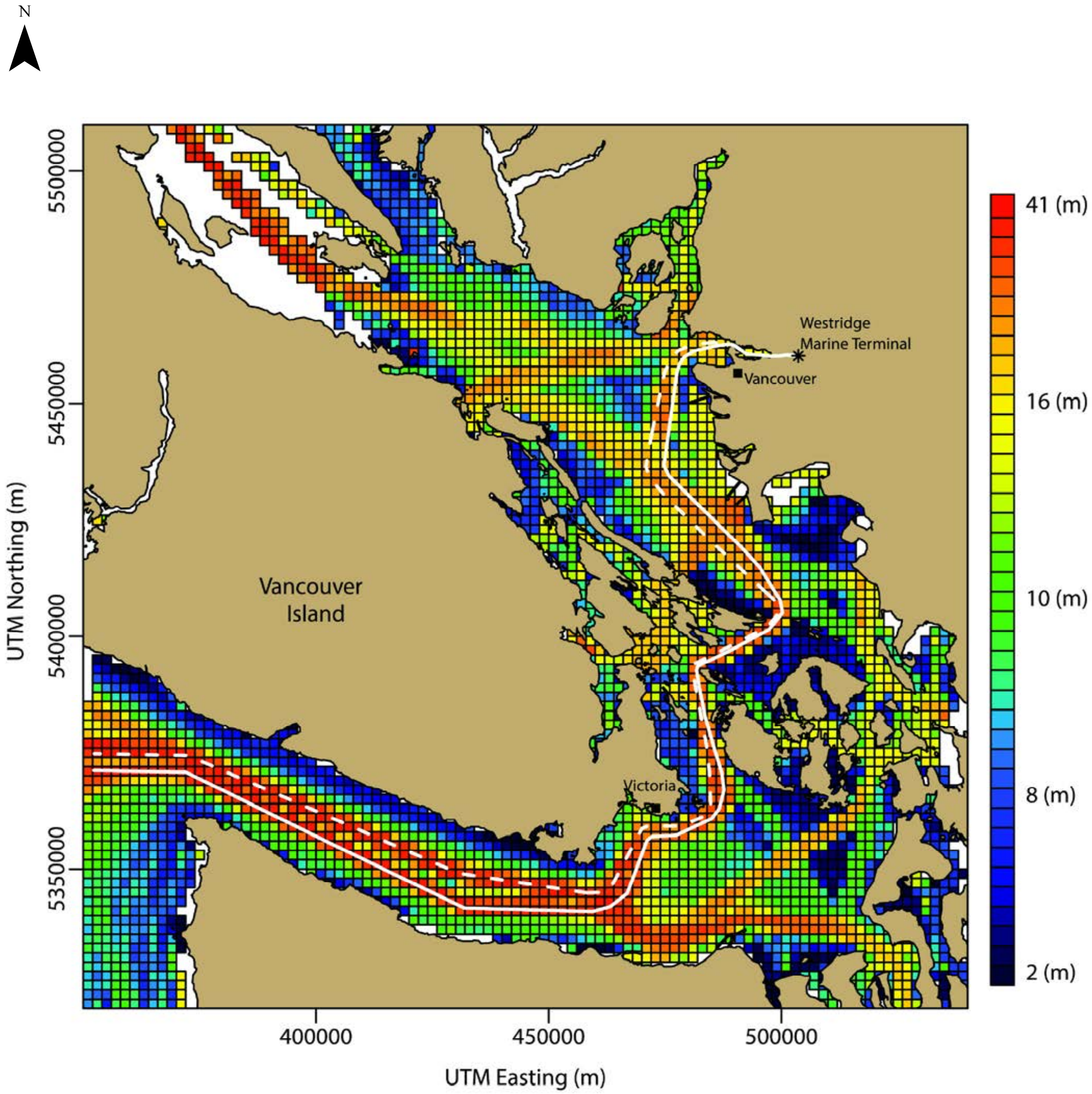
ESTIMATED BASELINE MEAN 2012 VESSEL LENGTH OVERALL (IN M) PER 2 KM X 2 KM CELL IN THE MARINE RSA

TRANS MOUNTAIN EXPANSION PROJECT

3.1.4 Vessel Beams

Analysis of the AIS data for 2012 indicated that the largest beamed vessels occurred along the shipping route in Juan de Fuca Strait, with a maximum per cell average of 41.39 m (Figure 6). Median beam size across the Marine RSA was 10.56 m (95% CI: 5.52 -31.26).



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Estimated baseline mean annual vessel beams (in m) per 2 km by 2 km cell are based on AIS traffic data for 2012. The white lines indicate the IMO-designated shipping lanes that Project related tankers will transit inbound (solid line) and outbound (dashed). White areas within the grid indicate no AIS traffic data.

TRANS MOUNTAIN

FIGURE: 6

ESTIMATED BASELINE MEAN 2012 VESSEL BEAMS (IN M) PER 2 KM BY 2 KM CELL IN THE MARINE RSA

TRANS MOUNTAIN EXPANSION PROJECT

MAP NUMBER		PAGE
10494_FIG_06		SHEET 1 OF 1
DATE Apr 2015	REF. 7894	REVISION 0
SCALE N.T.S.	PAGE SIZE 8.5x11	DISCIPLINE SD
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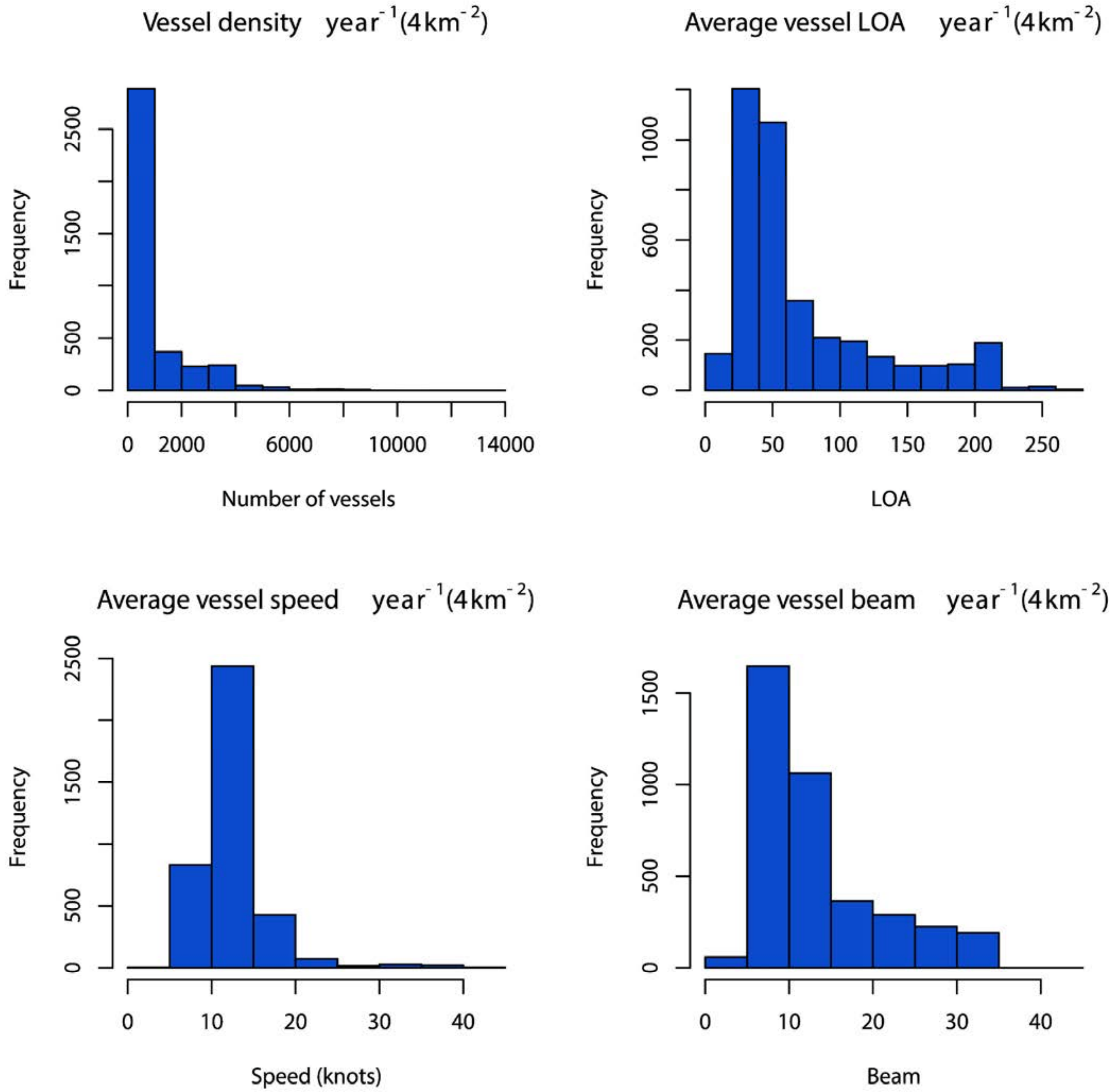
3.1.5 Vessel Summary Statistics

