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Information Request Package 4 from the Review Panel for the Roberts Bank Terminal 2 Project Environmental Assessment: Responses

List of Responses

IR4-01 Marine Shipping – Vessel Size

Information Source(s)

EIS Volume 1: Section 2.1; Appendix 9.8-B

EIS Volume 5: Appendix 30-A

Proponent Response to IR1-03, Appendix IR1-03-A; Proponent Response to IR1-14 (CEAR Doc#897)

Orientation Session #2, Undertaking #1 (CEAR Doc#667)

Context

In Source c. of Table 1 of the response to Undertaking #1 of Orientation Session #2, the Proponent identified that no vessels greater than 15,000 TEUs are anticipated to call on Roberts Bank Terminal 2 by 2030. However, in various sections of the information submitted by the Proponent to date, there have been indications that vessels greater than 15,000 TEUs could call on Roberts Bank Terminal 2. For example:

- In Appendix 30-A of the EIS, the Proponent stated that the maximum vessel size that could call at Roberts Bank Terminal 2 is based upon the Maersk "Triple-E" size which can hold approximately 18,000 TEUs.
- In Appendix 9.8-B of the EIS, the Proponent included a 400 m Triple-E-Class container ship in its modelling of underwater noise.
- In Appendix IR1-03-A of the Response to Package 1, the Proponent stated that the ability to berth vessels between 18,000 to 20,000 TEUs will be an important feature of the Port of Vancouver's competitive position over the forecast period.

Given the apparent discrepancies in the information provided to date, clarification of whether vessels of greater than 15,000 TEUs would be expected to call on Roberts Bank Terminal 2 by 2030 is required.

Furthermore, Appendix IR1-03-A indicated that vessels greater than 18,000 TEUs could be under consideration, with designs for vessels of 22,000 TEUs and even 24,000 TEUs, vessels being presently considered for the worldwide container fleet development. It was identified that the largest vessels that are on order have a length overall (LOA) of 430-433 metres, a beam of 59 metres and a design draught of around 15.5 metres. With careful management, the Proponent considered that berthing of these vessels would be possible at Roberts Bank Terminal 2 and at Prince Rupert. Vessels of 22,000 TEUs may have a role on the Transpacific trades at some point in the future. According to the Proponent, the shift to 24,000 TEU+ vessels would be more complex and would involve significant infrastructure and container crane investments.

The Proponent, in its response IR1-14, identified that water depths for the berth pocket and approach channels were designed to accommodate a ship with a draught up to 19 metres and allow for an under-keel clearance of not less than 10% of the loaded draught for the largest vessels with 18,000 TEU capacity (LOA 400m). Clarification is needed as to what 'careful management' is referred to for the 22,000 TEU vessels and what significant infrastructure and container crane investments would be required for the 24,000 TEU vessels to berth at Roberts Bank Terminal 2.

The Proponent in Section 2.1 of the EIS identified that the purpose of the proposed Project is to meet increasing forecasted demand for containerised trade on the west coast of Canada and to continue to maximize the potential economic and competitive benefits of the port at Roberts Bank. Additional information about potential changes needed to meet the purpose of the proposed Project in the future is required.

Information Request

Clarify whether vessels with a size greater than 15,000 TEUs would be expected to call on Roberts Bank Terminal 2 by 2030, and clarify the maximum potential size of vessels the proposed Project would be designed to accommodate after 2030.

Clarify what careful management would entail when berthing vessels of 22,000 TEUs.

Provide details as to what would be required in terms of significant infrastructure changes and container crane investments to properly accommodate vessels of 24,000 TEUS.

VFPA Response

Clarify whether vessels with a size greater than 15,000 TEUs would be expected to call on Roberts Bank Terminal 2 by 2030, and clarify the maximum potential size of vessels the proposed Project would be designed to accommodate after 2030.

Vessels greater than 15,000 twenty-foot equivalent units (TEUs) are not expected to call on RBT2 by 2030 based on the trend in fleet changes and current vessel orders, as outlined in Undertaking #1 of Orientation Session #2. The reason that the three-berth wharf for RBT2 has been designed to accept ultra-large container ships[1] and assessments have been undertaken on vessels larger than 15,000 TEUs is that ultra-large vessels could reasonably be anticipated to call during the greater than 50 year life of the Project.

Larger vessels can be accommodated as length is not the limiting factor—the limiting factors are draught and beam. Vessels with adequate draught and under keel clearance will be able to safely navigate to and berth at the RBT2 wharf. Based on Table 3.1 in Appendix IR1-03-A (see IR1-03 in CEAR Document #897[2]), the largest vessel accommodated by the current design is New Generation IIA, a 24,000 TEU vessel, with an anticipated length overall (LOA) of 450 metres, a beam of 59 metres, and a design draught of approximately 15.8 metres. As indicated in Appendix IR1-03-A, a berth design for the largest anticipated container ship

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[1] An ultra-large vessel has length greater than 390 m and/or capacity greater than 15,000 TEUs (IHS Fairplay 2016).

[2] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

should be predicated on a vessel length of 450 metres. The berthing of a longer vessel will limit the number of vessels simultaneously berthed.

Clarify what careful management would entail when berthing vessels of 22,000 TEUs.

Careful management when berthing a 22,000 TEU vessel (or New Generation IIA 24,000 TEU vessel) would entail a low speed approach and the use of tugs, with the number of tugs to be determined by conditions at the time of berthing. Additional real-time ship navigation simulations would be required as new vessel sizes are introduced to the routing to determine the tug requirements (refer to AECOM (2012) as an example of the type of simulations required).

Provide details as to what would be required in terms of significant infrastructure changes and container crane investments to properly accommodate vessels of 24,000 TEUS.

A 24,000 TEU vessel (New Generation IIA) can be accommodated with the current proposed terminal infrastructure as this vessel has the same beam width as the Project design specifications for an 18,000 TEU vessel (59 m, EIS Table 4-2).

Compared to the Triple-E design vessel (18,000 TEU capacity), these yet to be designed 24,000 TEU vessels could be one container hold longer, two rows wider, and one tier higher (Marine Insight 2017).

For a 24,000 TEU vessel with a wider beam (61.5 m, referred to as the New Generation IIB), ship-to-shore cranes with a wider or higher reach would be required. This could also affect crane rail spacing and required modifications to the apron configuration. Other significant infrastructure changes are not anticipated to be required. Any changes, significant or not, will not change the annual terminal throughput capacity, but could decrease annual ship calls.

References

AECOM. 2012. Roberts Bank Terminal 2 - Fast-time Ship Navigation Simulation Study.

IHS Fairplay. 2016. IMO. Available at http://www.ihsfairplay.com/IMO/imo.html. Accessed June 2017.

Marine Insight. 2017. Containerships With 24000 TEU Possible but Ship Size Approaching Limits. Available at http://www.marineinsight.com/shipping-news/containerships-24000-teu-possible-ship-size-approaching-limits/. Accessed May 2017.

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IR4-02 Vessel Traffic Projections – Vessel Size

Information Source(s)

EIS Volume 1: Section 4.2.1.2; Table 4-2

EIS Volume 2: Appendix A of Appendix 9.2-A

Marine Shipping Addendum: Table 4-4; Figure 4-4; Appendix 7.2-B

Orientation Session #2 Transcript Page 39 (CEAR Doc#558)

Orientation Session #2, Undertaking #1 (CEAR Doc#667)

Proponent Response to IR1-03 (CEAR Doc#897): Appendix IR1-03-A

Context

The Proponent, in Section 4.2.1.2 of the EIS, identified that the proposed 1,346 metre berth (wharf and dolphin) is designed to berth two Panamax 2014-class vessels (366m/12,000 TEUs) and one Maersk Triple-E class vessel (400m/18,000 TEUs).

During Orientation Session #2, the Proponent indicated that in the future, the fleet would be generally in the range of 14,000 TEUs and may include larger ships. Further, the 2016 Container Forecast Study, Appendix IR1- 03-A, forecasted that larger ship size distributions could be expected in the near future. These container ships could be up to 430 to 450 metres in length.

The proposed Project is projected to be completed and operational beginning in the mid 2020's and expected to operate for at least 60 years, potentially from 2025 – 2080.

In both the EIS and the Marine Shipping Addendum, environmental effects predictions were conducted for up to 2030.

In the wave environmental effects assessment, the assessment used characteristics from a representative container ship with a length of 338 metres.

In the air quality analysis, the Proponent used the 5,000-8,000 TEU vessel size range for the period between 2005-2012 and 8,000-12,000 TEU vessel size range for the period 2012-2025; and 12,000 TEUs (366 metres) was used as the representative vessel size for 2025 for the assessment.

Additional information about the effects to wave environment and air quality from ships larger than 366 metres is required.

Information Request

Using year 2050 as the long term mid-point of the proposed Project, provide a discussion of how Port operations and shipping, with increased ship size, would affect air quality and wave effect predictions made in the EIS and Marine Shipping Addendum. At a minimum, indicate to what extent the present evaluation in the EIS and Marine Shipping Addendum would be changed regarding air quality and wave effect if vessels larger than 366 metres were considered.

VFPA Response

Worldwide, and within the Vancouver region, container ship sizes are increasing. To assess the potential effects of increased ship size on air quality and wave effect predictions, it is necessary to estimate the number of vessels anticipated in the future for the various vessel size classes, and compare vessel design specifications for example vessels for each size class.

The projected vessel numbers by size class and distribution of vessel capacity (as percentage) for 2025, 2030, and 2035 are provided in Undertaking #1 (CEAR Document #667[1]). The estimated number of vessels calling at RBT2 by size class has been estimated for 2050 based on projections provided by Seaport (2014) for 2030 (see Appendix A of Undertaking #1 for more information). As uncertainty increases when projecting vessel fleet characteristics further into the future, two scenarios have been considered for 2050:

1. Scenario A – the percentage of vessels with greater than 10,000 twenty-foot equivalent unit (TEU) capacity calling at RBT2 in 2050 is 42%; and
2. Scenario B – the percentage of vessels with greater than 10,000 TEU capacity calling at RBT2 in 2050 is 50%.

Table IR4-02-1 provides the fleet distribution and number of vessel calls in 2050 for each scenario. RBT2 terminal operations in 2050 are assumed to be similar to 2030 at 2.4 million TEUs, and the number of weekly services and vessel calls is anticipated to decrease as ship sizes increase (as previously stated in EIS Section 4.4.2.1).

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[1] CEAR Document #667 From the Vancouver Fraser Port Authority to the Review Panel re: Orientation Session #2 Undertaking #1: Estimate of the number of ultra-large ships that would call on Roberts Bank Terminal 2.

Table IR4-02-1 RBT2 Vessel Fleet Distribution and Number of Vessel Calls in 2050 for Two Future Scenarios

Vessel Capacity (TEUs)	2030[a] % of Fleet	Scenario A-2050 % of Fleet	Scenario B-2050 % of Fleet
4,000 – 5,999	3	0	0
6,000 – 7,999	3	0	0
8,000 – 10,000	65	58	50
>10,000	29	42	50
Calculated Average Ship Size (TEU)	9,365	11,500	15,400
Estimated Number of Services per Week	5	4	3
Estimated Number of Calls Annually	260	208	156
RBT2 Terminal Annual TEUs	2,434,900	2,392,000	2,402,400

Source: a. From Seaport Consultants Canada Inc. Update of Projections of Container Ship Characteristics for Roberts Bank Terminal 2, September 2014; report provided as Appendix A in Undertaking #1.

Table IR4-02-2 summarises the design specifications for example vessels for four different vessel lengths: less than 340 m (under 10,000 TEU capacity), 340 m to 366 m (10,000 to 12,500 TEU capacity), and greater than 366 m and 400 m (13,000 to 18,000 TEU capacity).

Table IR4-02-2 Design Specification for Example Vessels Representative of Four Vessel Lengths

Design Specifications	Length Overall (m)			
	<340	340-366	>366	>400
Vessel Capacity	under 10K TEUs	10-12.5K TEUs[a]	13-18K+ TEUs[b]	
Size Class	Post-Panamax	New Panamax	E Class	Triple-E Class
Example Vessel	*Mærsk Algol*[c]	*CMA CGM Thalassi*[c]	*Emma Mærsk*[e]	*Mærsk Mc-Kinney Møller*[f]
Capacity (TEUs)	9,034 – 9,580	11,040	15,000	18,270
Length Overall (m)	338	347.5	397	400
Draught (m)	15	15.5	16	14.5
Main Engine Rating (MW)	69	72.3	80.1	64
Assumed Auxiliary Engine Power (MW)[g]	5.7	7.0	8.3	7.3
Maximum Design Speed (Kn)	25.5	24.7	25.5	23
Cruise Speed (Kn)	20	24.3	25.5	16

Notes:

a. A Panamax 2014 vessel (launched in 2006) with a capacity of 12,000 TEUs and length of 366 m was the smaller of the two design ships used in Project design (see EIS Table 4-2).

b. A Maersk Triple-E Class vessel (launched in 2013) with a capacity of 18,000 TEUs and length of 400 m was the larger of the two design ships used in Project design (see EIS Table 4-2).

c. Information from Table 4-4 of the Marine Shipping Addendum.

d. Information from CMA CGM (2017) and Wikipedia (2017a).

e. Information from www.Emma-Maersk.com/specification and Wikipedia (2017b).

f. Information from Wikipedia (2017c).

g. Information from IHS Fairplay (2017). Assumed auxiliary engine power is a proportion of the auxiliary engine rating for each vessel, noting that some auxiliary engines are used for waste heat recovery generators or main engine shaft generators (i.e., not as auxiliary engines while at berth). The auxiliary engine power values provided does not reflect projected power use at berth, as the values given do not reflect the load factors (see Section 2.4 in Appendix A of EIS Appendix 9.2-A for more information).

Changes in vessel length and the effect on the air quality and wave effect predictions provided in the EIS and/or Marine Shipping Addendum are described below.

Air Quality

The shipping industry has been focusing on moving more cargo with less impact on the environment. For example, Maersk Line has a target to reduce their ocean shipping carbon dioxide (CO_2) emissions by 60% per container transported between 2016 and 2020, and have reduced CO_2 emissions per container transported by 42% to date since 2007 (Maersk 2017). New technologies and innovations that increase fuel efficiency and operating procedures that reduce vessel fuel consumption also reduce air emissions. Maersk (2017) reports that their Triple-E vessels reduce both fuel consumption and air emissions by up to 35% per container transported compared to other vessels sailing on the same shipping route.

The assessment of air quality considered changes in the container fleet in the future (refer to Attachment 2 of Appendix A in EIS Appendix 9.2-A for a summary of ship activity level assumptions incorporated in the air quality study) and, therefore, changes in vessel length in the future will not invalidate the air quality study predictions. The air quality assessment presented in EIS Section 9.2 and Section 7.1 of the Marine Shipping Addendum included the evaluation of emissions from the *Emma Maersk*[2], a 397 m long vessel representative of larger vessels 366 m and greater in length anticipated to call at RBT2. As shown in **Table IR4-02-2**, this vessel has higher main and auxiliary power ratings than a Triple-E vessel, and therefore, the air quality study provides a conservative assessment of vessels greater than 366 m calling at RBT2 over the life of the Project. As hypothetical worst-case maximum hourly and daily emission scenarios, the air quality study assumed that an E Class (*Emma Maersk*-sized) ship was berthed at both the RBT2 and Deltaport terminals, and was representative of container ships in transit through the four segments (A to D) of the marine shipping area.

In addition to having already assessed a vessel greater than 366 m in length (i.e., the *Emma Maersk* is 397 m in length), the assessments provided in the EIS and/or Marine Shipping Addendum conservatively evaluated emissions for the following reasons:

- The number of vessel calls will decrease in the future as the percentage of larger vessels increase within the container vessel fleet (see Scenarios A and B predictions provided in **Table IR4-02-1**). The assessment assumed that 260 vessels would call annually at RBT2 (see EIS Table 9.2-8), irrespective of vessel size distribution. Predicted emissions presented in the EIS, at least for some averaging periods (e.g., 24-hour and 1-year), would be lower with a decrease in annual vessel calls. For the assessment of marine shipping associated with the Project, the assessment relied on observation studies of the contribution of ship emissions to air quality at several points along the marine shipping route as reported in published literature sources (see Marine Shipping Addendum Information Request #8 (MSA IR-02.24.16-8 of CEAR Document #391[3]) for more information), and estimations of the relative changes to air quality from RBT2-associated container ships as a proportion of all large marine vessel emissions.
- With decreasing vessel calls anticipated in the future (with greater proportion of larger vessels), therefore, the proportion of RBT2-associated emissions would be lower than the concentrations presented in air quality assessment.
- The newer, larger container ships will have smaller main engines for in-transit propulsion (due to lower design speed), as well as for manoeuvring, and less need for auxiliary power while at berth. Thus, the combined effect of fewer vessel calls with lower overall power requirements will lead to lower overall emissions.

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[2] In 2013 when the air quality study commenced, the 397-m long *Emma Maersk* was considered to be a 12,000 TEU E-Class vessel (see Table 2.1 of Appendix A in EIS Appendix 9.2-A). The carrying capacity of the E Class vessels were calculated differently at that time, and the capacity of this vessel is 15,000 TEUs.

[3] CEAR Document #391 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Marine Shipping Addendum Completeness Review - Responses to Additional Information Requirements (See Reference Document #386).

- Larger vessels are being designed to meet the International Maritime Organization's regulations on NOx emission standards that came into effect in 2016, which will lower emissions from these vessels compared to older, smaller vessels built prior to 2016.
- The implementation of shore power at one berth at Deltaport Terminal and at all three berths at RBT2, which will allow ships that are equipped to connect to shore power facilities to turn off their auxiliary engines, is expected to decrease predicted future emissions during Project operation (see EIS Sections 9.2.7.2, 9.2.7.4, and 9.2.8.2). As stated in EIS Section 9.2.5.1, newer ships will be capable of connecting to shore power while at berth at the terminal. The potential benefits with respect to reduced emissions were not accounted for in the air quality assessment of predicted changes in maximum hourly, maximum daily, or annual average concentrations of ambient contaminants of potential concern in 2025, as there is uncertainty about what proportion of the container vessel fleet will be capable of using shore power during the operation phase. Only the maximum potential changes in total annual emissions due to shore power were presented in the EIS (Sections 9.2.7.2, 9.2.7.4, and 9.2.8.2). Therefore, the projected changes in air quality as defined for emissions from berthing are higher than will likely be the case in the future.
- Apart from lower emission rates per vessel call for a fleet comprised of larger container ships, the probability of all six berths at RBT2 and Deltaport terminals being occupied simultaneously, as evaluated in the EIS, will be lower in 2050 than in 2025 due to the lower number of total container vessel calls. The air quality study assumed a hypothetical worst-case berth occupancy rate of 100% at both container terminals, compared to the actual simultaneous berth occupancy at Deltaport Terminal of only about 30% in the period from 2005 to 2012 (see Section 2.2 in Appendix A of EIS Appendix 9.2-A). With a lower frequency of vessel calls from larger vessels, the probability of all six berths at both container terminals being occupied simultaneously will decrease, and this will result in lower emissions from vessels at berth compared to those presented in the EIS, irrespective of whether those vessels use shore power.

Wave Environment

In general, wave height varies with vessel speed, vessel hull form, distance from transit line, and water depth. The assessment of potential changes to the wave environment due to marine vessel traffic associated with the Project was evaluated within the context of the existing wind-generated wave environment, as presented in Section 7.2 of the Marine Shipping Addendum. The predictions were based on the assessment of a vessel 338 m long (Marine Shipping Addendum Table 4-4), and are considered to be representative of future conditions with vessels that exceed 366 m in length for two primary reasons, as explained below.