Figure 7 presents histograms of the estimated baseline 2012 vessel densities, and mean speed, LOA, and beam across all 2 km by 2 km grid cells within the shipping routes of the Marine RSA.



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Histograms of estimated baseline vessel densities, and mean speed, LOA, and beam based on AIS traffic data for 2012, tallied across each 2 km by 2 km grid cell along the shipping within the Marine RSA.

TRANS MOUNTAIN

FIGURE: 7

BASELINE 2012 VESSEL STATISTICS ALONG THE SHIPPING LANES IN THE MARINE RSA

MAP NUMBER		PAGE
10494_FIG_07		SHEET 1 OF 1
DATE Apr 2015	REF. 7894	REVISION 0
SCALE N.T.S.	PAGE SIZE 8.5x11	DISCIPLINE SD
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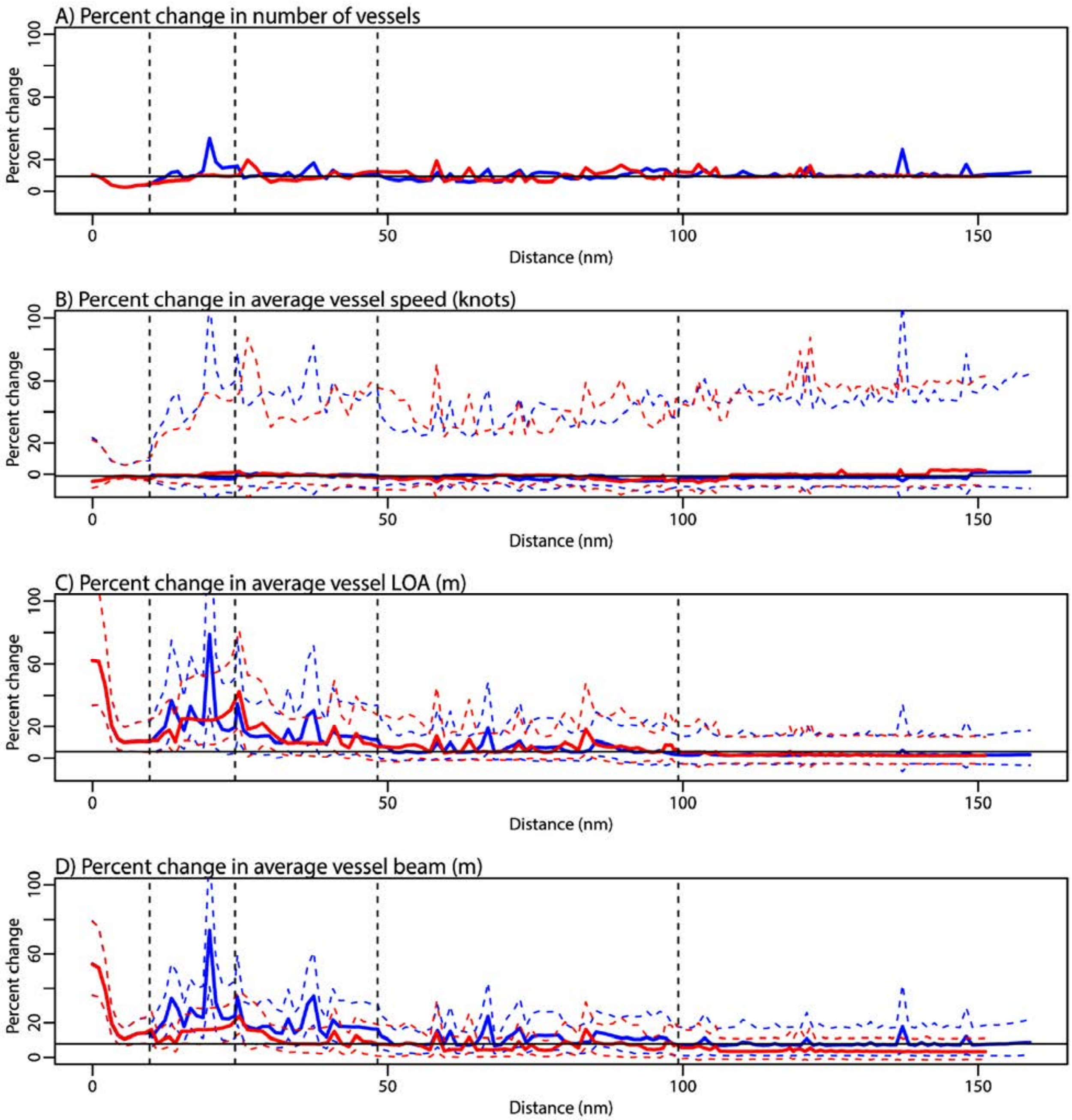
TRANS MOUNTAIN EXPANSION PROJECT

3.2 CHANGE IN BASELINE VESSEL TRAFFIC DUE TO THE PROJECT

The addition of Project-related tankers is estimated to increase baseline median vessel density along the shipping route by approximately 9.4% (range of 2.6% to 33.5%), from 3,721 to 4,069 vessels per cell per year (Figure 8). The Project is expected to have minimal effect on the median size of vessels, except within Burrard Inlet (Figure 8). Median vessel speeds along the shipping route are expected to decrease (-1.6%; range of -5.1% to 2.0%), from 14.7 to 14.5 knots (Figure 8).



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Estimated percentage change from 2012 AIS-based baseline vessel densities (A), and average speed (B), average LOA (C), and average beam (D) along the shipping routes in the Marine RSA. Blue lines are outbound shipping lane. Red lines are inbound shipping lane (starting at the Westridge Marine terminal for ease of comparison). Solid blue and red lines are median values from 10,000 bootstrapped samples. Dashed coloured lines are the 95% CI. Dashed black lines represent the route segments starting at the Westridge Marine Terminal (see Figure 2).

TRANS MOUNTAIN

FIGURE: 8

PROJECT-RELATED PERCENTAGE CHANGE IN VESSEL STATISTICS ALONG THE SHIPPING LANES IN THE MARINE RSA

MAP NUMBER		PAGE
10494_FIG_08		SHEET 1 OF 1
DATE Apr 2015	REF. 7894	REVISION 0
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TRANS MOUNTAIN EXPANSION PROJECT

3.3 ENCOUNTER RISK

Table 5 presents the model predictions for annual encounter risk and return interval along the shipping lanes for the baseline, Project, and combined case. Percentage change in annual encounter risk and the change in return interval as a result of the anticipated increase in Project related traffic is also shown. Table 6 shows the same calculations considered across the entire study area.

Model predictions for annual encounter risk and return interval based on predicted future traffic levels (in 2018, 2020, 2025, 2030) are shown for the areas along the shipping lanes in Table 7, and across the entire study area as a whole in Table 8.

Table 5 Annual Encounter Risk and Return Intervals for Baseline, Project, and Combined Case along the Shipping Lanes

Species	Baseline (2012)		Project		Combined		% Change in ER	Change in RI in Years or *Days
	Encounter Risk (ER)	Return Interval (RI) in Years or *Days	Encounter Risk (ER)	Return Interval in Years or *Days	Encounter Risk (ER)	Return Interval in Years or *Days		
Blue whale	0.0064	156.8	0.0009	1,155.7	0.0072	138.1	13.5353	-18.6970
Fin whale	0.0225	44.4	0.0031	320.4	0.0256	39.1	13.7363	-5.3645
Sei whale	0.0030	331.9	0.0004	2,360.2	0.0034	291.0	14.0227	-40.8125
North Pacific right whale	0.0033	301.3	0.0005	2,153.2	0.0038	264.3	13.9866	-36.9646
Humpback whale	7.0339	*50.3	1.0593	*334.2	8.0901	*43.8	15.0161	*-6.789
Killer Whale	401.8678	*0.9	62.5004	*5.7	464.3684	*0.8	15.5525	*-0.1095

Encounter risk, return interval, percent change in encounter risk, and change in return interval using whale base parameter values. Estimates are total over all areas along the proposed vessel route.

Encounter risk is the probability that a whale is encountered along the shipping lanes transited by baseline traffic, Project traffic alone, and combined Project + baseline traffic.

Return Interval is the expected number of years or days (for cells marked with an *) required to encounter an individual whale on the shipping lanes by baseline traffic, Project traffic alone, and combined Project + baseline traffic.

Percent change in encounter risk represents the change in probability of encounter over baseline levels as a result of the anticipated increase in Project-related vessels.

Change in years represents the change in the return interval (i.e., number of years until encounter) over baseline levels as a result of the anticipated increase in Project-related vessels.

Table 6 Annual Encounter Risk and Return Intervals for Baseline, Project, and Combined Case in the Entire Study Area

	Baseline (2012)		Project		Combined			
Species	Encounter Risk (ER)	Return Interval (RI) in Years or *Days	Encounter Risk (ER)	Return Interval in Years or *Days	Encounter Risk (ER)	Return Interval in Years or *Days	% Change in ER	Change in RI in Years or *Days
Blue whale	0.0087	114.4	0.0009	1155.7	0.0096	104.3	9.6176	-10.0341
Fin whale	0.0309	32.3	0.0031	320.4	0.0339	29.5	9.7461	-2.8714
Sei whale	0.0041	245.3	0.0004	2360.2	0.0045	222.8	10.1020	-22.5090
North Pacific right whale	0.0045	223.0	0.0005	2209.7	0.0049	202.6	10.0895	-20.4393
Humpback whale	16.5110	*21.4	0.9392	*376.9	17.4472	*20.3	5.6707	*-1.2045
Killer Whale	912.3569	*0.4	62.5004	*5.7	967.7510	*0.4	6.0715	*-0.0365

Encounter risk, return interval, percent change in encounter risk, and change in return interval using whale base parameter values. Estimates are total over all areas within the Marine RSA.

Encounter risk is the probability that a whale is encountered along the shipping lanes transited by baseline traffic, Project traffic alone, and combined Project + baseline traffic.

Return Interval is the expected number of years or days (for cells marked with an *) required to encounter an individual whale on the shipping lanes by baseline traffic, Project traffic alone, and combined Project + baseline traffic.

Percent change in encounter risk represents the change in probability of encounter over baseline levels as a result of the anticipated increase in Project-related vessels.

Change in years represents the change in the return interval (i.e., number of years until encounter) over baseline levels as a result of the anticipated increase in Project-related vessels.

Table 7 Annual Encounter Risk and Return Intervals for Future Case along the Shipping Lanes

	2018		2020		2025		2030	
Species	Encounter Risk (ER)	Return Interval (RI) in Years or *Days	Encounter Risk (ER)	Return Interval in Years or *Days	Encounter Risk (ER)	Return Interval in Years or *Days	Encounter Risk (ER)	Return Interval (RI) in Years or *Days
Blue whale	0.0074	135.1	0.0075	132.8	0.0079	127.0	0.0082	121.4
Fin whale	0.0261	38.3	0.0266	37.6	0.0278	36.0	0.0291	34.4
Sei whale	0.0035	286.0	0.0036	280.9	0.0037	268.7	0.0039	256.8
North Pacific right whale	0.0039	259.6	0.0039	255.0	0.0041	243.9	0.0043	233.2
Humpback whale	8.1406	*44.8	8.2865	*44.0	8.6651	*42.1	9.0656	*40.3
Killer Whale	465.1137	*0.8	473.4523	*0.8	495.0840	*0.7	517.9625	*0.7

Estimated encounter risk and return interval using whale base parameter values for 2018, 2020, 2025, and 2030 accounting for increases in vessel density. Estimates are total over all areas along the shipping lanes.

Encounter risk is the probability that a whale is encountered along the shipping lanes transited by four future traffic levels (i.e., in 2018, 2020, 2025, 2030).

Return Interval is the expected number of years or days (for cells marked with an *) required to encounter an individual whale on the shipping lanes under four future traffic levels (i.e., in 2018, 2020, 2025, 2030).

Table 8 Annual Encounter Risk and Return Intervals for Future Case in the Entire Study Area

	2018		2020		2025		2030	
Species	**Encounter Risk (ER)**	**Return Interval (RI) in Years or *Days**	**Encounter Risk (ER)**	**Return Interval in Years or *Days**	**Encounter Risk (ER)**	**Return Interval in Years or *Days**	**Encounter Risk (ER)**	**Return Interval (RI) in Years or *Days**
Blue whale	0.0101	98.6	0.0103	96.8	0.0108	92.5	0.0113	88.3
Fin whale	0.0359	27.8	0.0366	27.3	0.0383	26.1	0.0401	24.9
Sei whale	0.0047	210.6	0.0048	206.8	0.0051	197.6	0.0053	188.7
North Pacific right whale	0.0052	191.4	0.0053	188.0	0.0056	179.6	0.0058	171.6
Humpback whale*	18.4955	*19.7	18.8446	*19.4	19.7500	*18.5	20.7076	*17.6
Killer Whale*	1025.8206	*0.4	1045.1541	*0.3	1095.3084	*0.3	1148.3535	*0.3

Estimated encounter risk and return interval using whale base parameter values for 2018, 2020, 2025, and 2030 accounting for increases in vessel density. Estimates are total over all areas along the shipping lanes.