Decreases in Vessel Movements with Increasing Vessel Size

Section 7.2.4.2 of the Marine Shipping Addendum described that, except during calm conditions, the ship wake would be indistinguishable from the spectrum of wind-generated waves at most shoreline locations in the local study area. Based on the assumption that there is no greater probability that ships pass through the local study area when it is calm than when it is not, the estimated total number of ship movements (for all vessel type categories) that pass when it is calm was calculated. For instance, based on 8,896 vessel movements in Segment B of the marine shipping area in 2012 (Marine Shipping Addendum Table 4-2) and the probability of calm conditions in this segment, 3,766 vessel movements would be expected during calm conditions (see Table 7.2-5 in the Marine Shipping Addendum).

Potential changes, including cumulative changes, to the wave environment due to marine vessel traffic associated with the Project would decrease as the percentage of larger vessels increases because fewer ships are required. The assessment of wave environment included 260 container ship calls per year at terminal design capacity (2.4 million TEUs), or approximately three vessel movements every two days on average. As stated in Section 7.2.5.2 of the Marine Shipping Addendum, compared with the 8,896 vessel movements of all types that transit Segment B under existing conditions, this represents less than a 6% increase in vessel traffic.

The trend of increasing container vessel sizes will affect all of the container terminals in VFPA jurisdiction in the future (i.e., Deltaport, Centerm, Vanterm, and the proposed RBT2). If 50% of vessels in the container fleet that call on these terminals have greater than 10,000 TEU capacity, all container terminals within VFPA jurisdiction could be expected to experience a 40% decrease in container vessel calls or movements (i.e., based on Scenario B in **Table IR4-02-1** for RBT2, the number of ship annual calls is projected to decrease from 260 to 156, or 40% fewer calls). Assuming an annual decrease in container ship calls of 40%, the estimated number of vessel movements in Segment B for container ships bound for the four container terminals within VFPA jurisdiction would decrease from 2,046[4] to 1,228. As the number of vessel movements decreases, 40% fewer wake-generated waves would be expected from container vessels, including during calm conditions. The wave environment assessment provided in the Marine Shipping Addendum, therefore, is conservative based on the number of vessel movements considered, and additional factors described below.

Wave Environment Assessment Sensitivity Analysis

In the Marine Shipping Addendum, the wake generated by a moving ship and attenuation of vessel wake as a function of the distance from the ship course were calculated using the PIANC (1987) equation, as per the methodology presented in Moffatt and Nichol (2011). Marine Shipping Addendum Appendix 7.2-B provided the results of a sensitivity analysis of the wake calculations based on the PIANC (1987) formula with respect to variations in wake height as a function of distance from the ship for three conditions including vessel speed, water depth, and the hull coefficient for various vessel types.

The sensitivity analysis showed that at a distance of 1 km from the vessel, wake height is predicted to vary by less than 10 cm in response to vessel speed, more than 15 cm in response to water depth, and by a little over 10 cm in response to the vessel hull type. Vessels larger than 366 m were not included in the sensitivity analysis, as hull coefficient information was not available at the time of the wave environment assessment. This information remains

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[4] Based on vessel projections in 2030 for container ships bound for other terminals within VFPA jurisdiction (1,526) and RBT2 (520), as shown in Figure IR4-04-2 in IR4-04.

unavailable and could not be obtained from a shipping line that was recently contacted, due to the confidential nature of such information.

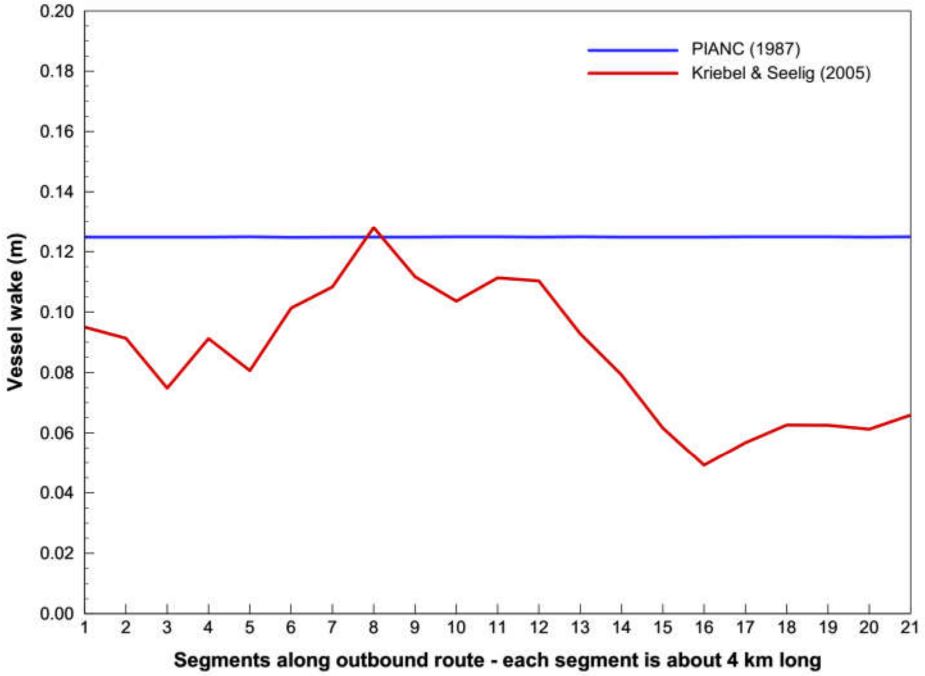
Based on the information provided in the sub-section below, vessels larger than 366 m fall within the sensitivity analysis conducted.

Wave Environment Assessment Methodology

To determine if the wave environment assessment captures changes anticipated from Project-associated vessels greater than 366 m and cumulative changes, wake calculated using the PIANC (1987) formula (used in the wave environment assessment) was compared to results from a formula described by Kriebel and Seelig (2005). This formula considers similar criteria for predicting wake height as the PIANC (1987) equation but instead of a single hull coefficient, this formula uses a coefficient that can be adjusted for the vessel draught and length, specifications that are publicly available for vessels larger than 366 m (see **Table IR4-02-2**), as well as vessel entry shape (blunt versus streamlined). The results of this comparison are as follows:

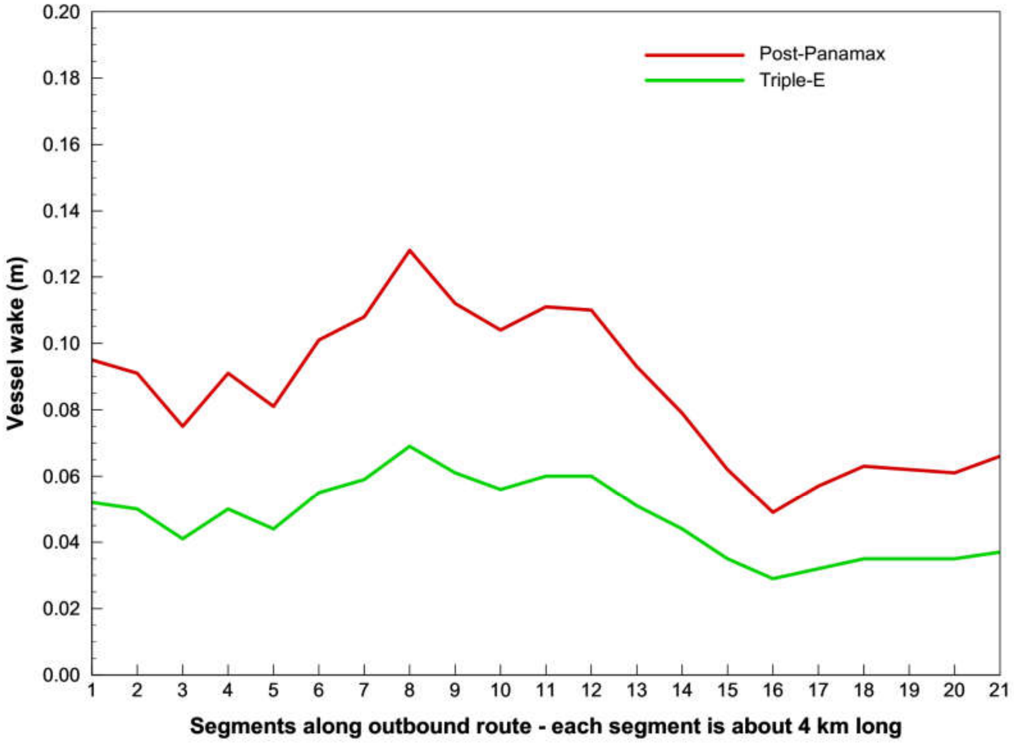
- Assuming a blunt hull shape for the representative vessel (Post-Panamax with 338 m length overall and 15 m draught) assessed in the wave environment assessment, the Kriebel and Seelig (2005) formula typically predicts smaller wake height within Segment B compared to that predicted by the PIANC (1987) formula, as shown in **Figure IR4-02-1**; and
- Using the Kriebel and Seelig (2005) formula to compare a Triple-E vessel (with 400 m length overall and 14.5 m draught) to a Post-Panamax vessel, the predicted wake-generated wave height from a Triple-E vessel is smaller than the predicted wake-generated wave height from a Post-Panamax vessel, as shown in **Figure IR4-02-2**. The decrease in predicted wave height from a Triple-E vessel is primarily due to its increased length (i.e., draught is only slightly greater as opposed to the greater length of the Triple-E vessel).

Figure IR4-02-1 **Comparison of Wake-Generated Wave Heights for a Post-Panamax Vessel using Different Formulas**



Note: For Kriebel and Seelig (2005) formula, it was assumed that the post-Panamax vessel has a blunt hull shape, length of 338 m, draught of 15 m, and has α = 0.2 and β = 9.

Figure IR4-02-2 **Comparison of Wake-Generated Wave Heights for a Post-Panamax Vessel and a Triple-E Vessel using Kriebel and Seelig Equation**



Wave Environment Summary

In summary, the wave environment assessment presented in Section 7.2 of the Marine Shipping Addendum adequately captures changes anticipated from Project-associated vessels greater than 366 m and cumulative changes, based on the following predictions:

- Container vessel movements per year are predicted to decrease as the percentage of larger vessels increase in the fleet;
- Using different formulas to predict wake-generated wave heights, the assessment presented in Section 7.1 provides a more conservative assessment of predicted wake height based on the approach taken; and
- Comparing a 400 m long Triple-E vessel to a 338 m long Post-Panamax vessel, the larger vessel is predicted to produce a smaller wake-generated wave height. As such, vessels larger than 366 m are captured within the sensitivity analysis conducted for the Marine Shipping Addendum (Appendix 7.2-B), as the Post-Panamax vessel represents the upper bound in the range of wake predicted from container vessels for the analysis.

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IR4-03 Vessel Traffic Projections – Vessel Size and Movements

Information Source(s)

Marine Shipping Addendum: Appendix 6-A

Context

In Appendix 6-A of the Marine Shipping Addendum, the Proponent indicated that the George Massey Tunnel replacement project is a road infrastructure project located inland and is not expected to influence the number of vessels in the marine shipping area.

Vessels transiting through the south arm of the Fraser River could contribute to vessel movements in the marine shipping area and additional information is required.

Information Request

Provide an estimate of number of movements and size of vessels in 2025 that would pass through the south arm of the Fraser River and past the replacement of the George Massey Tunnel.

VFPA Response

The number of vessel movements in 2025 through the south arm of the Fraser River has been estimated based on anticipated increases from actual 2014 vessel traffic data (VFPA 2017a), and expected changes (both increases and decreases) resulting from certain and reasonably foreseeable projects proposed upstream of the location of the George Massey Tunnel Replacement Project. Specifically, anticipated vessel traffic projections for 2025 were based on the following:

- A 1% per annum growth rate for the cargo/carrier, tug, service, and other/unknown vessel type categories, the same rates used in the assessment of marine shipping (see Table 2-2 in Appendix 10-A of the Marine Shipping Addendum);
- In addition to the 1% growth rate for the cargo/carrier (bulk) and tug vessel type categories, expected increases in vessel traffic for cargo/carrier, tanker, and tug vessel categories also include certain and reasonably foreseeable projects, specifically the BURNCO Aggregate Project, the Fraser Grain Terminal Project, the Fraser Surrey Docks Project, the Vancouver Airport Fuel Delivery Project, and the WesPac Tilbury Marine Jetty Project;
- As Fraser Surrey Docks will be re-purposed from a container terminal to a bulk terminal, container traffic in 2025 is expected to reduce to zero; and
- No increase (i.e., 0% growth rate) for the fishing vessel type category, the same rate provided in the assessment of marine shipping (see Table 2-2 in Appendix 10-A of the Marine Shipping Addendum).

Table IR4-03-1 provides the estimated number of movements for each of these projects by vessel type. **Table IR4-03-1** also provides the vessel sizes associated with each project, noting that the maximum vessel size of the Fraser River is 270 m length overall, 32.3 m beam, and 11.5 m draught (Pacific Pilotage Authority 2017). Note that maximum size of the liquified natural gas (LNG) carriers calling at the proposed WesPac Tilbury Marine Jetty Project will exceed the VFPA's current allowable beam width dimension limits and operation would likely take place under special operating procedures (EAO 2016)[1].

Table IR4-03-1 Estimated Number of Movements for Certain and Reasonably Foreseeable Projects in the South Arm of the Fraser River past the George Massey Tunnel

Certain or Reasonably Foreseeable Project	Vessel Type	Vessel Capacity and Size[a]	Annual Movements
BURNCO Aggregate Project[b]	Barge	Loaded Capacity: 5,500 DWT Size: 80 m length and 4.5 m draught	182
	Tug	N/A	182
Fraser Grain Terminal	Bulker	Preliminary Info – bulkers include Panamax, Supramax, and Handy-size vessels	160
Fraser Surrey Docks[c]	Bulker	Loaded Capacity: 54,000 tonnes Size: 225 m x 32.2 m x 11.7 m	160
Vancouver Airport Fuel Delivery Project[d]	Tanker	Capacity: 400,000 barrels Size: 228 m x 32.3 m x 11.5 m	24
	Barge	Capacity: 35,000 barrels Size: 78.0 m x 20.1 m x 4.5 m	52
	Tug	N/A	76
WesPac Tilbury Marine Jetty Project[e]	Tanker	Capacity: up to 90,000 m^3 Size: 242 m x 38 m x 10 m	180
	Barge	Capacity: up to 7,500 m^3 Size: 106 m x 16.5 m x 5.1 m (for 4,000 m^3 barge)	68
	Tug	N/A	608

Notes: N/A = not applicable.

a. Vessel size dimensions in metres (m) = length overall x beam x draught, unless otherwise stated.

b. DWT = deadweight tonnage. As outlined in BURNCO Rock Products Ltd (2016), filled barges from the proposed BURNCO Project will use the north arm of the Fraser River to deliver material to existing facilities in Burnaby and the south arm of the Fraser River to deliver to facilities in the Township of Langley. It is expected that tugs will deliver one barge and pick up an aggregate filled barge every other day (365 movements per year), and it is assumed for this response that about half will use the south arm of the Fraser River (182 movements per year).

c. It is assumed that Panamax bulkers will be loaded directly at the terminal and barges will not be required (i.e., 100% use of bulkers), as per details provided in the response to IR4-06. Bulkers do not require tug escort. Vessel capacity information from Fraser Surry Docks LP (FSD) (2015a). Annual movements and vessel size information from FSD (2015b). Since FSD will be re-purposed from a container terminal to a bulk terminal, container traffic in the Fraser River is expected to reduce from 154 movements annually (based on 2014 actual call data) to zero.

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[1] Special requests for vessels beyond the maximum size will be considered by the pilot committee on a case by case basis (Pacific Pilotage Authority 2017).

d. Vancouver Airport Fuel Facility Corporation (VAFFC 2016) has projected a tanker delivery per month and a barge delivery once every two weeks for the project. It is assumed that loaded oil tankers that carry liquids in bulk in excess of 6,000 tonnes will require tug escort, and these tugs will have to transit to their next operation; therefore, each tanker will have two associated tug movements. Note that the number of tank barges has decreased to 26 (VAFFC 2016) from the 48 assumed in EIS Table 8-8 and in EIS Appendix 30-A. Barges will be towed by a tug so no additional 'escort' tug is required. Vessel capacity and vessel size information from Det Norske Veritas (2012).

e. The number of LNG carriers is anticipated to be 90 (48 carriers up to 90,000 m^3 and 42 carriers up to 65,000 m^3) and the number of barges is 34 (up to 7,500 m^3) (based on revised project information described in EAO (2016)). It is assumed that loaded LNG carriers will require three escort tugs; therefore, each tanker will have six associated tug movements. LNG barges will be towed by a tug so no additional 'escort' tug is required. Tanker and barge vessel capacity information from EAO (2016) and vessel size information from WesPac Midstream (2015). Note that there is no publicly available information regarding the size of a 7,500 m^3 LNG barge; hence, the size of a 4,000 m^3 LNG barge is provided from older project information (WesPac Midstream 2015).

Table IR4-03-2 lists vessel traffic by vessel type through the south arm of the Fraser River for 2014 based on actual port vessel tracking system data (VFPA 2017a) and estimated traffic in 2025 based on the assumed increases, which are outlined above.

Table IR4-03-2 2014 Actual and 2025 Estimated South Arm of Fraser River Vessel Movements past the George Massey Tunnel

Vessel Type	2014	2025
Cargo/Carrier	970	1,402
Container Ships	154	0
Tug	756	1,709
Service	28	31
Passenger (including ferries)	0	0
Tanker (including LNG carrier)	0	204
Other/Unknown	30	33
Fishing	44	44
Total	**1,982**	**3,423**

As outlined by the VFPA (2017b), the replacement of the George Massey Tunnel will have no bearing on the port authority's plans to manage increasing trade on the Fraser River, as the existing tunnel is not constraining the current development potential of the river. Internationally, ships are getting larger to be more economically and environmentally efficient, but removing the tunnel in favour of a bridge will not significantly change the size of ships that are able to use the channel for the following reasons:

- The new bridge will be the same height above the water as the existing Alex Fraser Bridge, so maximum vessel height will remain unchanged; and
- Other impediments to larger ships are the shallower depth of the river at its mouth, the width of the river, which does not allow very large vessels to turn, and various underwater pipeline crossings.

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IR4-04 Vessel Traffic Projections - Vessel Movements: Segment G

Information Source(s)

Marine Shipping Addendum: Section 4.2.13, Figure 10-1

Proponent Response to IR1-05 (CEAR Doc#897): Table IR1-05-1; Table IR1-05-2; Table IR1-05-3; Appendix IR1-05-A; Revised Figure 4-2 and Figure 4-3

Context

The Proponent, in response to Review Panel information request IR1-05, updated information and maps about vessel movements through Segments A to D and F for 2012 and 2030 and, in Table IR1-05-3, provided information about vessels to and from Puget Sound to the Port of Vancouver Container terminals.

In Section 4.2.1.3 of the Marine Shipping Addendum, the Proponent stated that vessels calling on both U.S. and Canadian ports will require transiting through Segment G and may travel through Segment G twice on the inbound or outbound routes. Segment G (between Haro Strait and Puget Sound via Hein Bank) connects Segment B to C, or Segment F to C, or Segments B, C or F to Puget Sound.

Information is required for all categories of vessels in segments A-G of the marine shipping area including the inbound and outbound traffic for container ships routing between Haro Strait and Puget Sound using the traffic separation via Hein Bank (Segment G).

Information Request

Update the information provided in response to Review Panel information request IR1-05 and include information about all vessel types that transit through Segment G of the marine shipping area.

Explain how values for each segment were calculated, including how the results reflect vessels that may travel through Segment G more than once.

Update figures in Appendix IR1-05-A to include information about Segment G.

In tables IR1-05-1, IR1-05-2 and IR1-05-3, provide values for Segment G for all categories of vessels and explain how they are included or not in values given in these tables and in figures in Appendix IR1-05A for Segments B, C, and D.

VFPA Response

Update the information provided in response to Review Panel information request IR1-05 and include information about all vessel types that transit through Segment G of the marine shipping area.

Tables 4-2 and 4-7 of the Marine Shipping Addendum have been updated to include vessel movement through Segment G (Puget Sound - Hein Bank) (see **Tables IR4-04-1** and **IR4-04-2** for 2012 and 2030 vessel movements, respectively). Traffic information for Segment G is calculated from the difference between vessel movements across cross-section 2 (Haro Strait) and cross-section 1 (Juan de Fuca Strait). Vessel movements through all segments were determined based on existing information[1], including the following:

- Trans Mountain Expansion Project Application, Volume 8C TERMPOL Reports (TMX 2013a);
- Trans Mountain Expansion Project Application, Volume 8A Marine Transportation (TMX 2013b);
- Herbert Engineering Consultants, Marine Vessel Incidence Prediction Inputs to the Quantitative Risk Assessment (Marine Shipping Addendum Appendix 10-A);
- U.S. Army Corps of Engineers, BP Cherry Point Dock, Draft Environmental Impact Statement (USACE 2014); and
- Washington State 2014 Marine & Rail Oil Transportation Study. Appendix L: Salish Sea Workshop: Vessel Oil Spill Risk Assessment & Management Handbook (Ferguson 2014).

For anticipated vessel movements in 2030, the number of movements for Segments A to D and F have been updated from those provided in IR1-05 of CEAR Document #897[2] based on recent updates, including the following:

- The Gateway Pacific Terminal Project is no longer considered to be a reasonably foreseeable project. Pacific International Holdings formally withdrew its federal permit application on February 7, 2017 after the U.S. Army Corps of Engineers denied the application until impacts to treaty fishing rights can be resolved (Pacific International Holdings 2017). EIS Table 8-8 and Appendix B in EIS Appendix 30-A stated 25 bulkers for Gateway Pacific Terminal (i.e., 5% of the 487 cargo vessels were expected to travel through Boundary Passage) and Marine Shipping Addendum Appendix 6-A stated Panamax (318) and Capesize (169) bulkers. The number of movements through Segment F, therefore, has decreased compared to the information provided in the EIS, Marine Shipping Addendum, and IR1-05; and

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[1] The EIS Guidelines stated that the "proponent should maximise the use of existing material that is relevant to marine shipping activities associated with the Project which is beyond proponent's care and control and within the 12 nautical mile limit of the territorial sea." More recent publicly available information has been reviewed and relevant information integrated into this IR response.

[2] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

- As of April 1, 2017 with the establishment of new container shipping alliances[3], the split call service at Deltaport Terminal, which was assumed to continue in 2030 as stated in prior documentation (i.e., EIS and Marine Shipping Addendum, from assumptions provided in Appendix A of CEAR Document #667[4]) has been discontinued.

Table IR4-04-1 2012 Vessel Movements Through Segments A, B, C, D, F, and G
(Revised Table 4-2 of the Marine Shipping Addendum)

	Marine Shipping Area Segment					
Vessel Type	**A**	**B**	**C**	**D**	**F**	**G**
Cargo/Carrier[a,b]	3,617[g]	2,822[g]	4,431	4,431	795	1,609
Container ships bound for terminals within VFPA jurisdiction[b]	1,684[g]	1,684[g]	2,422[c]	1,580	0[d]	1,580
Tug	3,237	975	2,294	2,294	3,630	1,319
Service	1,316	850	2,189	2,189	466	1,339
Passenger (including ferries)	8,632[e]	506	2,146	2,146	n/a[f]	1,640
Tanker	385	391	1,197	1,197	684	806
Other/Unknown	1,262	1,368	2,240	2,240	n/a[f]	872
Fishing	459	300	742	742	159	442
Total	**20,592**	**8,896**	**17,661**	**16,819**	**5,734**	**9,607**

Sources: TMX 2013a Tables 5-1 to 5-3; Marine Shipping Addendum Appendix 10-A: Appendix B; USACE 2014.

Notes:

a. Cargo/carrier category includes all destinations except container ships bound for terminals within VFPA jurisdiction.

b. Cargo/carrier vessels are comprised of both container vessels and general cargo and bulk carriers in the analysis provided in TMX 2013a. Container ships bound for Port of Vancouver terminals were separated into a separate vessel type category in the Marine Shipping Addendum.

c. Accounts for assumed 100% container ship calls to both Canadian and U.S. Pacific Northwest ports resulting in one additional transit (i.e., inbound and outbound) across this segment, and the weekly split call service to Deltaport Terminal (i.e., routing is Canada – U.S.A. – Canada), which accounts for an additional transit through this segment. Split call service to Deltaport crosses Segments A, B, and C four times.

d. Container vessels bound for or departing from Port of Vancouver terminals do not transit through Segment F.

e. Compared to TMX 2013a, the Marine Shipping Addendum accounts for an additional 2,998 ferry traffic movements as a result of a slightly altered alignment of cross-section 3 used to calculate traffic in Segment A.

f. n/a = not applicable, as categories passenger and other/unknown in Segment F are not captured at cross-section calculation.

g. In Table 4-2 of the Marine Shipping Addendum and Table IR1-05-1 in IR1-05, Segments A and B erroneously accounted for the additional transit (i.e., 104 movements) for the weekly Deltaport Terminal split call service under cargo vessels instead of container ships for cross-sections 2 and 3 and Segments A and B. These movements are now included under the container ship category.

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[3] Information from www.icontainers.com/us/2017/03/21/new-shipping-alliances-what-you-need-to-know.

[4] CEAR Document #667 From the Vancouver Fraser Port Authority to the Review Panel re: Orientation Session #2 Undertaking #1: Estimate of the number of ultra-large ships that would call on Roberts Bank Terminal 2.

Table IR4-04-2 2030 Anticipated Movements by Vessel Type Through Segments A, B, C, D, F, and G (Revised Table 4-7 of the Marine Shipping Addendum)

Vessel Type	Marine Shipping Area Segment					
	A	B	C	D	F	G
Cargo/Carrier[a]	4,295[g]	3,344[g]	5,112[g]	5,112[g]	951	1,769[g]
Container ships bound for other terminals within VFPA jurisdiction	1,526[g]	1,526[g]	2,289[b,c]	1,526	0[d]	1,526
RBT2-bound container ships	520	520	780[b]	520	0[d]	520
Tug	4,592	1,886	3,464	3,464	4,386	1,578
Service	1,574	1,017	2,618	2,618	557	1,601
Passenger (including ferries)	9,570	605	2,567	2,567	n/a[e]	1,962
Tanker	1,270	1,278	2,430	2,430	840	1,152
Other/Unknown	1,509	1,637	2,680	2,680	n/a[e]	1,043
Fishing	459	300	742	742	159	442
Total	**25,315**	**12,113**	**22,682**	**21,659**	**6,893**	**11,593**

Sources: TMX 2013a Tables 5-1 to 5-3; Marine Shipping Addendum Appendix 10-A: Appendix B; USACE 2014.

Notes:
a. Cargo/carrier category includes all destinations except container ships bound for terminals within VFPA jurisdiction (as previously indicated in Table 4-2 of the Marine Shipping Addendum).
b. Cargo/carrier vessels are comprised of both container vessels and general cargo and bulk carriers in the analysis provided in TMX 2013a. Container ships bound for Port of Vancouver terminals were separated into a separate vessel type category in the Marine Shipping Addendum.
c. Accounts for assumed 100% container ship calls to both Canadian and U.S. Pacific Northwest ports resulting in one additional transit (i.e., inbound and outbound) across this segment.
d. Container vessels bound for or departing from Port of Vancouver terminals are not anticipated to transit through Segment F (Rosario Strait) in the future.
e. Compared to TMX 2013a, the Marine Shipping Addendum accounts for an additional 2,998 ferry traffic movements as a result of a slightly altered alignment of the cross-section used to calculated traffic in Segment A.
f. n/a = not applicable, as categories passenger and other/unknown in Segment F are not captured at cross-section calculation.
g. Movements updated to reflect the change in Deltaport Terminal split call service.

Explain how values for each segment were calculated, including how the results reflect vessels that may travel through Segment G more than once.

Vessel movements in 2012 for each segment were either sourced from 2012 Automatic Identification System (AIS) data at specific cross-sections (cross-sections 1 to 3 are shown on Figure IR4-04-A1 in **Appendix IR4-04-A**), calculated from differences in AIS data at cross-section locations, or a combination of AIS data and other data (e.g., B.C. Ferries data). Vessel movements in 2030 for each segment were based on projections from TMX (2013a) provided for these same cross-sections. The derivations of vessel movement values for 2012 and 2030 for each segment are as follows:

- Segment A data is partially calculated from 2012 AIS data at cross-section 3 plus B.C. Ferries traffic for vessels transiting on the Tsawwassen-Swartz Bay and the Tsawwassen-Southern Gulf Islands routings that cross cross-section 3[5];
- Segment B data is from AIS data at cross-section 2;
- Segment C data is from AIS data at cross-section 1 adjusted by the multiple crossings of the trans-border container vessel movements through this segment (i.e., as shown in Figure IR4-04-A3 in **Appendix IR4-04-A**, three movements through Segment C compared to four movements across cross-section 1 for regular calls and four movements through Segment C compared to six movements across cross-section 1 for the Deltaport split call service in 2012);
- Segment D data for all vessel classes is the same as Segment C, except for container vessel movement data, which is calculated by subtracting additional Canada – U.S.A container ship movements from Segment C data;
- Segment F is calculated by subtracting cross-section 2 data from cross-section 3 for vessels following international shipping lanes for most vessel categories. However, for tankers and tugs the calculated numbers were adjusted to account for the BP Marine Terminal Dock at Cherry Point. For 2012, 684 tanker movements and 1,368 tug movements were added. Similarly for 2030, 840 tanker movements and 1,680 escort tug movements were added for the BP Marine Terminal Dock[6]. Passenger and other/unknown vessel types were not calculated as data relevant to Segment F are not captured at these cross-sections; and
- Segment G is calculated by subtracting cross-section 2 data from cross-section 1 data.

Update figures in Appendix IR1-05-A to include information about Segment G.

Revised Figure 4-2 of Appendix IR1-05-A has been updated as Figure IR4-04-A1 in **Appendix IR4-04-A** and provides the location and data for each of the cross-sections used to determine vessel movements per segment.

In tables IR1-05-1, IR1-05-2 and IR1-05-3, provide values for Segment G for all categories of vessels and explain how they are included or not in values given in these tables and in figures in Appendix IR1-05A for Segments B, C, and D.

Tables IR1-05-1 and IR1-05-2 have been updated to include Segment G and are provided in **Tables IR4-04-1** and **IR4-04-2** above. All vessel categories are included in the values given in these tables.

For Table IR1-05-3, actual movements for 2012 based on direction of travel and last port of call for each Port of Vancouver terminal is provided for Segment B, and these movements include vessels that transit through Segment G, as the direction of travel will not change

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[5] Note that although peak and non-peak weekly movements at the B.C. Ferries Tsawwassen Terminal are provided in IR4-07 based on the ferry schedules for Tsawwassen-Swartz Bay, Tsawwassen-Southern Gulf Islands, and Tsawwassen-Duke Point, vessels on the latter routing do not cross cross-section 3. For additional information on ferry traffic, refer to Appendix A of Appendix 10-A in the Marine Shipping Addendum.

[6] Information sourced from USACE (2014).

based on segment of interest. Projected movements for 2030 are also anticipated to follow a similar directional pattern as shown for Segment B, and therefore, Segment G.

Figure IR4-04-A2 in **Appendix IR4-04-A** provides vessel movements by category for Segments A, B, C, D, F, and G.

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Appendices

Appendix IR4-04-A Updated Figures

APPENDIX IR4-04-A
UPDATED FIGURES

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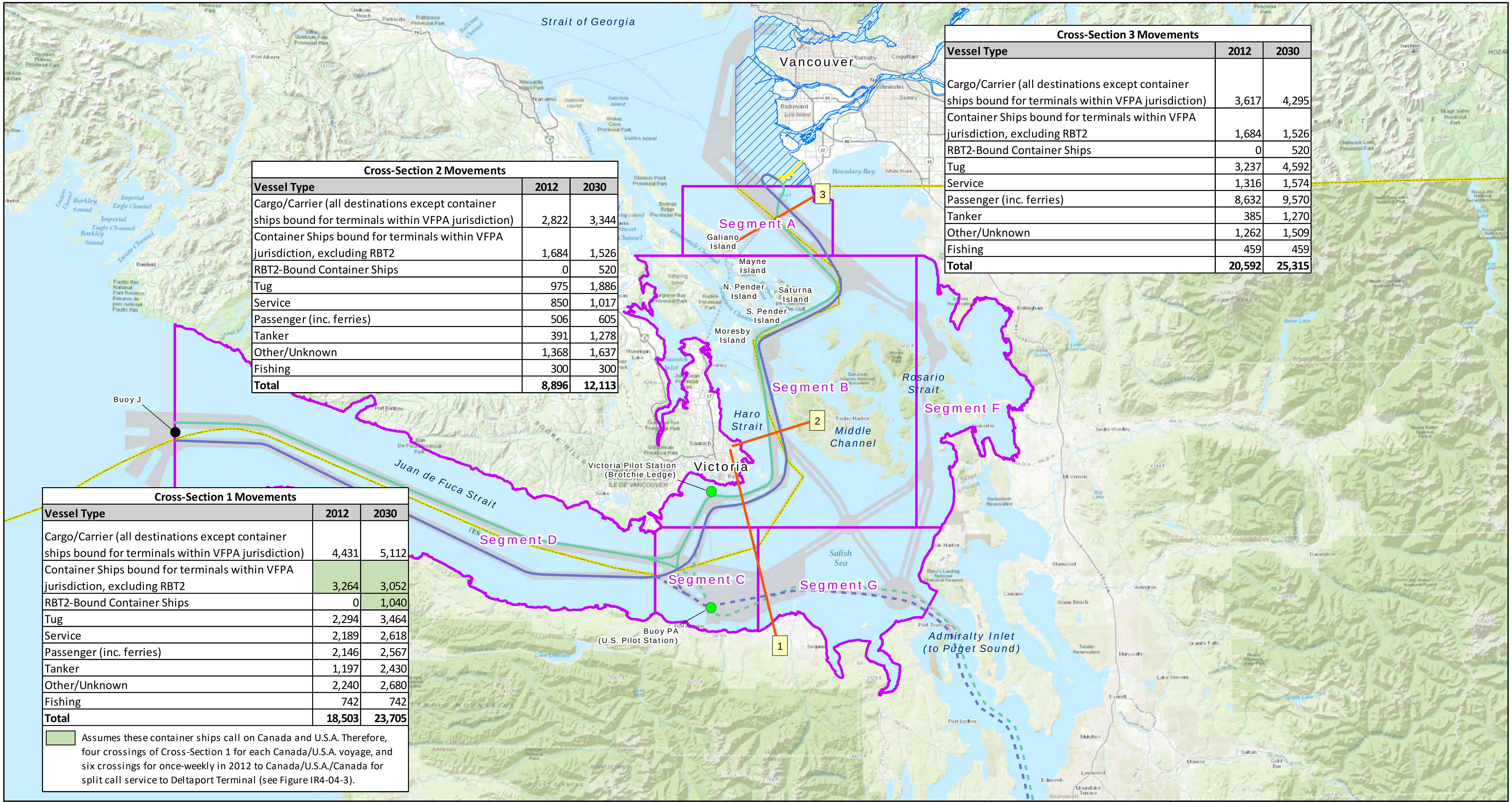

Cross-Section 1 Movements		
Vessel Type	**2012**	**2030**
Cargo/Carrier (all destinations except container ships bound for terminals within VFPA jurisdiction)	4,431	5,112
Container Ships bound for terminals within VFPA jurisdiction, excluding RBT2	3,264	3,052
RBT2-Bound Container Ships	0	1,040
Tug	2,294	3,464
Service	2,189	2,618
Passenger (inc. ferries)	2,146	2,567
Tanker	1,197	2,430
Other/Unknown	2,240	2,680
Fishing	742	742
Total	**18,503**	**23,705**

🟩 Assumes these container ships call on Canada and U.S.A. Therefore, four crossings of Cross-Section 1 for each Canada/U.S.A. voyage, and six crossings for once-weekly in 2012 to Canada/U.S.A./Canada for split call service to Deltaport Terminal (see Figure IR4-04-3).

Cross-Section 2 Movements		
Vessel Type	**2012**	**2030**
Cargo/Carrier (all destinations except container ships bound for terminals within VFPA jurisdiction)	2,822	3,344
Container Ships bound for terminals within VFPA jurisdiction, excluding RBT2	1,684	1,526
RBT2-Bound Container Ships	0	520
Tug	975	1,886
Service	850	1,017
Passenger (inc. ferries)	506	605
Tanker	391	1,278
Other/Unknown	1,368	1,637
Fishing	300	300
Total	**8,896**	**12,113**

Cross-Section 3 Movements		
Vessel Type	**2012**	**2030**
Cargo/Carrier (all destinations except container ships bound for terminals within VFPA jurisdiction)	3,617	4,295
Container Ships bound for terminals within VFPA jurisdiction, excluding RBT2	1,684	1,526
RBT2-Bound Container Ships	0	520
Tug	3,237	4,592
Service	1,316	1,574
Passenger (inc. ferries)	8,632	9,570
Tanker	385	1,270
Other/Unknown	1,262	1,509
Fishing	459	459
Total	**20,592**	**25,315**

Legend

🟨	BOUNDARY OF PROJECT AREA
🟪	MARINE SHIPPING AREA SEGMENT
▨	VFPA NAVIGATIONAL JURISDICTION AREA
—	CROSS-SECTION 1. VICTORIA-PORT ANGELES 2. HARO STRAIT 3. STRAIT OF GEORGIA
●	PILOT STATION
—	RBT2 ASSOCIATED INBOUND SHIPPING ROUTE
—	RBT2 ASSOCIATED OUTBOUND SHIPPING ROUTE
- -	INBOUND NON-PROJECT ASSOCIATED U.S.A. ROUTE
- -	OUTBOUND NON-PROJECT ASSOCIATED U.S.A. ROUTE
- -	U.S.A.-CANADA BORDER

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N

PORT of vancouver

ROBERTS BANK TERMINAL 2

CURRENT AND FUTURE SHIPPING TRAFFIC MOVEMENTS BY CROSS-SECTION

DATE: 07/28/2017
FIG No. IR4-04-A1

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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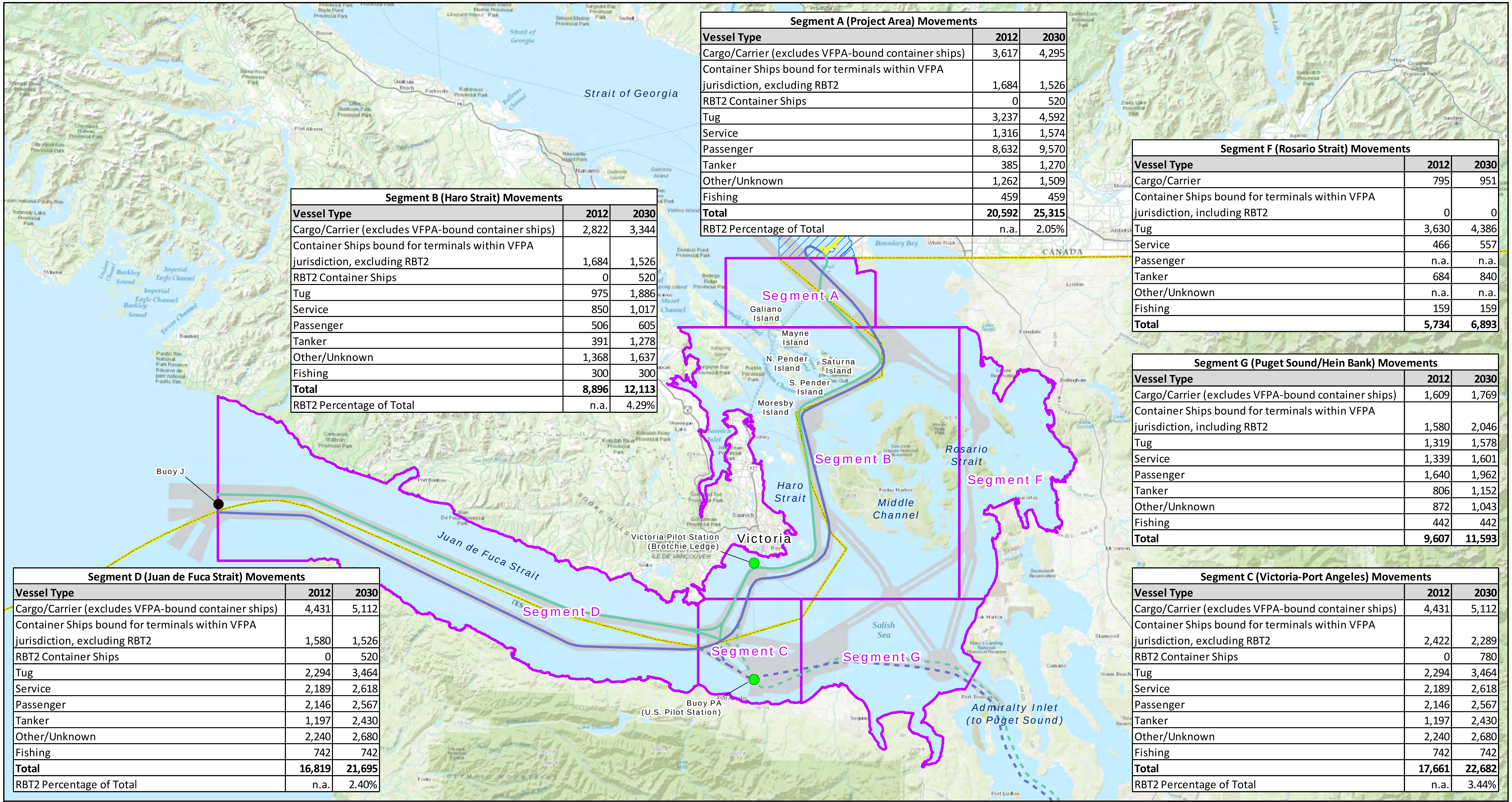