Encounter risk is the probability that a whale is encountered along the shipping lanes transited by four future traffic levels (i.e., in 2018, 2020, 2025, 2030).

Return Interval is the expected number of years or days (for cells marked with an *) required to encounter an individual whale on the shipping lanes under four future traffic levels (i.e., in 2018, 2020, 2025, 2030).

Table 9 Project Percent Contribution to Future Case (Cumulative Effects) Encounter Risk

	2018		2020		2025		2030	
Species	**Project % Contribution to Encounter Risk in Shipping Lanes**	**Project % Contribution to Encounter Risk in the Entire Study Area**	**Project % Contribution to Encounter Risk in Shipping Lanes**	**Project % Contribution to Encounter Risk in the Entire Study Area**	**Project % Contribution to Encounter Risk in Shipping Lanes**	**Project % Contribution to Encounter Risk in the Entire Study Area**	**Project % Contribution to Encounter Risk in Shipping Lanes**	**Project % Contribution to Encounter Risk in the Entire Study Area**
Blue whale	11.69	8.31	11.49	8.16	10.99	7.80	10.50	7.45
Fin whale	11.94	8.47	11.73	8.32	11.22	7.95	10.73	7.59
Sei whale	12.12	8.69	11.90	8.54	11.38	8.16	10.88	7.79
North Pacific right whale	12.06	8.66	11.84	8.51	11.33	8.13	10.83	7.76
Humpback whale	13.01	5.08	12.78	4.98	12.23	4.76	11.69	4.54
Killer Whale	13.44	5.40	13.20	5.30	12.62	5.06	12.07	4.82

Estimated Project % contribution to encounter risk for future traffic levels (i.e., in 2018, 2020, 2025, and 2030) accounting for increases in vessel density both along the shipping lanes and in the entire Marine RSA.

4.0 DISCUSSION

4.1 INTERPRETATION OF ENCOUNTER RISK

Based on the results of the encounter risk model, for four of the five baleen whale species considered (blue, fin, sei, and North Pacific right whale), the overall probability of a Project-related vessel encountering a marine mammal is considered very low. While encounter risk is higher for humpback whales and killer whales compared to the other species and regardless of the inclusion of Project vessels or not, this is to be expected given their higher predicted densities in the study area. Based on the assumptions presented above, a Project-related vessel was predicted to encounter a marine mammal along the shipping lanes once every 1,156 years for blue whales; once every 320 years for fin whales, once every 2,360 years for sei whales; and once every 2,153 years for North Pacific right whales (Table 5). For the most likely species of baleen whale to be seen in the Marine RSA (humpback whales), the Project-related return interval along the shipping lanes was predicted to be once every 334 days, and for killer whales, the only toothed whale assessed in this analysis, it was once every 6 days (Table 5).

The above return intervals only represent the frequency with which a Project-related vessel and marine mammal are expected to co-occur in the same place at the same time, assuming random ballistic trajectories of the whale. They do not factor in any behavioural responses of the whale (i.e., movement out of the area as the vessel approaches), nor any avoidance response (e.g., dives, bursts of speed, changes of course). Only a fraction of the above number of encounters will result in actual physical contact between a vessel and a whale; and if physical contact does occur, only a fraction of these incidents may result in fatal injuries (see Section 4.2). For the species examined for this report, publicly available behavioural or density data either do not exist or are not sufficient to predict levels of physical contact and fatalities.

While ship strikes leading to marine mammal fatalities can and do occur, such occurrences are infrequent relative to the number of vessels on the water. As demonstrated by the numbers presented above for Project-related vessels, the encounter risk for any particular vessel is also small. It is therefore important to also consider the combined effects across vessels of all sizes and classes.

The baseline probability that any vessel encounters a blue whale along the shipping lanes, based on 2012 traffic levels, is predicted to be once every 157 years. With the addition of Project-related vessel traffic, the overall combined encounter risk increases, and the return interval drops to once every 138 years. This is a decrease in return interval (RI) of 18.7 years (i.e., the increase in Project-related vessel traffic results in a change in encounter risk [ER] of13.5%). Similarly, the overall combined probability of a vessel-marine mammal encounter along the shipping lanes is: once every 39 years for fin whales (change in ER due to Project of 13.7%); once every 291 years for sei whales (change in ER of 14.0%); once every 264 years for North Pacific right whales (change in ER of 14.0%); once every 0.8 days for killer whales (change in ER of 14.0%) and for humpback whales, once every 44 days (change in ER of 15.0%). While the actual encounter risk is much higher for killer whales and humpback whales compared to the other species (i.e., every 44 days for humpback whales as opposed to every 138 years for blue whales), this is largely a factor of the much higher likelihood of humpback whales and killer whales occurring within the study area to encounter. Without the addition of Project-related vessel traffic, 2012 baseline vessel traffic is already predicted to encounter a humpback whale every 50.3 days. Thus, the effect of the additional Project-related traffic is to decrease the return interval of encounters by 6.8 days (Table 5). Predicted encounter risks and return intervals along the shipping lane under four future traffic levels (i.e., 2018, 2020, 2025, 2030) are presented in Table 7, and the Project's percent contribution to the cumulative effects of future encounter risk are presented in Table 9.

With respect to the study area as a whole, the overall combined probability of a vessel (baseline traffic or Project-related) encountering a marine mammal anywhere in the Marine RSA is: once every 104 years for blue whales (change in [ER] due to the increase in Project-related vessel traffic of 9.6%); once every 30 years for fin whales (change in ER due to Project of 9.7%); once every 223 years for sei whales (change in ER due to Project of 10.1%); once every 203 years for North Pacific right whales (change in ER due to Project of 10.1%); once every 20.3 days for humpback whales (change in ER due to Project of 5.7%); and once every 0.4 days for killer whales (change in ER due to Project of 6.1%)(Table 6). Thus, while the Project's influence along the shipping lanes is predicted to increase the change in encounter risk by 13.5 – 15.6%, when considered across the Marine RSA as a whole, the increase in Project-related vessels is predicted to result in an increased change in encounter risk of 5.7 – 10.1%. Predicted encounter risks and return intervals in the Marine RSA as a whole under four future traffic levels (i.e., 2018, 2020, 2025, 2030) are presented in Table 8.

Table 9 presents the Project's percent contribution to the cumulative effects of encounter risk under four future traffic levels. While traffic in the Marine RSA is predicted to increase according to the annual percent growth factors presented in Table 3, the anticipated increase in the number of Project-related vessels will stay the same. As a result, the Project's relative contribution to encounter risk will decrease over time (Table 9). Since Project-related vessels will travel along the designated shipping lanes, the Project will have a larger relative effect when only vessel traffic along the shipping lanes is considered. The Project contribution to encounter risk along the shipping lanes is predicted to be 11.7 – 13.4% in 2018 (depending on the species considered), and 10.5 – 12.1% in 2030). Considered across the Marine RSA as a whole, the Project's contribution to encounter risk is predicted to be 5.1 – 8.7% in 2018, and this contribution is expected to drop to 4.5 – 7.8% by 2030.

This risk analysis is considered conservative because it does not consider behavioural responses of the whale to approaching vessels and thus encounter risks as presented overstate the risk for vessel strikes.