Segment A (Project Area) Movements

Vessel Type	2012	2030
Cargo/Carrier (excludes VFPA-bound container ships)	3,617	4,295
Container Ships bound for terminals within VFPA jurisdiction, excluding RBT2	1,684	1,526
RBT2 Container Ships	0	520
Tug	3,237	4,592
Service	1,316	1,574
Passenger	8,632	9,570
Tanker	385	1,270
Other/Unknown	1,262	1,509
Fishing	459	459
Total	**20,592**	**25,315**
RBT2 Percentage of Total	n.a.	2.05%

Segment B (Haro Strait) Movements

Vessel Type	2012	2030
Cargo/Carrier (excludes VFPA-bound container ships)	2,822	3,344
Container Ships bound for terminals within VFPA jurisdiction, excluding RBT2	1,684	1,526
RBT2 Container Ships	0	520
Tug	975	1,886
Service	850	1,017
Passenger	506	605
Tanker	391	1,278
Other/Unknown	1,368	1,637
Fishing	300	300
Total	**8,896**	**12,113**
RBT2 Percentage of Total	n.a.	4.29%

Segment F (Rosario Strait) Movements

Vessel Type	2012	2030
Cargo/Carrier	795	951
Container Ships bound for terminals within VFPA jurisdiction, including RBT2	0	0
Tug	3,630	4,386
Service	466	557
Passenger	n.a.	n.a.
Tanker	684	840
Other/Unknown	n.a.	n.a.
Fishing	159	159
Total	**5,734**	**6,893**

Segment G (Puget Sound/Hein Bank) Movements

Vessel Type	2012	2030
Cargo/Carrier (excludes VFPA-bound container ships)	1,609	1,769
Container Ships bound for terminals within VFPA jurisdiction, including RBT2	1,580	2,046
Tug	1,319	1,578
Service	1,339	1,601
Passenger	1,640	1,962
Tanker	806	1,152
Other/Unknown	872	1,043
Fishing	442	442
Total	**9,607**	**11,593**

Segment D (Juan de Fuca Strait) Movements

Vessel Type	2012	2030
Cargo/Carrier (excludes VFPA-bound container ships)	4,431	5,112
Container Ships bound for terminals within VFPA jurisdiction, excluding RBT2	1,580	1,526
RBT2 Container Ships	0	520
Tug	2,294	3,464
Service	2,189	2,618
Passenger	2,146	2,567
Tanker	1,197	2,430
Other/Unknown	2,240	2,680
Fishing	742	742
Total	**16,819**	**21,695**
RBT2 Percentage of Total	n.a.	2.40%

Segment C (Victoria-Port Angeles) Movements

Vessel Type	2012	2030
Cargo/Carrier (excludes VFPA-bound container ships)	4,431	5,112
Container Ships bound for terminals within VFPA jurisdiction, excluding RBT2	2,422	2,289
RBT2 Container Ships	0	780
Tug	2,294	3,464
Service	2,189	2,618
Passenger	2,146	2,567
Tanker	1,197	2,430
Other/Unknown	2,240	2,680
Fishing	742	742
Total	**17,661**	**22,682**
RBT2 Percentage of Total	n.a.	3.44%

Legend

- ☐ BOUNDARY OF PROJECT AREA
- ☐ MARINE SHIPPING AREA SEGMENT
- ▨ VFPA NAVIGATIONAL JURISDICTION AREA
- ● PILOT STATION
- — RBT2 ASSOCIATED INBOUND SHIPPING ROUTE
- — RBT2 ASSOCIATED OUTBOUND SHIPPING ROUTE
- - - INBOUND NON-PROJECT ASSOCIATED U.S.A. ROUTE
- - - OUTBOUND NON-PROJECT ASSOCIATED U.S.A. ROUTE
- — U.S.A.-CANADA BORDER

0 20 40
Kilometres
1:800,000
NAD 1983 UTM Zone 10N
N

PORT of vancouver

ROBERTS BANK TERMINAL 2

CURRENT AND FUTURE SHIPPING
TRAFFIC MOVEMENTS BY SEGMENT

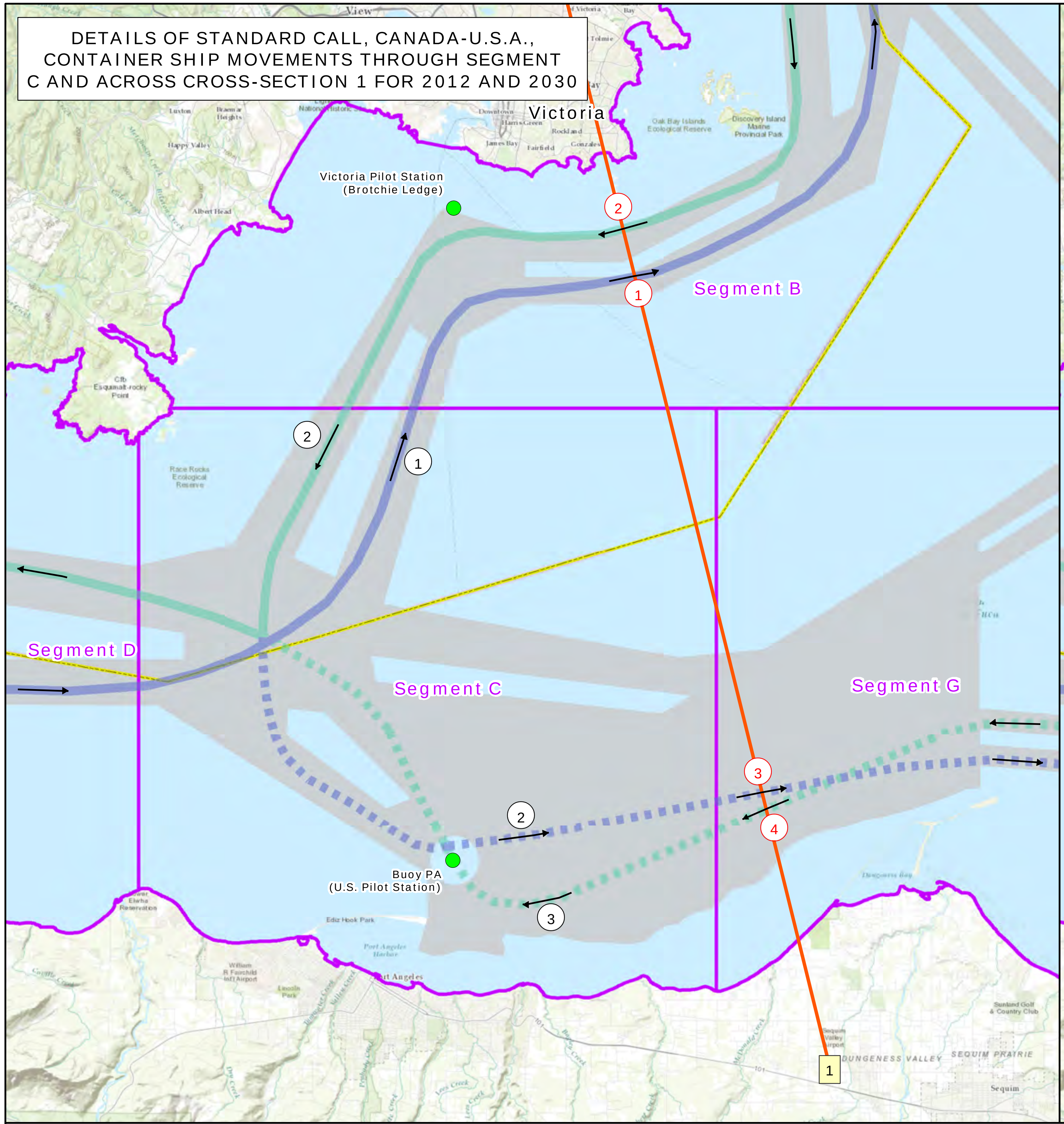
DATE: 07/28/2017

FIG No. IR4-04-A2

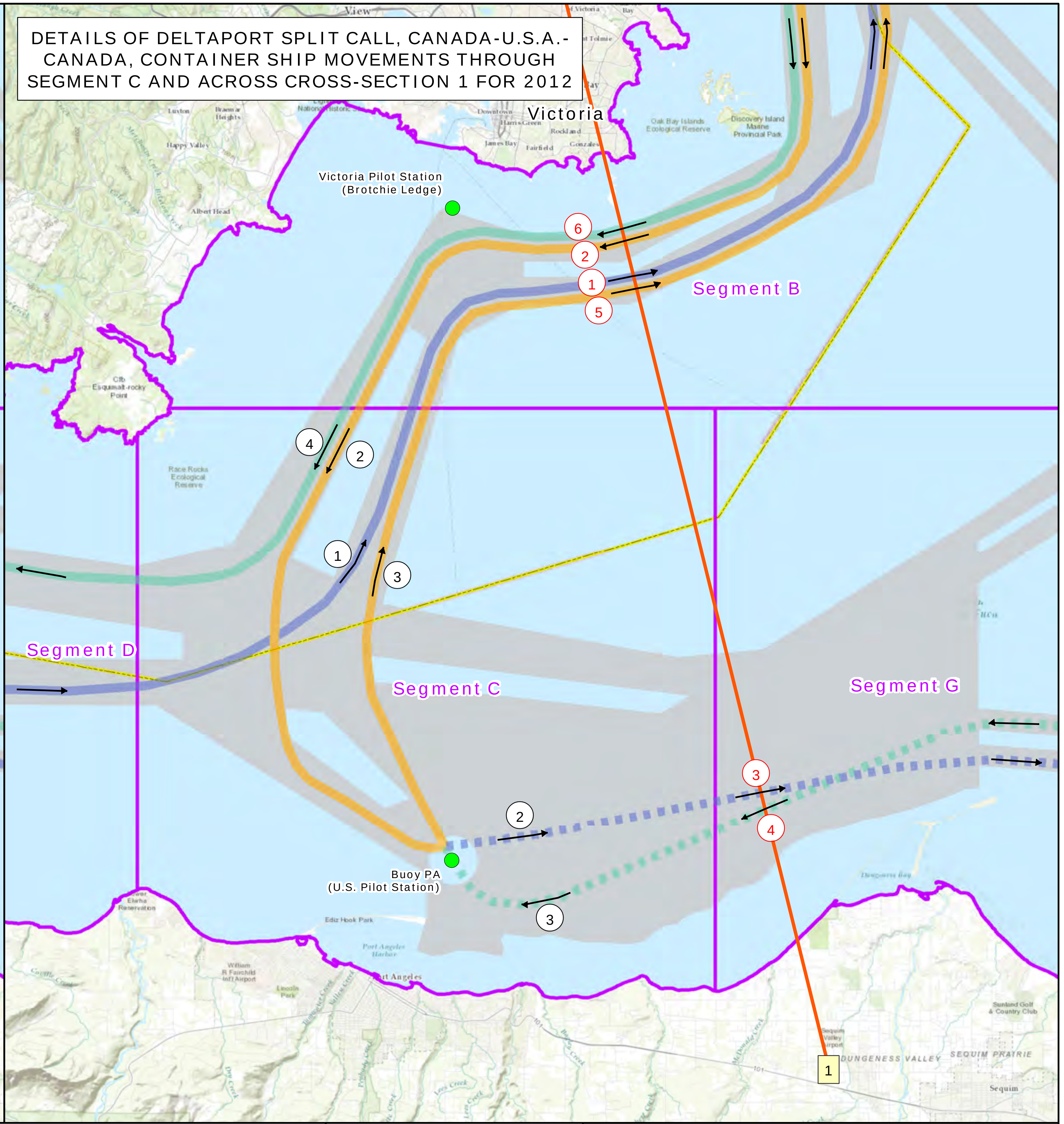
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Path: O:\!1200-\1246\EIS_INFORMATION_REQUESTS\IR4_4\mxd\IR4_04_A3_SegmentMovementDetails_XS1_170721.mxd

DETAILS OF STANDARD CALL, CANADA-U.S.A., CONTAINER SHIP MOVEMENTS THROUGH SEGMENT C AND ACROSS CROSS-SECTION 1 FOR 2012 AND 2030



DETAILS OF DELTAPORT SPLIT CALL, CANADA-U.S.A.-CANADA, CONTAINER SHIP MOVEMENTS THROUGH SEGMENT C AND ACROSS CROSS-SECTION 1 FOR 2012



Legend

- CROSS-SECTION 1
- ▭ MARINE SHIPPING AREA SEGMENT
- ▨ INTERNATIONAL SHIPPING LANES
- U.S.A.-CANADA BORDER
- ● PILOT STATION
- ② MOVEMENTS ACROSS CROSS-SECTION 1
- ③ MOVEMENTS THOUGH SEGMENT C
- CANADA ASSOCIATED INBOUND SHIPPING ROUTE
- CANADA ASSOCIATED OUTBOUND SHIPPING ROUTE
- U.S.A. ASSOCIATED INBOUND SHIPPING ROUTE
- U.S.A. ASSOCIATED OUTBOUND SHIPPING ROUTE
- DELTAPORT SPLIT CALL ADDITIONAL OUT AND INBOUND ROUTES

0 5 10
Kilometres
1:200,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

MARINE SHIPPING AREA,
CROSS-SECTION 1, AND
SEGMENT C MOVEMENT DETAILS

DATE: 07/21/2017

FIG No. IR4-04-A3

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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IR4-05 Vessel Traffic Projections – Small Vessels

Information Source(s)

EIS Volume 2: Section 9.2; Section 9.8.5.3

Proponent Response to IR1-05 (CEAR Doc#897): Table IR1-05-01; Table IR1-05-02; Appendix IR1-05-A; Revised Figure 4-2 and Figure 4-3

Marine Shipping Addendum: Section 9.2; Appendix A of Appendix 10-A; Section A-2.7, Table A-2

Context

Throughout the EIS and the Marine Shipping Addendum, the Proponent indicated the types of vessels that it included in its analysis. Small vessels of certain types were included in some of the assessments, but have not been included in others.

In Section 9.2 of the Marine Shipping Addendum, the Proponent indicated that the Pacific Whale Watch Association members conduct approximately 13,600 tours using 86 vessels in an average year. Further, in Table A-2 and Section A-2.7 of Appendix A of Appendix 10-A of the Marine Shipping Addendum, data is given for small vessel movements in Segment A under the other/unknown category. The volume of small vessels reported in Section 9.2 and Appendix 10-A of the Marine Shipping Addendum do not support the lack of inclusion of small vessels in the assessment.

In Table IR1-05-01, Table IR1-05-02, revised Figure 4-2 and revised Figure 4-3 of its response to Review Panel information request IR1-05, the Proponent described vessel movements by vessel type but it is unclear whether small vessels were also included in the figures and tables under the category other/unknown.

Clarification of the numbers and movements of small vessels and the areas where they would congregate in the marine shipping area and especially in Segment A is required.

Information Request

Clarify whether small vessels, including whale watching boats, are included in the other/unknown category of Tables IR1-05-1, IR1-05-2, and revised Figures 4-2 and 4-3 of the Proponent's response to Review Panel information request IR1-05. If small vessels are not included, provide an estimate of the number of movements of small vessels and update these tables and figures accordingly.

Provide map(s) of the marine shipping area that display the actual (2012) and projected (2030) small vessels movements for each segment.

VFPA Response

Clarify whether small vessels, including whale watching boats, are included in the other/unknown category of Tables IR1-05-1, IR1-05-2, and revised Figures 4-2 and 4-3 of the Proponent's response to Review Panel information request IR1-05. If small vessels are not included, provide an estimate of the number of movements of small vessels and update these tables and figures accordingly.

Small vessels equipped with Automatic Identification System (AIS)[1] transponders, including recreational and whale watching boats, were included in the 'other/unknown' vessel category[2] for 2012 and 2030 (from calculated projections, explained below) in the tables and figures provided in IR1-05 of CEAR Document #897[3]. Small vessels not equipped with AIS were not included in the other/unknown category in the tables and figures provided in IR1-05. The information provided in IR1-05 has been superseded by Figure IR4-04-2 in IR4-04, which provides movement data for Segments A to G (except Segment F, as noted).

As explained in Marine Shipping Addendum Appendix 10-A Section 2.4.2 and Marine Shipping Addendum Information Request #7 (MSA IR-02.24.16-7 in CEAR Document #391[4]), a growth rate from 2012 traffic levels of 1% per year to 2030 was assumed for the 'other/unknown' category. A 1% increase annually was assumed, as not all small vessels have been tracked through AIS, which is a known limitation of all existing marine traffic monitoring systems (BC Ministry of Environment 2013).

Two previous (non-AIS) studies of recreational boating traffic volumes have been conducted in the Salish Sea. As explained in the 2017 JASCO report included as **Appendix IR4-05-A**, neither was suitable for independently estimating the overall size of the recreational fleet in the Salish Sea, as sampling was too limited to be able to infer from the results the overall quantity of the recreational boating fleet in the study areas. In one study, vessel track data was gathered via face-to-face surveys with recreational boaters between June and September 2007 at six sampling sites throughout the Gulf Islands, with each site being sampled for eight days (Gray et. al 2011). In the other study, boat positions in the San Juan Islands were recorded via aerial surveys two times per day over nineteen days between June and September 2010 (Dismukes et. al 2010).

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[1] In Canada, federal regulations require vessels (other than fishing vessels) of 500 deadweight tons (DWT) or more not engaged on an international voyage and of 300 DWT or more engaged on an international voyage to carry AIS transponders (Canadian Coast Guard 2017). In practice, many smaller craft and fishing vessels also carry AIS transponders for safety reasons.

[2] Other vessels that could not be classified into one of the other vessel type categories are also included in the 'other/unknown' category.

[3] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

[4] CEAR Document #391 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Marine Shipping Addendum Completeness Review - Responses to Additional Information Requirements (See Reference Document #386).

Provide map(s) of the marine shipping area that display the actual (2012) and projected (2030) small vessels movements for each segment.

In the absence of mapped information for small vessel movements for each segment, density maps showing movement patterns[5] in the Salish Sea (including within Segments A to G) are provided for January and July 2015, based on 2015 AIS data[6] for recreational vessels (**Figures IR4-05-1** and **IR4-05-2**, respectively) and calculated data[7] for whale watching vessels (**Figures IR4-05-3** and **IR4-05-4**, respectively). Information was sourced from the Regional Ocean Noise Contributors Analysis Study Report by Jasco Applied Sciences commissioned by the Port of Vancouver report provided in **Appendix IR4-05-A**). Based on the density maps for these two months, small vessel and whale watching vessel movements are substantially higher in the summer than winter, and greater in proximity to urban centres (e.g., Vancouver, Richmond, Victoria in B.C., and Puget Sound in Washington State) and around islands (e.g., Gulf Islands in B.C. and San Juan Islands in Washington State).

Movement patterns in 2030 are expected to be the same as shown in **Figures IR4-05-1** to **IR4-05-4**, and 'other/unknown' vessels (including recreational vessels and whale watching vessels) are projected to increase (as described above). For projected movements in 2030 for this category, refer to the tables provided for each segment in Figure IR4-04-2 of IR4-04.

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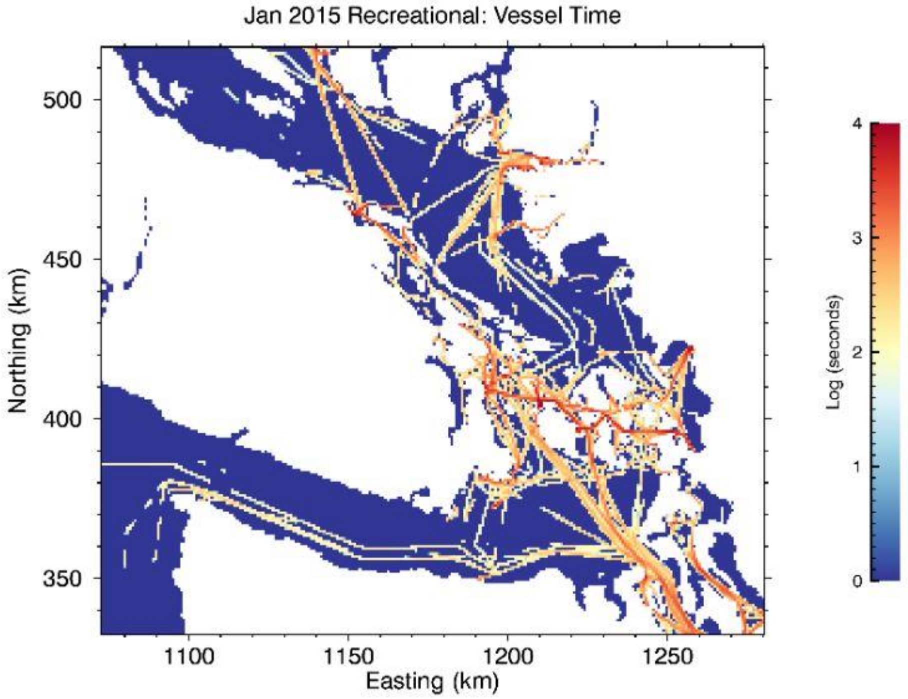
[5] Density maps show vessel duration in seconds on a logarithmic scale per 800 m x 800 m grid cell.

[6] The raw 2015 AIS data consisted of time-stamped position reports as well as other relevant vessel information for those vessels moving in the Salish Sea study area carrying AIS transponders. The dataset contained approximately 3 million position reports for the two months covered by the 2017 JASCO study (see **Appendix IR4-05-A**).

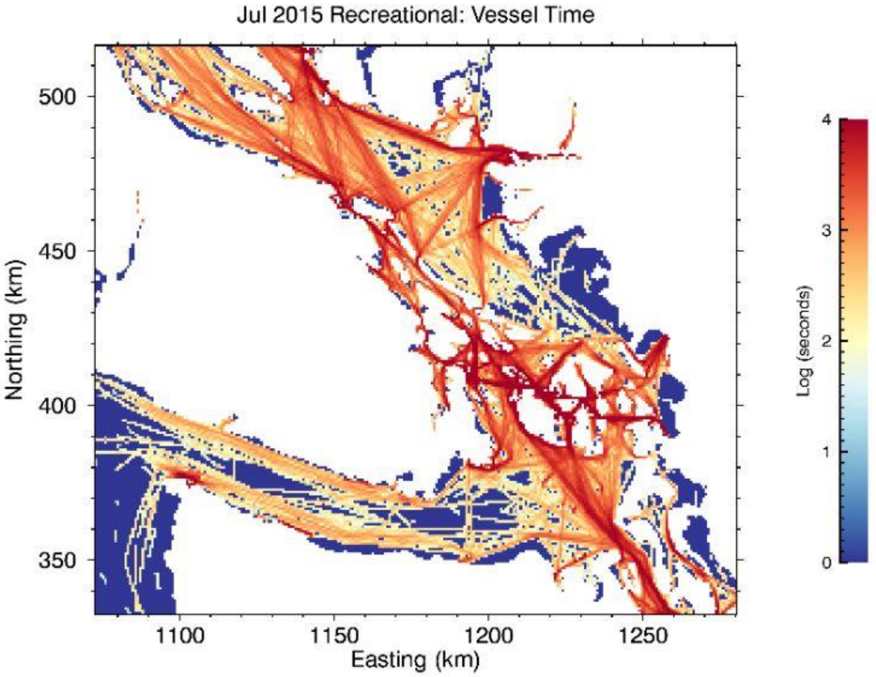
[7] Whale watching vessel time in the Salish Sea study area was calculated based on data from the Whale Museum Soundwatch Program and incorporated the number of vessels in the fleet, the average duration of their trips, the total number of trips per day, and the distribution of whales in the study area. For more information, refer to Appendix C in **Appendix IR4-05-A**.

Figure IR4-05-1 Recreational Vessel Movement Patterns in the Salish Sea Based on 2015 January AIS Data



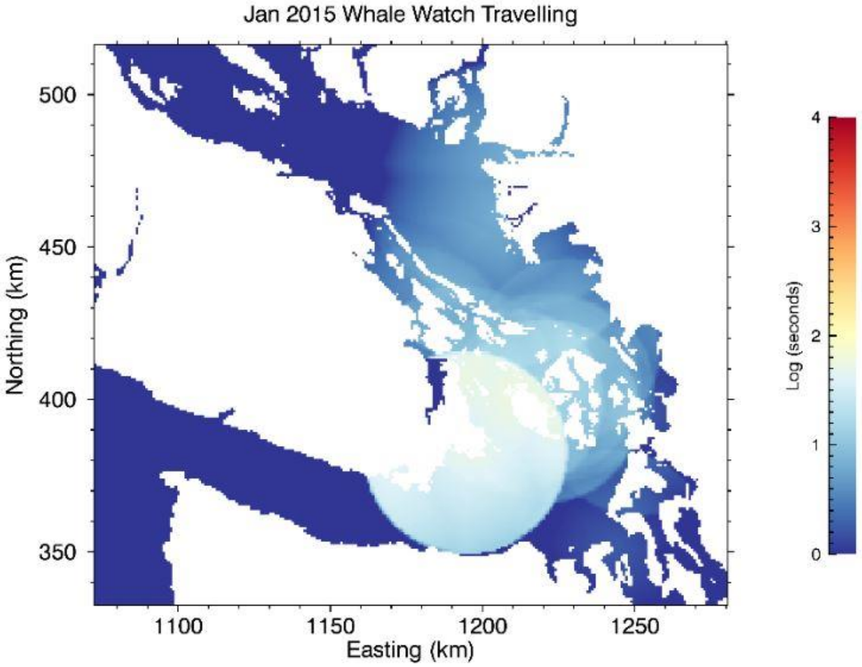
Source: see **Appendix IR4-05-A**

Figure IR4-05-2 Recreational Vessel Movement Patterns in the Salish Sea Based on 2015 July AIS Data



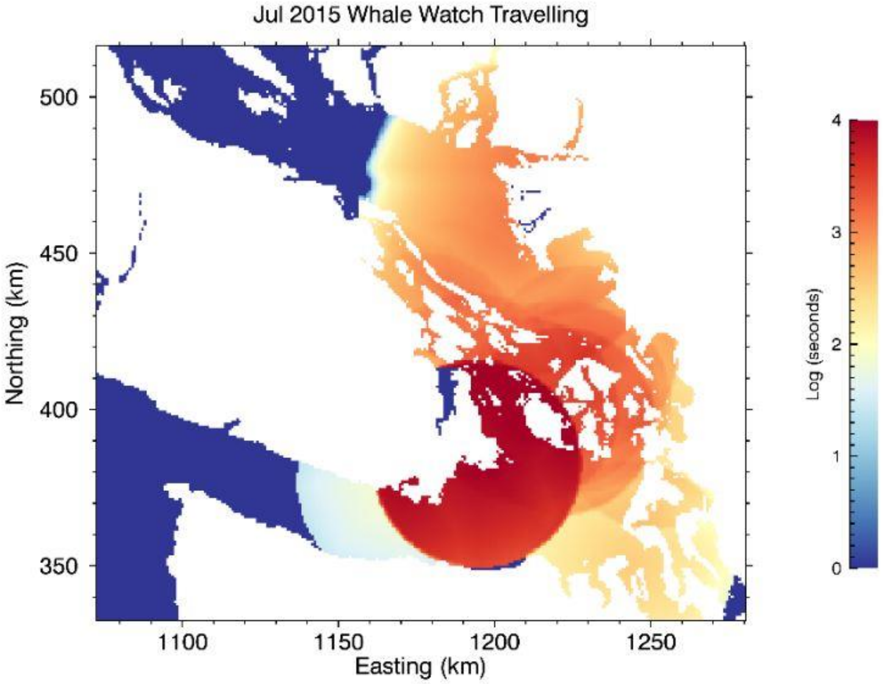
Source: see **Appendix IR4-05-A**

Figure IR4-05-3 **Simulated Whale Watch Vessel Movement Patterns in the Salish Sea for January 2015**



Source: see **Appendix IR4-05-A**

Figure IR4-05-4 **Simulated Whale Watch Vessel Movement Patterns in the Salish Sea for July 2015**



Source: see **Appendix IR4-05-A**

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BC Ministry of Environment. 2013. West Coast Spill Response Study – Volume 2: Vessel Traffic Study. Available at http://www.env.gov.bc.ca/main/west-coast-spill-response-study/docs/WestCoastSpillResponse_Vol2_VesselTrafficStudy_130722.pdf. Accessed June 2017.

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Gray, D.L., R. R. Canessa, C. P. Keller, P. Dearden, and R. B. Rollins. 2011. Spatial Characterization of Marine Recreational Boating: Exploring the Use of an On-the-water Questionnaire for a Case Study in the Pacific Northwest. Marine Policy 35:286-298.

Appendices

Appendix IR4-05-A	Port of Vancouver. Enhancing Cetacean Habitat and Observation Program Study Summary: An Analysis of Regional Ocean Noise Contributors (January 2017)

APPENDIX IR4-05-A

PORT OF VANCOUVER. ENHANCING CETACEAN HABITAT AND OBSERVATION PROGRAM STUDY SUMMARY: AN ANALYSIS OF REGIONAL OCEAN NOISE CONTRIBUTORS (JANUARY 2017)

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An Analysis of Regional Ocean Noise Contributors

The Enhancing Cetacean Habitat and Observation (ECHO) Program commissioned a study to better understand the contributions of various vessel types to underwater noise in the Salish Sea.

This summary document was prepared to describe why the study was conducted, its key findings and conclusions, and how the results are planned to be used by the ECHO Program to help manage the impact of shipping activities on at-risk whales throughout the southern coast of British Columbia.

What questions was the study trying to answer?

Endangered Southern Resident Killer Whales (SRKW) and other at-risk whale species frequent the Salish Sea, which also hosts commercial and recreational vessel activities. Noise from vessel traffic combines to increase ambient underwater noise levels and can interfere with the ability of animals to hunt their prey and communicate with one another.

Previous studies have quantified underwater noise generated by vessels in the region, but data available at the time did not include all vessel types or provide enough detail to fully understand the contribution of various vessel categories in the critical habitat of the SRKW.

The noise contribution of a given vessel category (such as tanker, ferries, container ships, recreation boats) varies depending on: the noise characteristics of the specific vessels; the intensity (loudness) of the vessels; the number of vessels of that category transiting; the amount of time a vessel spends in a given area; and the environmental conditions that affect how sound travels in water.

The noise contribution of various vessel categories depends on several operational and environmental factors.

The ECHO Program commissioned a study to answer the following questions:

- How much underwater noise do different commercial vessel sectors (e.g., commercial deep-sea vessels, passenger ferries, tug boats etc.) contribute in the region?
- How much noise do recreational, fishing and whale watching boats contribute in the region?
- Does the noise contribution of different vessel categories vary throughout the year and throughout the region?

Who conducted the study?

JASCO Applied Sciences Ltd. (JASCO) was selected to undertake this study based on their expertise in underwater noise and existing tools (models) they have developed specifically for this region.

What methods were used?

JASCO used an existing regional acoustic model and vessel information from 2015 to produce more detailed and fulsome noise estimates in the region. Information used to create the noise model includes:

1) Automated Identification System (AIS) information from vessels transiting the region in winter (January) and summer (July) of 2015 (e.g., vessel type, route and speed) as well as and simulations of whale watch vessel traffic (whale watch boats are not AIS-equipped);
2) information on vessel-generated noise for different vessel types; and
3) environmental data such as water temperature, salinity etc. that governs how sound travels through water.

The results of the updated acoustic model were used to create noise maps, pie-charts and ranking tables which display underwater noise levels and the relative contributions of different vessel categories to overall underwater noise levels. The noise information was represented by vessel category (using 11 categories), season (winter and summer) and sub-region (6 smaller geographic areas within the Salish Sea).

What were the key findings and conclusions?

The study generated the average total sound levels within the Salish Sea for a month in summer and a month in winter, based on noise generated by transiting vessels using 2015 data. The study found that:

- Sound generally travels faster and further through the colder waters in winter than in the warmer waters in summer and therefore underwater noise levels in the region are typically higher in winter despite the lower winter vessel traffic volumes;
- The commercial vessel sector (commercial deep-sea vessels, ferries, tugs etc.) is the main contributor of underwater noise in the region;
- Vessel categories with the largest overall noise contributions in the study area are those that spend the most time travelling in the region (i.e., tugs and ferries);
- Commercial deep-sea vessels make a relatively large contribution to underwater noise, mostly along the international shipping lanes where they navigate;
- Smaller crafts (e.g. recreational, fishing and whale watch vessels) make an important contribution in sub-regions such as Haro Strait and the San Juan Islands, especially in summer. Their localized noise contribution may be particularly important in areas where their presence overlaps with high-use areas for SRKW;
- The study likely underestimated the noise contribution of small crafts due to limited vessel tracking (AIS) information available for these vessels.

The commercial vessel sector (commercial deep-sea vessels, ferries, tugs etc.) is the main contributor of underwater noise in the region.

How are the results being used to help reduce underwater noise and its effects on at-risk whales?

The results of this study furthered the ECHO Program's understanding of how different vessel sectors (commercial shipping and transportation, recreational boating, whale watching and fishing) and vessel categories (e.g., tugs, bulk carriers, container ships, cruise ships, ferries, whale watching boats etc.) are contributing to existing underwater noise levels. The ECHO Program is using this knowledge to help focus management efforts and inform the development of vessel noise reduction solutions that are appropriate for the vessel sectors (or categories) and sub-regions.

Regional Ocean Noise Contributors Analysis

Enhancing Cetacean Habitat and Observation Program

Submitted to:
Orla Robinson
Krista Trounce
Port of Vancouver

Authors:
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Michael Wood
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David Hannay

24 January 2017

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of this report's entire information. The results may also not be representative of different acoustic sources, receivers, fauna, and physical environments. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must include a clear citation of the original report and the latter shall be made readily available to the recipients in integral and unedited form.

JASCO provides modelling and analysis for determining noise emissions based on assumptions regarding types of noise-generating equipment and their emission levels, locations of their operations and environmental conditions ("Noise Emissions") and relies on third party data and information. The Client is solely responsibility for determining whether or not such assumptions and third party data and information are appropriate for the commercial purposes in which Client intends to use such Noise Emissions. JASCO disclaims any and all warranties and representations that any Noise Emissions used by Client based on such assumptions and third party data and information will be error free or be appropriate for Client's actual operation and Client acknowledges and agrees that it is solely liable and responsible for its reliance on such assumptions and third party data and information in any and all circumstances.

Contents

Figures

Tables

1. Introduction

Commercial shipping routes in the Salish Sea pass through important marine mammal habitat, including areas often used by an endangered population of Southern Resident Killer Whales (SRKW) (Fisheries and Oceans Canada 2011). Cumulative noise from vessels can negatively affect marine wildlife: elevated background noise reduces their effective communication and available foraging space, and chronic exposure to manmade noise could make whales avoid an area or otherwise change their normal behaviours (Tyack 2008). Managing the potential effects of commercial shipping noise requires an understanding of how different sources contribute to the underwater soundscape in the region. Model-based noise mapping provides an effective tool for assessing noise originating from large numbers of vessels at a regional scale (Erbe et al. 2012).

The Vancouver Fraser Port Authority (VFPA) has initiated the Enhancing Cetacean Habitat and Observation (ECHO) program which is “aimed at better understanding and managing the impact of cumulative shipping activities on at-risk whales throughout the southern coast of British Columbia” (Port of Vancouver 2016). To this end, the ECHO Advisory Working Group identified the following information requirements:

1. How much does the commercial vessel sector (e.g. commercial deep-sea vessels, passenger ferries, tugs) contribute to the underwater noise baseline in southern resident killer whale (SRKW) critical habitat?
2. Of the commercial vessel sector noise contribution, to what extent are the different vessel categories (ie. tugs vs. ferries) contributing to the underwater noise budget, and how does this differ by geographical sub-region?
3. How much do other different categories of vessel fleets (e.g. whale watch vessels, fishing boats, recreational vessels) respectively contribute to the underwater noise baseline in SRKW critical habitat?

To help answer these questions, JASCO has developed regional ocean noise contributors model, based on vessel tracking data from the Automated Identification System (AIS), to create cumulative noise maps for the Salish Sea. This model framework was used for the Roberts Bank Terminal 2 (RBT2) project Environmental Impact Statement (MacGillivray et al. 2014), but it has since been updated with expanded vessel categories and more recent vessel tracking data for 2015 to address the specific requirements of the ECHO program. The noise maps produced by the model have been broken down by vessel category (11 total) and by geographic sub-region (6 total) to estimate the contributions of different vessel categories to the underwater noise budget in the vessel noise contributors study area (Figure 1).