4.2 SENSITIVITY ANALYSIS

A sensitivity analysis was conducted to explore how various parameters used in the model might positively or negatively bias the model should the assumptions behind them prove faulty. The first set of analyses considered the effects that the biological parameters have on model results. For each species, the combined parameters of whale length, whale width, and whale speed were increased (Table A-1) and then decreased (Table A-2) by a factor of 20% each, and the results on the predicted encounter risks were calculated. The results indicate that if, for example, the modelled representative blue whale had been assigned a width of 4.7 m instead of 3.9 m, a length of 29.6 m instead of 24.7 m, and a speed of 3.6 knots instead of 3.0 knots, then this larger, faster blue whale would have encountered Project-related vessels at a return interval that was 5.4% shorter than the one predicted (i.e., an encounter would have been predicted every 1,093 years instead of every 1,155 years). Likewise, if the humpback whale had been modelled as a smaller, slower whale (decreases of width, length, and speed), the model would have predicted a combined encounter risk (for baseline and project vessels) along the shipping lanes, every 17.2 days, instead of every 16.4 days (a change in RI of 5.0%)(Table A-2). Overall, across all species and cases considered, an increase in the biological parameters by 20% would have altered the encounter risk by a maximum of 9.1%, and a decrease of 20% would have lowered them no more than 8.2%.

Changes in encounter risk scaled directly with the assigned density, '% time in study area', and '% time in surface waters' (Figures A-3 to A-8) so that increases or decreases in a parameter by 20% resulted in a corresponding increase or decrease of 20%. For return intervals, the change of 20% resulted in a change of 25% (for an increase) or -16.7% (for a decrease).

4.3 EXTRAPOLATION FROM ENCOUNTER RISK

Should a mathematical, species-specific understanding of strike risks become available in the future, the annual probability of whale mortality (p_m) for a given 2 km by 2 km cell could be calculated as the product of encounter probability (p_e), strike probability given speed (p_s), and probability of lethal strike given the speed (p_l)(i.e., $p_m = p_e \times p_s \times p_l$).

As an example of how these probabilities might interact, the case of the North Atlantic right whale can be explored. Kite-Powell et al. (2007) developed a model relating vessel speed to probability of striking a North Atlantic right whale by using "probabilistic description of right whale response based on [...] observed behaviours". Different species of whale no doubt show a range of responses to an approaching vessel (i.e., whether they dive, turn, speed up, slow down, and at what point, if any, they respond (e.g., Croll et al. 2001; Nowacek et al. 2004; Williams and Ashe 2007; Williams et al. 2002; Williams et al. 2009). Since Kite-Powell's 2007 study is the only one of its kind to date, a better understanding of the behavioural responses of species found locally would be required to develop and apply this type of mathematical relationship. However, for discussion purposes, we can consider the type of influence that the probability of strike might have on our probabilities of encounter.

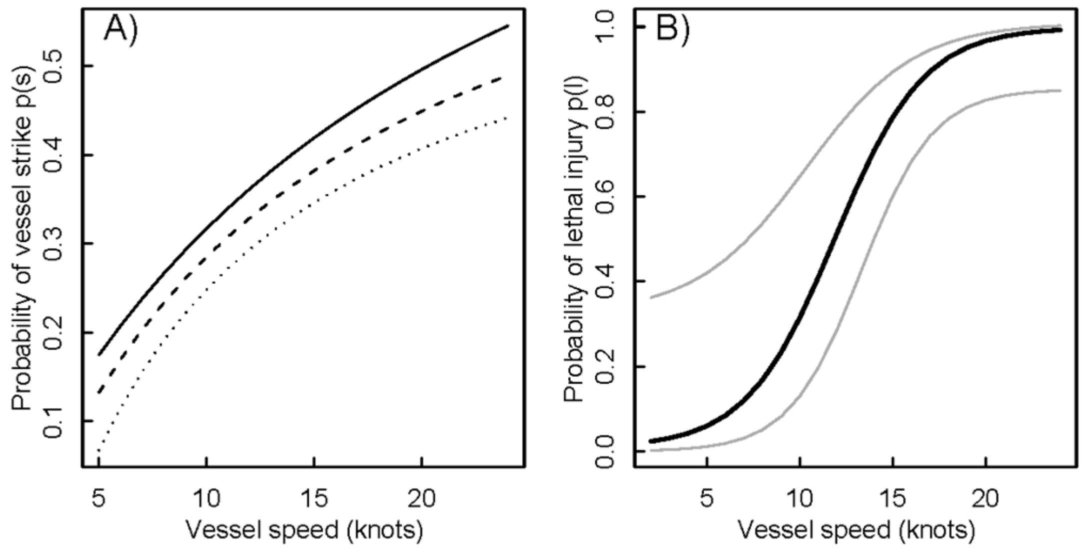

Figure 9 Relationships between Vessel Speed and Probability of (A) vessel strike, and (B) Lethality

1. *Probability of strike, p_s, given vessel speed estimated from data presented in Kite-Powell et al. (2007) for large container ships (solid line), bulk carrier (dashed line), and large catamaran (dotted line). Median predicted vessel speeds along the shipping route under the baseline and combined case were most comparable to Kite-Powell et al. (2007)'s bulk carrier category [i.e., typical operating speed: 15 knots].*
2. *Probability of lethal injury, p_l, estimated from Vanderlaan and Taggart (2007). Solid line indicates maximum likelihood fit for a logistic model and the grey lines are the upper and lower 95% confidence intervals.*

Along the shipping routes in the Marine RSA median vessel speeds for the combined case were calculated to be 14.5 knots (a decrease from the baseline case of 14.7 knots). At these speeds, Kite-Powell et al. (2007) predicted that North Atlantic right whales have an approximate 0.38 probability of being struck (from Figure 9A dashed line; median vessel speeds along the shipping route were most comparable to Kite-Powell et al. (2007)'s bulk carrier category [typical operating speed: 15 knots]).

The relationship to probability of strike lethality (see Figure 9B) developed by Vanderlaan and Taggart (2007), was based on worldwide records of strikes to large whales. If one assumes that this relationship is a true reflection of probability of lethality for right whales, than at the speeds under discussion (14.5 knots) along the shipping lanes of the Marine RSA (should a right whale be present), Vanderlaan and Taggart (2007) predict that for a given strike, probability of lethality is 0.74. Thus, out of the number of right whales encountered, 28% are likely to be fatally wounded (i.e., 0.38 probability of strike x 0.74 probability of lethality). Extrapolating to a local species, the return interval calculated for this study predicted that on average, for the combined case (baseline plus Project), a vessel transiting in the Marine RSA would encounter an individual North

Pacific right whale approximately once every 200 years, and using the Atlantic right whale values, would be predicted to result in a fatal injury once every 709 years. While North Atlantic right whales are certainly struck and killed on a far more frequent basis, the low predictions for North Pacific whales are due to the extreme difference in population densities between the two species. North Pacific right whales are basically not expected in the Marine RSA, whereas on the Atlantic coast, most of the North Atlantic right whale aggregation areas are in or near major shipping lanes (Knowlton and Kraus 2001). In the Bay of Fundy for example, the internationally-mandated Traffic Separation Scheme was shifted 4 nautical miles to the east, from an area with high North Atlantic right whale densities to an area with lower right whale densities (Knowlton and Brown 2007).

Vanderlaan and Taggart (2007) determined that North Atlantic right whales were the most frequently struck species worldwide on a per capita basis, so it is expected that right whale's behavioural responses may be less effective than those of other species. They are also simply a lot slower moving both with respect to vessels and with respect to other species (e.g., burst speed of a right whale is 5 knots; burst speed of a blue whale is 20 knots; Table 4). Therefore, the 28% probability discussed above (that given an encounter, a strike is fatal), is expected to be unrealistically high with respect to many other species of whale. Killer whales in particular are small, agile, and fast-moving. Although no mathematical probabilities have been determined to calculate actual strike risk for any species other than North Atlantic right whales, based on historical records, the percentage of encounters that ultimately lead to a collision with killer whales are expected to be low. Caution is therefore urged in using any of the probabilities of strike modelled by Kite-Powell et al. (2007) for North Atlantic right whales to extrapolate strike risk to any other species.

5.0 CLOSURE

This report has been prepared by Stantec Consulting Ltd., on behalf of Trans Mountain Pipeline ULC, in response to Information Request No. 4.72b from the National Energy Board. If you should have any questions or comments regarding the content of this report, please contact the undersigned at (604) 436-3014.

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APPENDIX A
SENSITIVITY ANALYSIS

Appendix A SENSITIVITY ANALYSIS

Results of the Sensitivity Analysis are presented in Tables A-1 to A-8 below. For each table, ER = encounter risk and RI = return interval in years or *days.

Table A-1 Percent change in base run values with a simultaneous +20% change to each of whale length, width, and speed

Species	Baseline		Project		Combined	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	7.2	-6.7	5.7	-5.4	7.0	-6.6
Fin	9.1	-8.3	7.9	-7.4	8.9	-8.2
Sei	5.4	-5.1	4.2	-4.1	5.2	-5.0
Right	5.5	-5.2	4.3	-4.1	5.3	-5.0
Humpback*	5.1	-4.9	3.6	-3.5	4.9	-4.7
Killer Whale*	3.1	-3.0	1.9	-1.9	2.9	-2.8

Table A-2 Percent change in base run values with a simultaneous -20% change to each of whale length, width, and speed

Species	Baseline		Project		Combined	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	-7.0	7.5	-5.4	5.7	-6.8	7.3
Fin	-8.2	9.0	-7.1	7.7	-8.1	8.8
Sei	-5.2	5.5	-4.0	4.2	-5.0	5.3
Right	-5.2	5.5	-4.0	4.2	-5.1	5.3
Humpback*	-5.0	5.3	-3.5	3.6	-4.8	5.0
Killer Whale*	-3.1	3.2	-1.9	1.9	-2.9	3.0

Table A-3 Percent change in base run values with a +20% change to whale density

Species	Baseline		Project		Total	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	20.0	-16.7	20.0	-16.7	20.0	-16.7
Fin	20.0	-16.7	20.0	-16.7	20.0	-16.7
Sei	20.0	-16.7	20.0	-16.7	20.0	-16.7
Right	20.0	-16.7	20.0	-16.7	20.0	-16.7
Humpback*	20.0	-16.7	20.0	-16.7	20.0	-16.7
Killer Whale*	20.0	-16.7	20.0	-16.7	20.0	-16.7

Table A-4 Percent change in base run values with a -20% change to whale density

Species	Baseline		Project		Total	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	-20.0	25.0	-20.0	25.0	-20.0	25.0
Fin	-20.0	25.0	-20.0	25.0	-20.0	25.0
Sei	-20.0	25.0	-20.0	25.0	-20.0	25.0
Right	-20.0	25.0	-20.0	25.0	-20.0	25.0
Humpback*	-20.0	25.0	-20.0	25.0	-20.0	25.0
Killer Whale*	-20.0	25.0	-20.0	25.0	-20.0	25.0

Table A-5 Percent change in base run values with a +20% change to whale percent time in study area

Species	Baseline		Project		Total	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	20.0	-16.7	20.0	-16.7	20.0	-16.7
Fin	20.0	-16.7	20.0	-16.7	20.0	-16.7
Sei	20.0	-16.7	20.0	-16.7	20.0	-16.7
Right	20.0	-16.7	20.0	-16.7	20.0	-16.7
Humpback*	20.0	-16.7	20.0	-16.7	20.0	-16.7
Killer Whale*	20.0	-16.7	20.0	-16.7	20.0	-16.7

Table A-6 Percent change in base run values with a -20% change to whale percent time in study area

Species	Baseline		Project		Total	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	-20.0	25.0	-20.0	25.0	-20.0	25.0
Fin	-20.0	25.0	-20.0	25.0	-20.0	25.0
Sei	-20.0	25.0	-20.0	25.0	-20.0	25.0
Right	-20.0	25.0	-20.0	25.0	-20.0	25.0
Humpback*	-20.0	25.0	-20.0	25.0	-20.0	25.0
Killer Whale*	-20.0	25.0	-20.0	25.0	-20.0	25.0

Table A-7 Percent change in base run values with a +20% change to whale percent time in surface waters

Species	Baseline		Project		Combined	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	20.0	-16.7	20.0	-16.7	20.0	-16.7
Fin	20.0	-16.7	20.0	-16.7	20.0	-16.7
Sei	17.6	-15.0	17.6	-15.0	17.6	-15.0
Right	5.3	-5.0	5.3	-5.0	5.3	-5.0
Humpback*	20.0	-16.7	20.0	-16.7	20.0	-16.7
Killer Whale*	3.1	-3.0	3.1	-3.0	3.1	-3.0

Note: Values presented in this table scale in the same fashion as those presented in Tables A-2, 3, 4, 5, 6, and A-8; however, in some cases in Table A-7 values are capped at a maximum % change as whales cannot exceed 100% of their time in the surface waters.

Table A-8 Percent change in base run values with a -20% change to percent whale time in surface waters

Species	Baseline		Project		Combined	
	%Change ER	*%Change RI*	*%Change ER*	*%Change RI*	*%Change ER*	*%Change RI*
Blue	-20.0	25.0	-20.0	25.0	-20.0	25.0
Fin	-20.0	25.0	-20.0	25.0	-20.0	25.0
Sei	-20.0	25.0	-20.0	25.0	-20.0	25.0
Right	-20.0	25.0	-20.0	25.0	-20.0	25.0
Humpback*	-20.0	25.0	-20.0	25.0	-20.0	25.0
Killer Whale*	-20.0	25.0	-20.0	25.0	-20.0	25.0

APPENDIX B
WEBSITE REFERENCES

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Help the Southern Resident Orca's »

Center for Whale Research

The Center for Whale Research (CWR) is dedicated to the study and conservation of the Southern Resident Killer Whale (Orca) population in the Pacific Northwest.

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3. "Best of CWR" Photo Gallery, taken by CWR's accomplished wildlife photographers **(Value - Priceless)**

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Click on one or more of the buttons below to play an important part in the lives of the endangered Southern Orcas.

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K14, K42 and K26 - Sept. 17, 2009

Southern Resident Killer Whales

The **Southern Resident Killer Whales (SRKW)**, or Orcas, are actually a **large extended family**, or clan, comprised of three pods: **J, K, and L pods**.

Within each pod, families form into sub-pods centered around older females, usually grandmothers or great-grandmothers. Both male and female offspring remain in close association with their mothers for life.

Each Southern Resident pod uses a characteristic dialect of calls (sounds) to communicate. Certain calls are common between all three pods. The calls used by the Southern Resident community are unlike the calls used by any other community of killer whales. These calls can travel 10 miles or more under water.