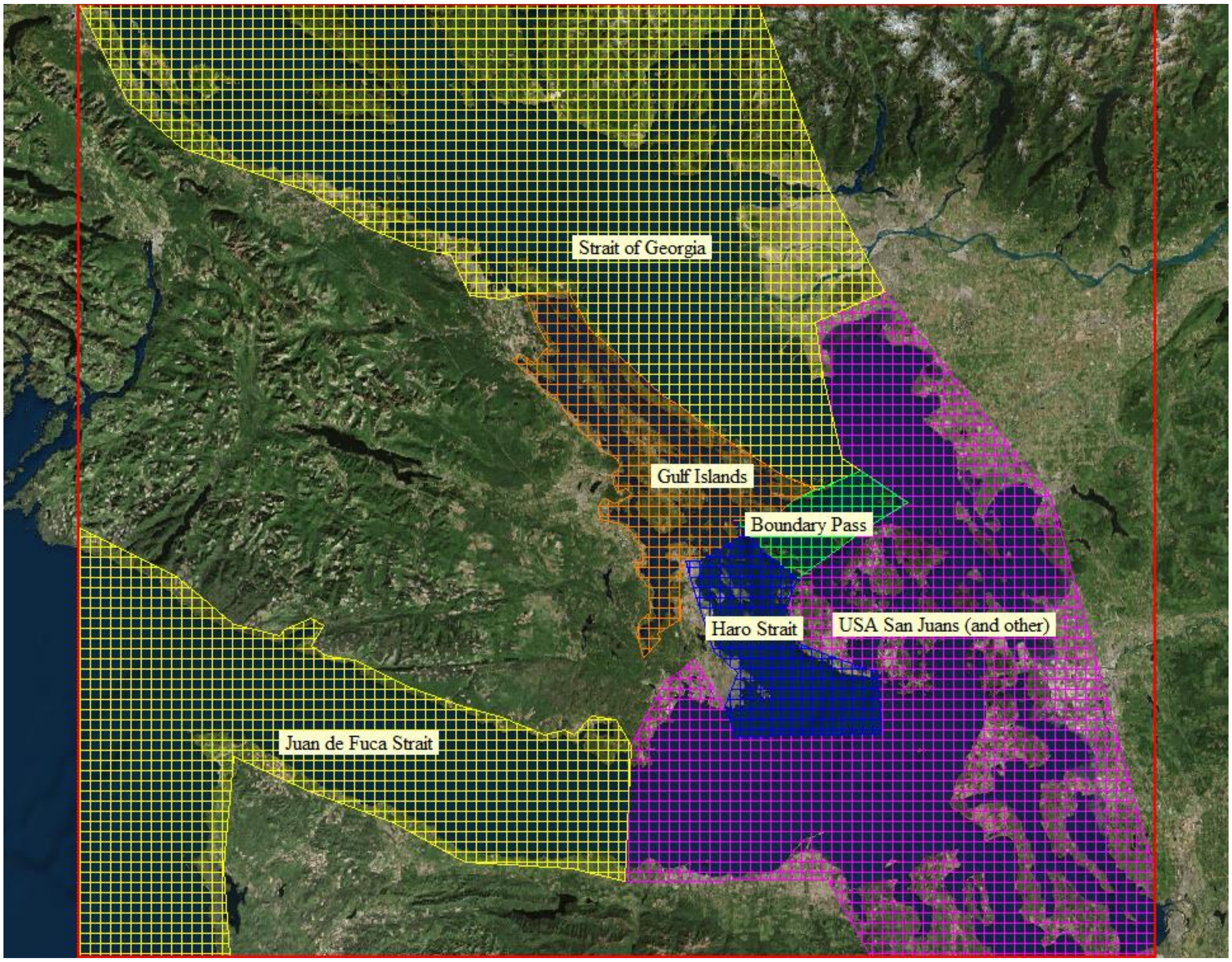

Figure 1. Vessel noise contributors study area (red box) and the six geographic sub-regions (hatched areas).

2. Model Description

The cumulative vessel noise model was developed by JASCO to map time-averaged noise levels generated by large numbers of vessels on a regional scale. The model synthesizes a number of data sources—including vessel tracking data, noise emission data, and environmental data—to produce noise maps for the study area (Figure 2).

The steps in the model calculation are as follows:

1. The model represents the region of interest on a computational grid (easting and northing) where the vessel density and speed is specified in each grid cell (Section 3.1).
2. For each category, the total vessel noise emitted in each grid cell is calculated according to the characteristic noise emissions, the total vessel time in each grid cell, and the mean vessel transit speed in each grid cell (Section 3.2).
3. The propagation of vessel noise to surrounding grid cells is calculated according to sound transmission curves, which are based on water depth, water column properties, and the seabed composition (Section 3.3).
4. The noise contributions from all vessel categories are summed together to calculate the cumulative noise in each grid cell.
5. The model generates maps of monthly-average sound levels (L_{eq}) for the study area, in decibels, broken down according to vessel category.

All model calculations are frequency-dependent, where the frequency range covers the hearing range of most marine mammals present in the study area (from 10 Hz to 64 000 Hz). This means the model outputs can be analyzed in terms of animal-specific hearing sensitivity (i.e., using audiogram weighting), however, for this study, the total broadband noise has not been weighted according to a specific marine mammal. More details about the development of the cumulative vessel noise model are provided in Section 2.1 of MacGillivray et al. (2014).

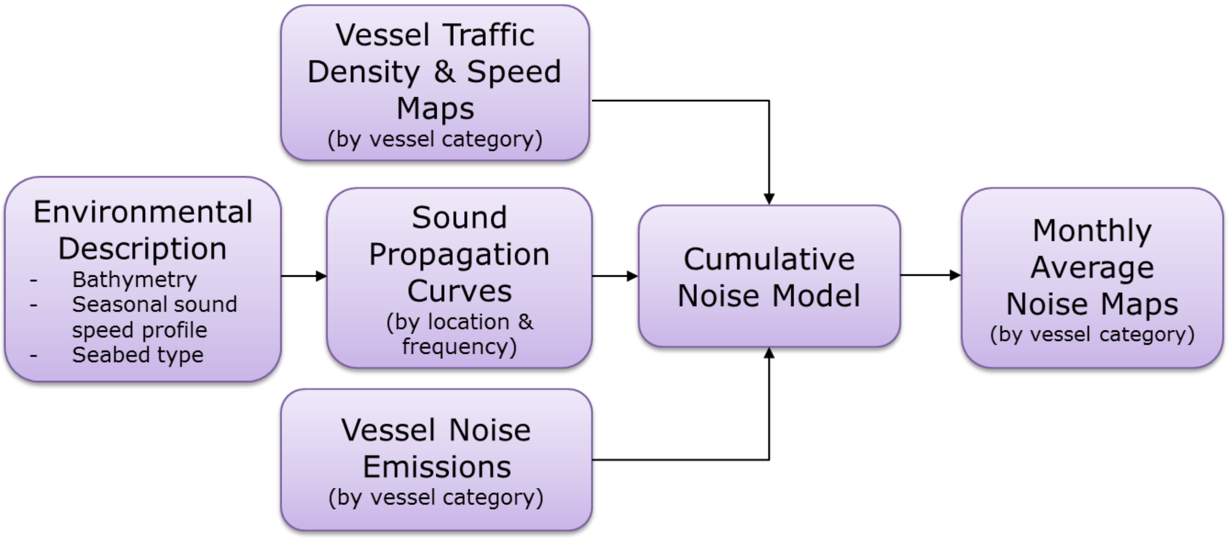

Figure 2. High-level flow chart of the regional vessel noise model.

3. Data Sources

3.1. Vessel Traffic

Historical vessel tracking data for the study area, for January and July of 2015, were obtained from the Marine Traffic AIS network (MarineTraffic.com). The raw data consisted of time-stamped position reports as well as other relevant vessel information (Table 1). The AIS dataset only included those vessels carrying AIS transceivers, and only moving vessels were included in the study. In Canada, federal regulations require every vessel of 500 deadweight tons or more to carry AIS, except fishing vessels. In practice, many smaller craft and fishing vessels also carry AIS for safety reasons. As such, the AIS dataset contained approximately 3 million position reports for the two months covered by this study (1.2 million for January and 1.8 million for July).

Table 1. Data fields included in the AIS dataset.

Field	Description
MMSI	A unique 9-digit vessel identifier
STATUS	Vessel status (under way, at anchor, moored, etc.)
SPEED	Speed over ground in knots
LON	Vessel longitude in degrees
LAT	Vessel latitude in degrees
COURSE	Vessel course in degrees
HEADING	Vessel heading in degrees
TIMESTAMP	Time of position report (UTC)
VESSEL_ TYPE	See Appendix A
NEXT_PORT	Destination of vessel
DRAUGHT	Vessel draught in metres
LENGTH	Vessel length in metres
DWT	Vessel tonnage in DWT

To generate the monthly traffic density and speed maps used in the model, individual vessels in the AIS dataset were divided into different categories according to their vessel type code (Appendix A). For each of these categories (except whale watch vessels), density and speed maps were calculated according to the following procedure:

1. Individual position reports were joined into contiguous tracks (i.e., sequences of consecutive position reports corresponding to vessel trips).
2. The tracks were overlaid onto an easting/northing grid (BC Albers projection) covering the study area. The dimensions of the grid were 208 km × 184 km and the individual grid cells were 800 m × 800 m.
3. A computational geometry algorithm was used to calculate the overlap between the vessel tracks and the grid cells.
4. Based on the overlap, the total vessel time and average vessel speed were calculated in each grid cell for each vessel category.

Traffic density and speed maps for the study area (Appendix B) were the primary inputs to the cumulative vessel noise model. The density maps for the individual vessel categories were summed to create maps of total AIS vessel traffic density for the study area in January and July (Figure 3).

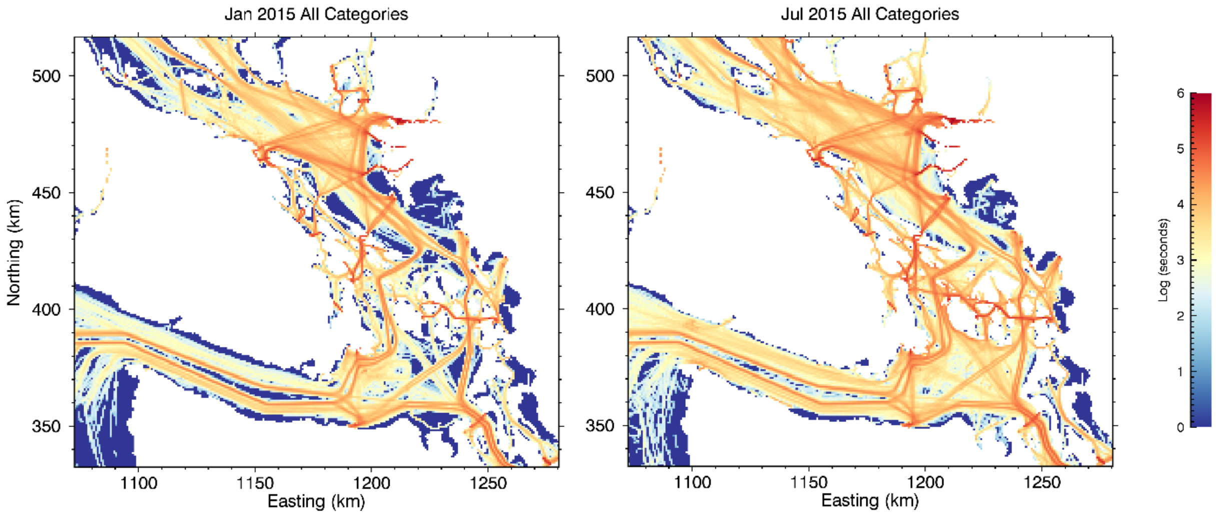

Figure 3. Total AIS vessel density (all categories except whale watch vessels) in the study area for January (left) and July (right). Maps show total vessel duration (seconds, log scale) per 800 m × 800 m grid cell on a logarithmic scale (BC Albers projection).

Traffic density and speeds for whale watch fleet in the Salish Sea were treated separately from other vessel categories because these predominantly small craft do not typically carry AIS transceivers, and were therefore assumed not to be represented in the AIS data. SMRU Consulting simulated traffic density for the Salish Sea whale watch fleet based on data from the Whale Museum's Soundwatch program (The Whale Museum 2016). The simulated whale watch traffic density was based on the number of vessels in the fleet, the average duration of their trips, the total number of trips per day, and the distribution of whales in the study area. Furthermore, it was assumed that whale watch vessels spend two thirds of their time transiting (at high speed) and one third of their time observing whales (at low speed). Appendix C provides further details about the methods used to simulate whale watch traffic density. Simulated traffic density maps were used to calculate the noise contribution of whale watch vessels in the model.

3.2. Vessel Noise Emissions

Different types of vessels have characteristic noise emissions because of their specific design and operating conditions. Propeller cavitation and hull-borne machine vibration are the predominant sources of underwater noise from vessels (Ross 1976). Vessels in this study were divided into fifteen source types, based on their class and size. Each source type was assigned a frequency-dependent source level curve that represented its characteristic noise emissions (Figure 4), which were used in the cumulative vessel noise model. These fifteen source level types were assigned to eleven different vessel categories (Table 2), where each category represented one sector's contribution to the regional noise budget[1].

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[1] These eleven category names appear capitalized (e.g., Tugs, Ferries, Container Ships, etc.) when referring to to the specific vessel category definitions used in the model (see Appendix A).

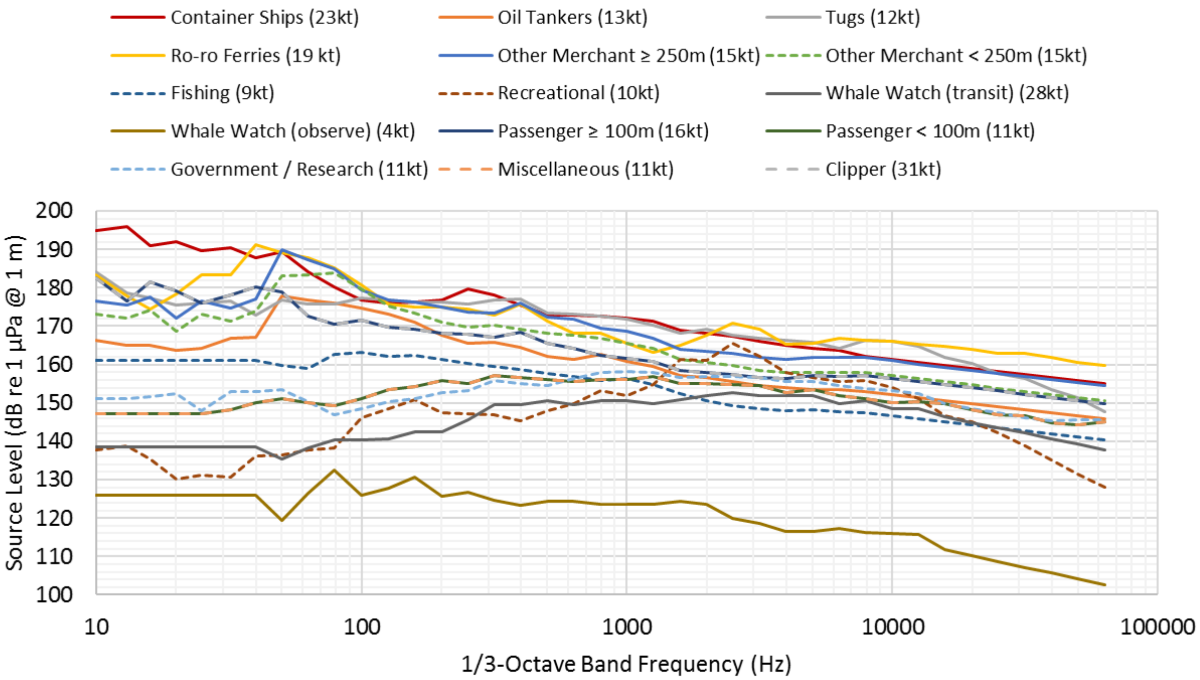

Figure 4. Frequency-dependent source levels (characteristic noise emissions) by vessel type in 1/3-octave bands. The reference speed (average transit speed) for each vessel type is indicated in the plot legend.

Table 2. Vessel categoriy definitions used for the noise contributors study. Some categories include source level subtypes, for vessels with distinct size, class, or operating conditions.

Vessel Category	Source Level Subtypes
Container Ships	n/a
Ferries	Ro-ro Ferries Clipper
Fishing	n/a
Government, Navy, and Research	n/a
Other Merchant Vessels	Other Merchant < 250 m Other Merchant ≥ 250 m
Passenger	Passenger < 100 m Passenger ≥ 100 m
Recreational	n/a
Oil Tankers	n/a
Tugs	n/a
Whale Watch	Transiting Observing
Miscellaneous	n/a

Source levels for most vessel types were based on measurements of representative vessels obtained in the study area. The majority of source level data were obtained from a collection of thousands of measurements collected by The Whale Museum and Beam Reach at their Lime Kiln hydrophone station, which is situated adjacent to the northbound international shipping lane in Haro Strait (Hemmera Envirochem Inc. et al. 2014). Gaps in the Lime Kiln data at very low frequencies (50 Hz and below) and very high frequencies (above 8000 Hz) were supplemented using data from past JASCO measurements and measurements from the published literature (see Table 2-2 in MacGillivray et al. (2014)). Source levels for two vessel types, roll-on/roll-off (ro-ro) passenger ferries and whale watch boats, were not represented in the Lime Kiln dataset, and so their characteristic noise emissions had to be obtained from other sources.

The Ferries category encompassed vessels from the following fleets: BC Ferries, Washington State Ferries, Blackball Line, Alaska Marine Highway Service, Clipper Line, and SeaSpan Ferries[2]. Source levels for ro-ro ferries were derived from dedicated source level measurements performed by JASCO at Roberts Bank near the Tsawassen Ferry terminal[3]. In addition, a special source level type was used for the Clipper Line, a passenger ferry service that travels between Victoria and Seattle. The high-speed jet catamarans in the Clipper fleet cannot be represented using ro-ro passenger ferry source levels. Instead, they were represented using passenger vessel (≥ 100 m) source levels from the Lime Kiln dataset[4], though they were classified under Ferries for the purpose of this study.

Source levels for the Whale Watch category were provided by Christine Erbe (Curtin University CMST) from a large collection of measurements of planing-hull vessels, which were collected in Haro Strait and Juan de Fuca Strait (Erbe 2002). Whale watch boats are unique, in that they operate in two very distinct speed regimes: travelling at high speed while transiting, and travelling at low speed while observing whales. Vessels in the Whale Watch category were therefore represented using separate source levels for these two operational regimes.

3.3. Noise Propagation

JASCO’s Marine Operations Noise Model (MONM) was used to simulate frequency-dependent sound transmission curves (i.e., transmission loss) for the study area. This model was previously validated via field tests using a controlled sound source at several different locations within the study area (Warner et al. 2014). The propagation model accounts for the different environmental factors that influence underwater sound propagation, which includes the temperature and salinity of the water, the water depth, and the seabed sediment type.

The sound transmission curves were based on a detailed description of the study environment. Different sound speed profiles were used for January and July, based on a collection of 130 temperaure and salinity profiles collected by Fisheries and Oceans Canada over the period 2006-2010 (Figure 5). Water depths in the study area were based on a high-resolution bathymetry map for the Salish Sea (Figure 6). Seabed sediment properties were defined for four different zones inside the study area (Figure 7). These environmental parameters were used to calculate a set of 80 frequency-and-range-dependent sound transmission curves, which represented noise propagation in different parts of the study area (Figure 8). These transmission curves were used to predict how vessel noise propagates in the cumulative vessel noise model[5].

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[2] Only ro-ro vessels from the SeaSpan fleet were included under Ferries. Articulated tug and barge vessels from the SeaSpan fleet were assigned to the Tug category.

[3] Ferry source levels were based on the average of 9 independent measurements of two different ro-ro passenger ferries (140 m and 160 m length) transiting along the Tsawassen-Duke Point route (Mouy et al. 2012, Appendix B).

[4] This assignment was based on the magnitude of measured Clipper source levels, as reported in Bassett et al. (2012) and Veirs et al. (2016), rather than vessel size.

[5] Range-dependent propagation between locations with different transmission loss curves was calculated according to the method described in Section 2.1.9 of MacGillivray et al. (2014).