The Southern Resident Killer Whales are frequently seen, from spring through fall, in the protected inshore waters of the Salish Sea. The Salish Sea includes the Strait of Juan de Fuca, Strait of Georgia, and Puget Sound, and all their connecting channels and adjoining waters, and the waters around and between the San Juan Islands in Washington State and the Gulf Islands in British Columbia.

As of Dec 31st 2014, the SKRW population totaled 79.

As of spring 2014, the SRKW population totaled 80 individuals (J Pod=25, K Pod=19, L Pod=35). The size of all three Southern Resident pods was reduced in number from 1965-75 as a result of whale captures for marine park exhibition. At least 13 whales were killed during these captures, while 45 whales were delivered to marine parks around the world. Today, only Lolita (Tokitae) remains alive in captivity at the Miami Seaquarium. Annual SRKW population updates occur on July 1 and December 31 each year.

* The SRKW population totals cited in this website are for the general public and are provided as estimates. The number of whales in this population is constantly changing. Please contact the Center for Whale Research directly to receive the most current information, prior to any publication of this population estimate. The information on this page is updated on July 1 and December 31 each year. Any published or broadcast reference to this population estimate must include credit to the Center for Whale Research.

The primary focus of CWR research is the Southern Resident population of killer whales (orcas).
All three pods uniting is referred to as a *super pod*. The photograph above was taken on July 7, 2010.

J Pod

J Pod is the pod most likely to appear year-round in the waters of the San Juan Islands and Southern Gulf Islands, lower Puget Sound (near Seattle), and Georgia Strait. This 25-member pod tends to frequent the west side of San Juan Island in mid to late spring. The oldest member of J pod is J2 (Granny), estimated to be 103 years old. J pod's mature males are now J26, J27 and J34. J pod had one new calf in 2012, J49 (male), the first calf of J37.

K Pod

With only 19 members, **K Pod** is the smallest of the three pods in the Southern Resident Killer Whale community. The two oldest females in K pod are K12 and K13, both estimated to have been born in 1972. K pod has three mature males, K21, and K26, and K25. The most recent calf born into K pod is K44 (male, born 2011), the first known calf of K27.

L Pod

L Pod is by far the largest of the three Southern Resident pods. Its members currently total 35. L pod's mature males are L41, L84, L85, L87 and L88. L87 has been traveling with J pod since 2010. L pod had one new calf born in 2012, L119. L119 is the second and only surviving calf of L77.

MORE

The Southern Residents Killer Whale diet, range, social behavior, kinship and linguistic system are distinct from other killer whale populations in the Pacific Northwest. In the North Pacific, in addition to the Southern Resident Killer Whale community, there is a Northern Resident community (Northern B.C.), a Transient community, and an Offshore killer whale community. Pods from one community have never been observed traveling with those from another community, although their ranges partly overlap. The call dialects of the four communities are also distinct.

The Northern Resident community, which is found primarily in the Johnstone Strait area of British Columbia, and northern British Columbia, is made up of about 220 whales in 16 pods. The Northern and Southern Residents are fully described in the book *Killer Whales* by Ford, Ellis, and Balcomb (UBC/UW Press, 2000).

Another community of killer whales, called Transients, can be found in small groups from Mexico to the Bering Sea. They often appear in the Salish Sea and around Vancouver Island. Transients are characterized by a diet of marine mammals, especially seals, sea lions, and porpoises. There are over 250 transients, but they tend to travel in small groups of one to five individuals, staying close to shorelines, often near seal rookeries when pups are being weaned.

In 1991, another community, called Offshores, was discovered. These whales may be the ancestral population of the Northern and/or Southern Residents. They are most often seen 15 to 25 miles out at sea, off Vancouver Island and Haida Gwaii (formerly Queen Charlotte Islands), though members of this community have been seen from southern California to the Bering Sea.

Transient killer whales
(near Salt Spring Island, June 6, 2010)

Fisheries and Oceans Canada. 2013b. Rare Whale Sighted Off British Columbia Coast. News Releases 2013. Website: http://www.dfo-mpo.gc.ca/media/npress-communique/2013/pac04-eng.htm. Accessed: April 2015.

Rare Whale Sighted Off British Columbia Coast

June 19, 2013

NANAIMO, British Columbia – For the first time in over 60 years, a North Pacific right whale has been spotted in British Columbia waters. Fisheries and Oceans Canada biologist James Pilkington made the discovery while surveying for whales off the west coast of Haida Gwaii aboard the CCGS *Arrow Post*, a Canadian Coast Guard vessel, on June 9, 2013. Pilkington and fellow Fisheries and Oceans Canada whale biologists John Ford and Graeme Ellis observed the whale for a total of 17 hours over the next few days as it foraged on zooplankton at the surface. Sightings of these whales are extremely rare – there are only six records of the species in Canadian waters over the past century, and all were killed by whalers; the last in 1951. Fewer than 50 individuals are thought to currently exist in the eastern North Pacific Ocean. North Pacific right whales are listed as Endangered in Canada.

"When we realized what we were looking at, we were in a state of disbelief" said Pilkington. "I never thought I'd see a North Pacific right whale in my lifetime, let alone have the opportunity to study it over several days. I was ecstatic!"

North Pacific right whales are large baleen whales that were once commonly found in British Columbia waters, most likely for feeding on their preferred prey, tiny copepods (zooplankton). They were abundant from the British Columbia coast north to the Gulf of Alaska and Bering Sea before being decimated by whaling. Nineteenth-century whalers preferred this species because they were large, slow swimming, and floated when killed. They were hunted to near extinction before 1900. Most remaining individuals were killed by illegal whaling in the 1960s. Today, the North Pacific right whale is one of the most critically endangered whale species in the world. It is estimated that there may only be a few hundred alive today, mostly in the western North Pacific.

"This is a very exciting discovery. Our research group has conducted over 50,000 km of whale surveys off the BC coast over the past 10 years and have sighted thousands of whales, but this is the first North Pacific right whale. It was wonderful to see it and to confirm that the species still exists in Canadian waters" said Dr. John Ford, head of the Cetacean Research Program at DFO's Pacific Biological Station in Nanaimo, BC.

The North Pacific right whale is protected by the federal *Species at Risk Act* (SARA). It is also protected under the Marine Mammals Regulations, which fall under the *Fisheries Act*.

A Recovery Strategy for the North Pacific right whale was prepared by DFO in 2011, and an Action Plan to implement the recommendations in the Recovery Strategy is currently in preparation.

-30-

For more information:

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(604) 666-7120

NR-PR-13-04E

Date modified: 2013-06-19

Pynn, L. 2013. Second sighting of endangered North Pacific right whale in B.C. waters in 62 years. Vancouver Sun. October 31, 2013. Website: http://www.vancouversun.com/technology/Second+sighting+endangered+North+Pacific+right+whale+waters+years/9108970/story.html. Accessed: April 2015.

Second sighting of endangered North Pacific right whale in B.C. waters in 62 years

Researchers 'astonished' after whale spotted off the entrance to Juan de Fuca Strait near Victoria

BY LARRY PYNN, VANCOUVER SUN OCTOBER 31, 2013

For just the second time in more than 60 years, an endangered North Pacific right whale has been sighted in B.C. waters, this time off the entrance to Juan de Fuca Strait near Victoria.