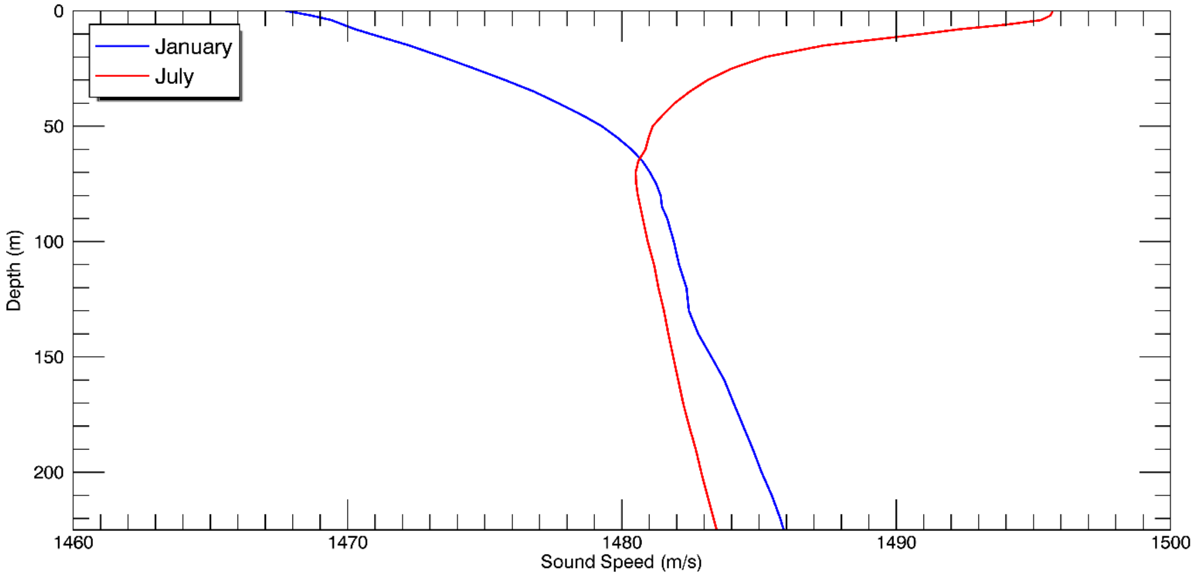

Figure 5. Mean sound speed profiles for the study area, based on historical ocean temperature and salinity profiles for January and July from Fisheries and Oceans Canada (DFO).

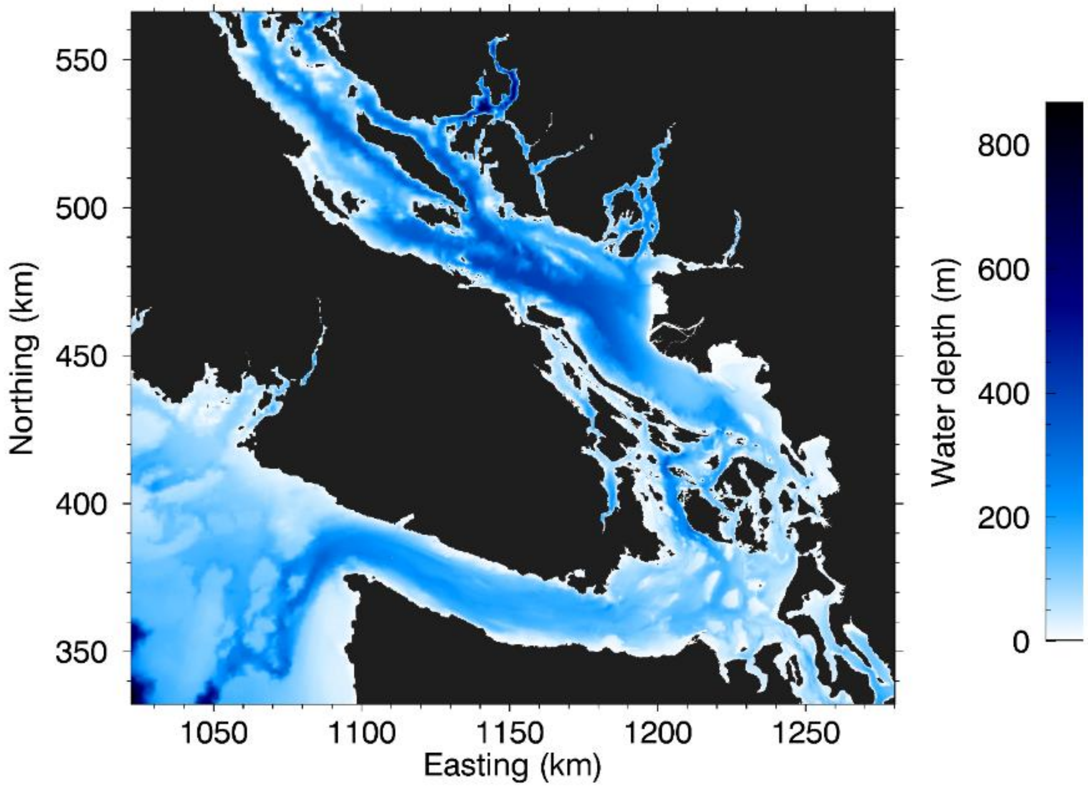

Figure 6. Map of water depths for the study area (BC Albers projection).

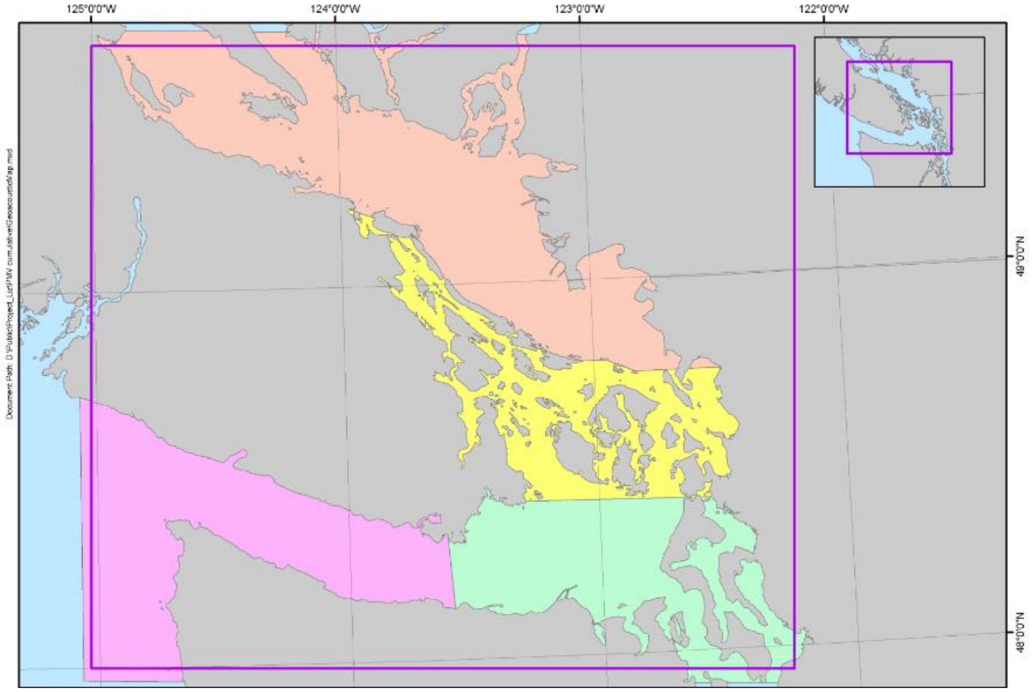

Figure 7. Map showing the four zones with different seabed sediment types used for defining sound propagation in the model. Clockwise from the top, they are as follows: Georgia Strait, Gulf & San Juan Islands, East Juan de Fuca Strait, and West Juan de Fuca Strait. For more details on seabed sediment types see Section 2.1.5 in MacGillivray et al. (2014).

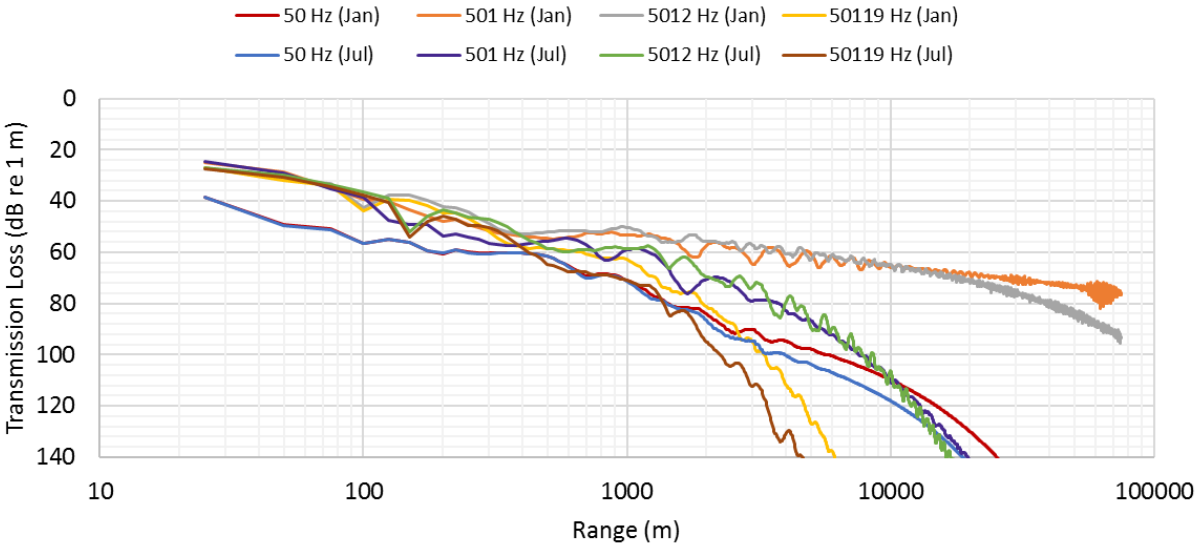

Figure 8. Examples of frequency-dependent sound transmission curves in Georgia Strait for January and July, as calculated by JASCO's Marine Operations Noise Model (MONM). The modelled receiver depth is 10 m, which is near the sea surface, since marine mammals spend most of their time in this zone. Differences between long-range sound propagation in January and July are due to seasonal differences in the sound speed profile (see Figure 5).

4. Noise Contributors Analysis

The objective of the noise contributors analysis was to break down the regional vessel noise model into a budget that shows the relative contribution of each vessel category to the total noise in the study area. The preferred “currency” for calculating a noise budget is the average sound intensity (NRC 2003) which, for long-term time averages, is proportional to the mean squared sound pressure (Miller et al. 2008). For large numbers of distributed sound sources, mean squared sound pressure is strictly an additive quantity and is therefore suitable for calculating a noise budget. Following this convention, the noise budget for the current study has been broken down in terms of the mean squared sound pressure contributed by each vessel category[6]. The resulting noise budgets are presented as pie charts, which show how each category contributed over the study area as a whole and within six geographic sub-regions (Section 5).

The noise budgets calculated in the present study only include contributions from vessels. Other sources of ocean noise, such as wind and waves, precipitation, and biological sources, are not included in the noise budget. Past measurements suggest that vessels are the overwhelming (> 99%) source of underwater noise in the Salish Sea (Bassett et al. 2012). This study presents total vessel noise in terms of unweighted broadband SPLs, which are a direct measure of physical sound pressure. They can be understood as the raw sound levels that would be measured by a calibrated acoustic sensor. By definition, they have not been weighted according to the hearing sensitivity of any marine animal.

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[6] Note that sound pressure level, in decibels, represents mean squared sound pressure on a logarithmic scale, so the two quantities are directly related. See glossary for details.

5. Model Results

The cumulative vessel noise model was used to create maps of mean noise levels in the study area for January and July (Figure 9), based on the combined 2015 Marine Traffic AIS dataset (Appendix B) and the Soundwatch whale watch traffic dataset (Appendix C). These maps represent the total time-averaged noise levels in the study area from all vessel categories captured by the model in a single month. Ferry routes and international shipping lanes appear as areas with higher sound levels on the noise maps. Outside the main traffic routes, differences between the January and July noise maps are mostly due to seasonal differences in the sound transmission curves rather than seasonal differences in the vessel traffic density (see Section 3.3).

For the noise budget calculation, the maps were broken down into individual vessel layers containing each vessel category's unique noise contribution to the total. The noise contributions from the different vessel categories were compared in terms of their total average sound pressure level for each month (Figure 10). Sound pressure levels provide a useful method to compare the categories since the logarithmic (decibel) scale is a standard quantity for reporting acoustic measurements, and is related to hearing perception. Nonetheless, it is for this same reason that sound pressure levels are not well suited to breaking down a noise budget: decibels are not strictly an additive quantity (see Section 4). Therefore, the relative noise contribution of each category, as a percentage of the total, was computed from the individual layers according to their mean squared sound pressure contributions over each of the six sub-regions (Table 3 and Table 4). Noise pie charts were also created for the six sub-regions: these were rendered as maps (Figure 11 and Figure 12) and as individual charts (Appendix D).

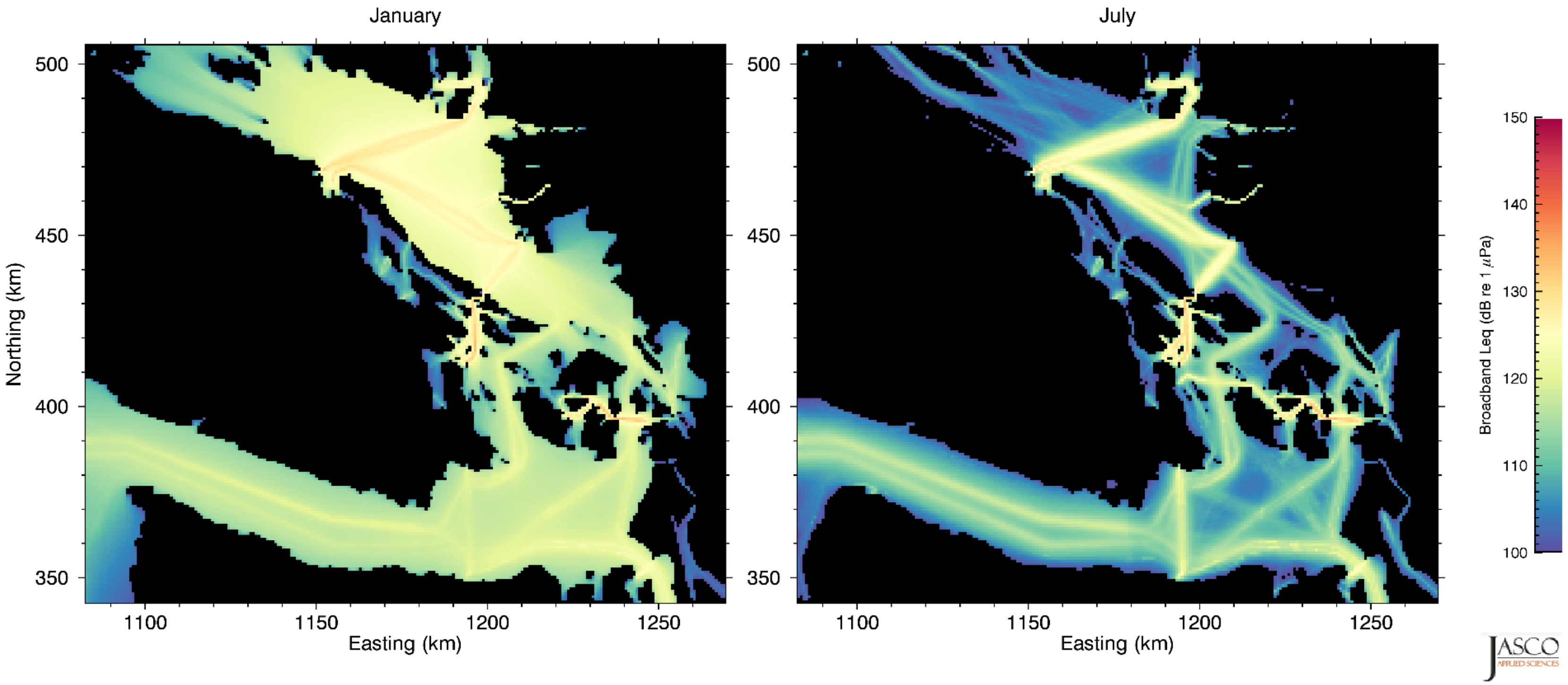

Figure 9. Monthly average sound pressure level (L_{eq}) for January (left) and July (right) as calculated by the cumulative vessel noise model (BC Albers projection). The L_{eq} is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

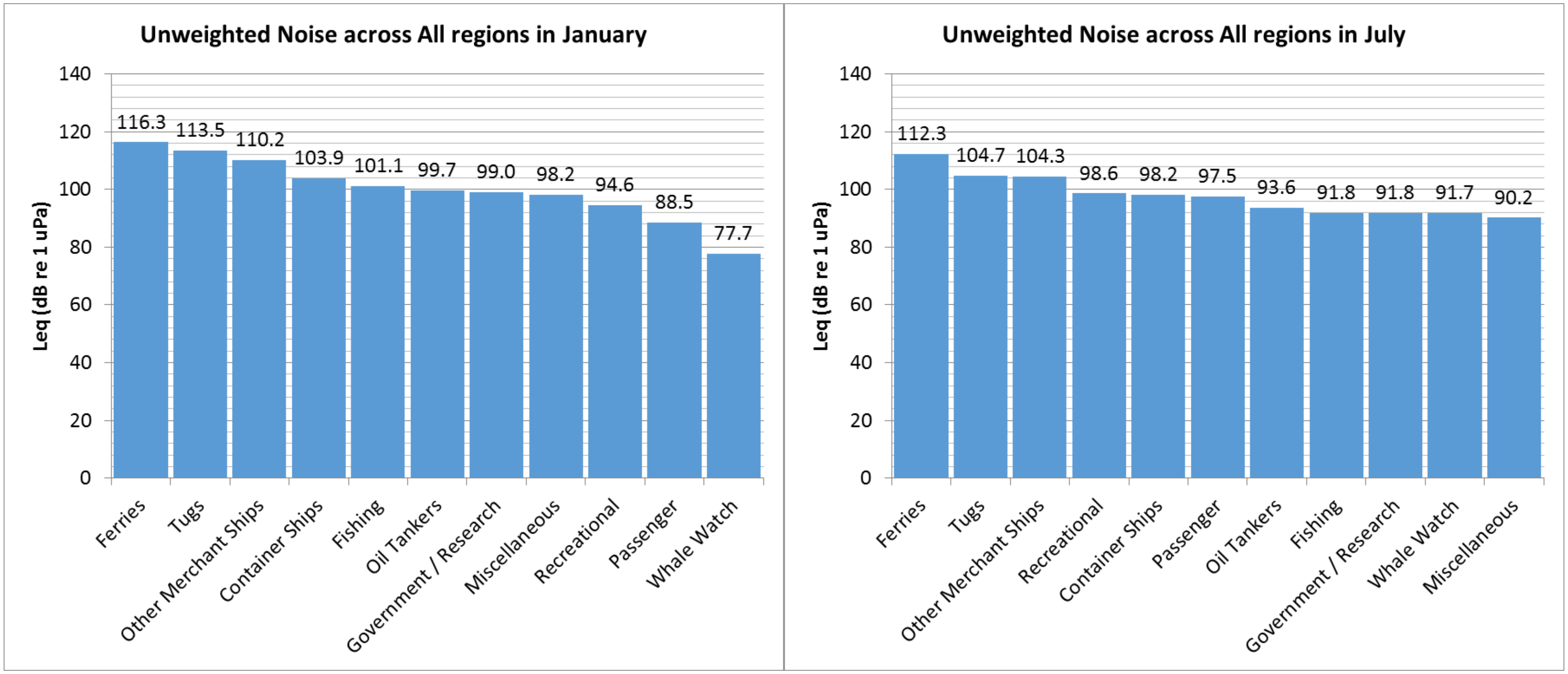

Figure 10. Bar charts showing the mean sound pressure level from each vessel category across all regions for January (left) and July (right) Each bar represents the average sound pressure level (linear mean) across the entire study area from all vessels in a particular category. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

Table 3. Relative noise contribution, by vessel category, sub-region and region, for January. Percentages are the proportion of the total mean squared sound pressure attributed to all vessels in each category over the specified region. The total mean squared sound pressure is also listed for each sub-region, as well as the region as a whole. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