Photograph by: John Ford, DFO

For just the second time in more than six decades, an endangered North Pacific right whale has been sighted in B.C. waters, this time off the entrance to Juan de Fuca Strait near Victoria.

John Ford, head of the cetacean research program at Pacific Biological Station in Nanaimo, said the most recent whale was spotted Oct. 25 by Brian Gisborne, the operator of a water taxi service between Port Renfrew and Bamfield, who is also federally contracted to look for marine species at risk. Ford and his research colleagues went out the next day to see for themselves.

"It's exciting, kind of astonishing, really, to have two different animals sighted four months apart on our coast when there haven't been any confirmed sightings for the last 62 years," Ford said in an interview Thursday. "We were uncertain whether the species still occurred in Canadian waters and this clearly shows that they do."

The right whale, observed with a group of humpbacks, had a "nasty looking but healed wound" on the upper jaw, "very likely from a previous entanglement in fishing gear that he evidently survived," Ford explained.

Entanglement in fishing gear is a major issue with right whales in the Atlantic.

Federal biologist James Pilkington made the first confirmed sighting in recent history of a right whale in B.C. waters on June 9, 2013, aboard the Canadian Coast Guard vessel Arrow Post off the west coast of Haida Gwaii.

That whale was observed for a total of 17 hours over a few days feeding at the surface on copepods, zooplankton measuring about 10 millimetres. Only about 30 right whales are thought to exist in the eastern North Pacific.

The last previous B.C. sighting dated to 1951, an animal killed by whalers.

Ford said that the right whale observed last week was larger than the first and measured an estimated 16 to 17 metres in length.

He noted that commercial whaling virtually wiped out the North Pacific right whale over a decade starting in the 1840s, compounded by another round of whaling by the Russians in the 1960s, when they took 529 whales.

"This is probably why they've failed to recover," he said.

Whalers preferred this species because they were large, slow swimming, and floated when killed.

Ford said it's possible that this latest whale was migrating south, but that "we really don't know much about them."

Hydrophones will continue to be deployed along the B.C. coast in hoping of finding evidence of the whales' vocalizations.

Analysis of ancient bones on the west coast of Vancouver Island also shows that aboriginals historically killed right whales for food.

lpynn@vancouversun.com

For just the second time in more than 60 years, an endangered North Pacific right whale has been sighted in B.C. waters, this time off the entrance to Juan de Fuca Strait near Victoria.

Photograph by: John Ford, DFO



Seaspan ULC. 2009. Seaspan Raven. Website: http://www.seaspan.com/wp-content/uploads/Raven.pdf. Accessed: April 2015.

SEASPAN RAVEN

GENERAL

Owner	Seaspan ULC
Designer	Robert Allan Ltd.
Built	2009
Certification	Transport Canada NC2, Limited HT3
Classification	ABS +1, Towing & Escort Vessel Fi-Fi 1, +AMS, +ABCU Unrestricted service
Official No.	835230

DIMENSIONS

Length overall	28.20 m / 92.52'
Breadth	12.60 m / 41.34'
Draft	5.39 m / 17.68'
GRT	441 tonnes

ENGINES, PROPULSION & PERFORMANCE

Main engine	2 x Caterpillar 3516B
Total power	3,728 kw / 5,000 BHP @ 1,600 RPM
Propulsion	Z-Peller
Bollard pull	71 t / 157,000 lbs
Propellers	4 Blade CP, 240 cm / 94.5" dia.

DECK EQUIPMENT

Hawser winch	Rolls-Royce TW 2000/500 AW 24 U2 H
Aft towing winch	Rolls-Royce single drum
Deck crane	Palfinger knuckle boom crane of 1,040 kg pull at 10.3 outreach
Tow line length	152 m / 500'

TANK ARRANGEMENT

Fuel capacity	119,300 L / 26,246 Imp. gallons
Fresh water capacity	12,900 L / 2,838 Imp. gallons

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The Whale Museum. 2013. J, K and L-Pods Annual Monthly Arrivals and Departures from the Salish Sea. Website: http://hotline.whalemuseum.org/assets/ArrDepChart-82d53f4c0645940bb7b8a1128433c073.jpg. Accessed: April 2015.

J, K & L-PODs Annual Monthly Arrivals & Departures from the Salish Sea

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1976	?	?	?	J & K	J			J, K & L			?	J
1977	?	?	?	?	?	?		J, K & L				
1978	J	J	J & K	J	J	J		J, K & L			J	J
1979	J	J	J	J	J			J, K & L			J & K	J
1980	J	J	J	J	J			J, K & L			J	J
1981	J	J	J	J & K	J			J, K & L				J
1982	J	J	J	J	J	J & K		J, K & L		J & K	J	J
1983	J	J	J	J	J			J, K & L			J & K	J
1984	J	J	J	J	J	J & K		J, K & L		J	J	J
1985	J	J	J	J	J	J & K		J, K & L			J	J
1986	J	J	J	J	J & K			J, K & L		J	J	J
1987	J	J	J	J				J, K & L			J & K	
1988	J	J	J	J	J & K			J, K & L			J	J
1989	J	J	J & K	J				J, K & L			J & K	
1990	J	J	J	J				J, K & L			J	J
1991	J	J	J	J	J & K			J, K & L		J & K	J	J
1992	J	J	J	J				J, K & L				
1993	J	J	J	J	J & K			J, K & L		J	J	J
1994	J	J	J	J	J			J, K & L		J & L	J	J
1995	J	J	J	J				J, K & L		J	J	J
1996	J	J	J	J	J			J, K & L			J & K	J
1997	J	J	J	J				J, K & L		Dyes Inlet	J & L	J & K
1998	J	J	J	J				J, K & L			J & K	J
1999	J	J	J	J	J			J, K & L				
2000	J,K & L	J	J	J	J			J, K & L				
2001		J,K & L	J	J				J, K & L				
2002	J,K & L	J	J,K & L ?	J				J, K & L				
2003	J,K & L	J	J	J	J			J, K & L				J & K
2004	J,K & L	J	J	J	J & L	J & L		J, K & L				
2005	J,K & L	J ?	J	J	J & L			J, K & L				J & K
2006	J ?	J	J, K & L	J				J, K & L				
2007	J ?	J	J	J	J	J & L		J, K & L			J	J, K, & L
2008	J, K, & L	J & L	J	J	J			J, K & L				J, K, & L(p)
2009	J ?	J,K & L	J	NONE	J & K			J, K & L			J & K	
2010	J	J,K & L	J	J	J & L			J, K & L				J, K, & L
2011	J, K, & L(p)	J & K	J	J	J & L (p)	J, K, & L(p)		J, K & L				J & K
2012	J & K	J & K	J					J, K & L				
2013	J	J & L	J, K, & L	NONE	J	J & L		J, K & L				J & K

(Compiled by TWM staff from records maintained by Orca Survey, C.W.R.(1976-82),The Whale Museum's Whale Hotline (1978-present), the Marine Mammal Research Group's Hotline (1985-2003);
Bob Otis's Lime Kiln Lighthouse records (1990-present); Soundwatch field data (1993-present); SeaCoast Pager Records (1996-2007), Orca Network (2000-present); and the SPOT recorder data (2008-present).

UPDATED: 4/13 (PMC) ["?" means no positive identification on the sightings]

J-Pod= (yellow) J&K-Pod= (light blue) J&L-Pod= (light green) J,K & L-Pods= (dark green) (p) = partial