January	**Regional Average**	**Sub-regions**					
		Haro Strait	**Boundary Pass**	**Gulf Islands**	**Strait of Georgia**	**San Juans and Other**	**Strait of Juan de Fuca**
Average total mean squared sound pressure (kPa²)	**0.82**	**0.54**	**0.47**	**0.80**	**1.48**	**0.59**	**0.33**
Container Ships	3.0%	10.7%	10.8%	0.3%	0.8%	6.3%	7.4%
Ferries	52.3%	5.3%	15.4%	88.4%	70.6%	27.5%	0.3%
Fishing	1.6%	1.8%	0.6%	0.2%	0.7%	2.6%	5.2%
Government / Research	1.0%	3.5%	1.8%	0.9%	0.6%	1.5%	1.2%
Other Merchant Ships	12.6%	41.0%	45.9%	1.9%	4.3%	16.1%	46.4%
Miscellaneous	0.8%	1.5%	0.4%	0.3%	0.2%	2.1%	1.4%
Passenger	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%
Recreational	0.4%	1.5%	0.9%	0.2%	0.2%	0.7%	0.4%
Oil Tankers	1.2%	2.1%	1.6%	0.0%	0.2%	1.5%	6.2%
Tugs	27.1%	32.4%	22.5%	8.0%	22.4%	41.5%	31.5%
Whale Watch	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 4. Relative noise contribution, by vessel category, sub-region and region, for July. Percentages are the proportion of the total mean squared sound pressure attributed to all vessels in each category over the specified region. The total mean squared sound pressure is also listed for each sub-region, as well as the region as a whole. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

July	Regional Average	Sub-regions					
		Haro Strait	Boundary Pass	Gulf Islands	Strait of Georgia	San Juans and Other	Strait of Juan de Fuca
Average total mean squared sound pressure (kPa²)	**0.25**	**0.20**	**0.14**	**0.73**	**0.32**	**0.24**	**0.12**
Container Ships	2.6%	7.9%	13.2%	0.1%	0.4%	3.5%	8.6%
Ferries	66.9%	27.8%	8.2%	94.7%	88.6%	57.9%	0.0%
Fishing	0.6%	1.4%	0.6%	0.2%	0.1%	0.4%	2.7%
Government / Research	0.6%	1.6%	1.3%	0.4%	0.3%	0.9%	0.7%
Other Merchant Ships	10.6%	34.2%	53.8%	0.3%	1.8%	7.9%	48.0%
Miscellaneous	0.4%	0.5%	1.6%	0.1%	0.1%	1.0%	0.3%
Passenger	2.2%	1.5%	1.0%	0.0%	0.3%	2.3%	11.0%
Recreational	2.8%	10.0%	8.5%	1.6%	1.2%	5.2%	1.8%
Oil Tankers	0.9%	1.0%	1.4%	0.0%	0.0%	0.7%	5.3%
Tugs	11.7%	9.5%	8.1%	2.5%	7.2%	19.2%	21.0%
Whale Watch	0.6%	4.6%	2.4%	0.2%	0.1%	1.0%	0.5%

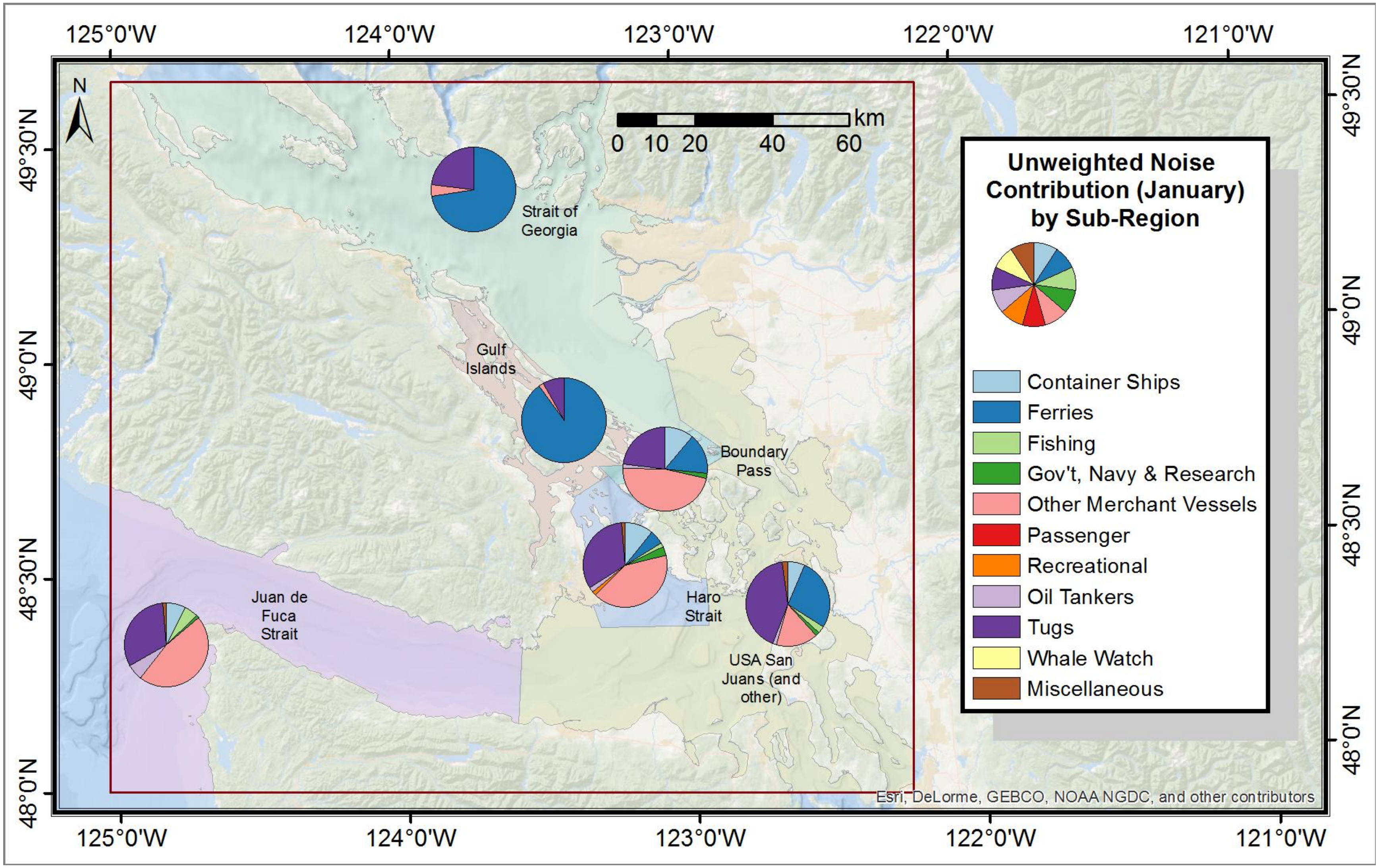

Figure 11. Map showing the relative noise contribution of all vessels in each category, broken down by sub-region, for January. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

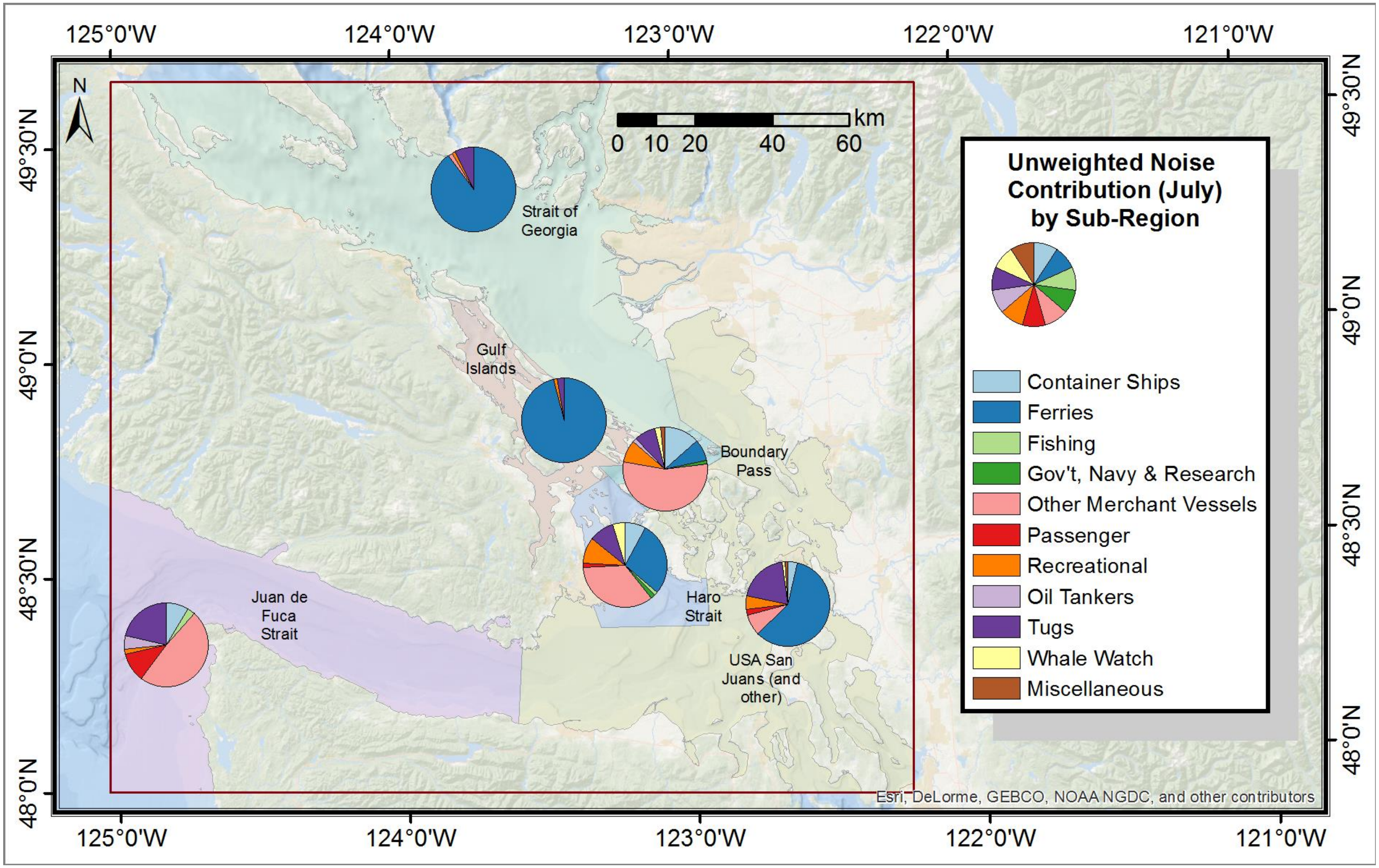

Figure 12. Map showing the relative noise contribution of all vessels in each category, broken down by sub-region, for July. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

6. Discussion

6.1. Vessel Noise Contributors

The model results show that, while many different vessel sectors contribute to ocean noise in the study area, the commercial vessel sector is the dominant source throughout the region. Nonetheless, categories for smaller craft (Recreational, Fishing, Whale Watch) make an important contribution in certain sub-regions, such as Haro Strait and the San Juan Islands, where these vessels congregate in greater numbers. Ultimately, because large commercial vessels have much higher noise emissions than smaller craft, their total contribution is greater.

Ferries make a relatively large contribution to regional ocean noise because they make frequent trips and their routes are widely distributed throughout the study area. As expected, their greatest contributions are in those sub-regions containing the most frequently-travelled inter-island routes (Georgia Strait, Gulf Islands, and San Juan Island). Similarly, Tugs make a relatively large contribution to regional ocean noise due to the substantial volume of tug traffic in the study area. This category has the greatest total number of vessel hours of all the vessel categories in the AIS dataset (Figure 13). The noise contribution of Tugs is widely distributed across all sub-regions in the study area, over both seasons. The merchant vessel categories (Container Ships, Oil Tankers, Other Merchant Ships) make a relatively large contribution, but it is focused in those sub-regions intersecting the international shipping routes.

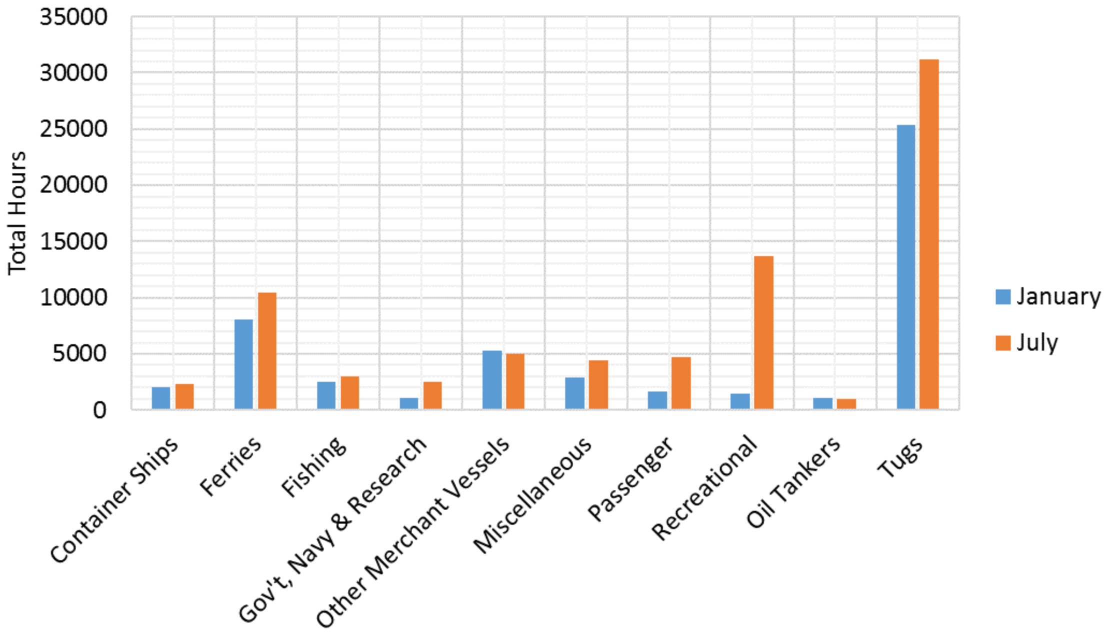

Figure 13. Total AIS vessel hours in the study area, by category, for January and July. Whale watch vessels are not shown, as they were not part of the AIS dataset (see Appendix C).

Most of the vessel categories captured by the model exhibit a seasonal component, with more traffic present in summer than in winter. The most significant seasonal variations are in the Recreational, Whale Watch, and Passenger categories, which have substantially more activity in July than in January. Ferry traffic volume is also seasonal to a smaller extent, which is why the Ferries contribution is greater in July than January. In contrast, traffic volumes in the Merchant, Container, and Tanker vessel categories do not increase substantially in summer, which is why their relative noise contributions appear to decrease in July. Nonetheless, overall noise levels in the region are higher in January, despite the lower traffic density, due to oceanographic conditions that favour long-range sound propagation in winter (see Figure 8).

6.2. Sources of Uncertainty

While the cumulative vessel noise model applied in this study is based on the best available data at the time of writing, some data gaps must be acknowledged when interpreting the results.

The most important data gap is regarding the proportion of vessels in the Recreational and Fishing categories that are represented in the AIS dataset. Despite the fact they are not required to do so, a large number of vessels in both these categories did in fact transmit on AIS (Figure 14) and were thus captured in the Marine Traffic database. In particular, the Recreational category contained the largest number of unique vessels, even though most vessels in this category were under 30 m in length. Adjusting the contribution of the Recreational and Fishing categories to correct for the proportion of these fleet that are not sampled by AIS would require an independent (non-AIS) count of absolute number of vessel trips per month in these categories. At the time of writing, however, no known data source could be identified that provides this information for study area.

While two previous (non-AIS) studies of recreational boating traffic volumes have been conducted in the Salish Sea, neither was suitable for independently estimating the overall size of the recreational fleet in the study area. In one study, vessel track data was gathered via face-to-face surveys with recreational boaters between June and September 2007, at six sampling sites throughout the Gulf Islands, with each site being sampled for eight days (Gray et al. 2011). In the other study, boat positions in the San Juan Islands were recorded via aerial surveys, two times per day, over 19 days between June and September 2010 (Dismukes et al. 2010). In both cases, the sampling was too limited to be able to infer from the results the overall quantity of the recreational boating fleet traffic in the focus areas. For fishing vessels, no publicly available data were found detailing the size of the Salish Sea fleet. It is possible that the size of the combined U.S. and Canadian fishing fleets could be estimated from fisheries licensing and landing statistics for the study area (e.g., from Fisheries and Oceans Canada and NOAA Fisheries), but this is a data mining exercise that is well outside the scope of the current study. Thus, it is likely that the present study underestimates the overall contribution of the Recreational and Fisheries categories. It is nonetheless highly unlikely their ocean noise contribution would exceed that of larger commercial vessels in the study area as a whole because these categories consist mainly of small vessels which have much lower noise emissions.

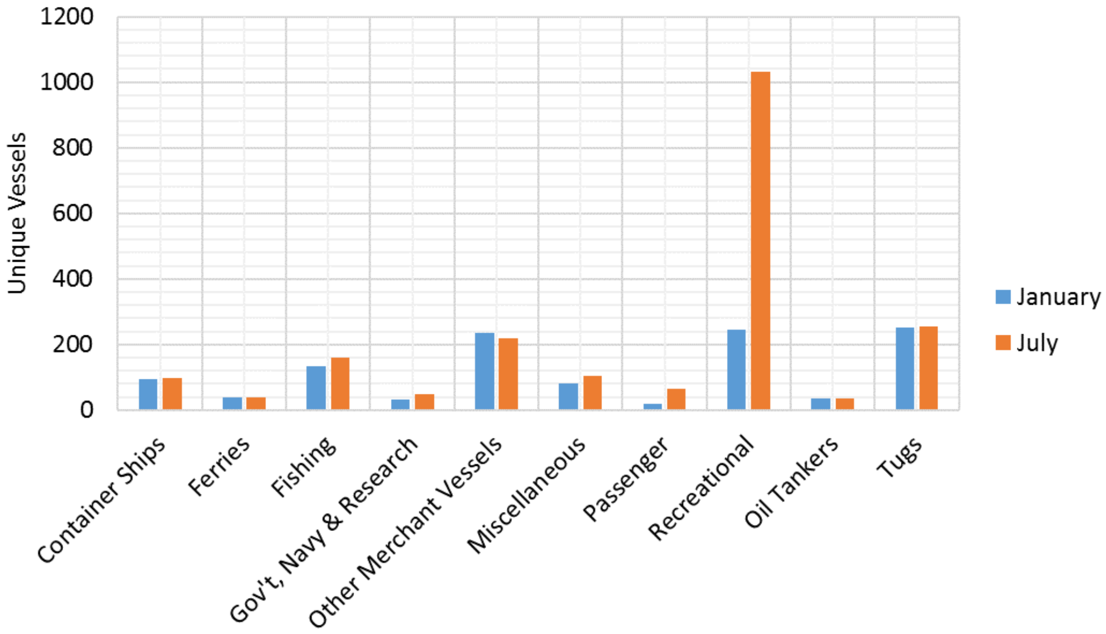

Figure 14. The number of unique AIS vessels in each category, for January and July. Whale watch vessels are not shown, as they were not part of the AIS dataset (see Appendix C).

Another source of uncertainty is related to gaps in the vessel noise emissions data collected at Lime Kiln. Ferries were not present in the Lime Kiln dataset, due to the fixed location of the hydrophone near the international shipping lanes. Instead, noise emissions for ferries were based on long-term hydrophone data collected from regular passes of two large roll-on/roll-off ferries on the Tsawassen-Duke Point ferry route. It is not known whether source levels of ferries along this route are representative of the broader regional ferries fleet. Nonetheless, ferries undoubtedly contribute a large amount of noise in the study area, due both to their size (average length 109 m) and the large number of monthly ferry trips, so the magnitude of their contribution in the model is likely correct. In addition, some vessel categories (for example Miscellaneous, and Government, Naval & Research) contained a mixture of vessel sizes and types, ranging from the very small (under 10 m) to the very large (over 200 m), which are not likely to be well represented using an average source level. Nonetheless, the total amount of traffic in these categories is small so the resulting error is likely also small. A final limitation of the Lime Kiln data is related to gaps in the measurements at low (50 Hz and below) and high (10 000 Hz and above) frequencies, caused by the distance (2.5 km) of the Lime Kiln hydrophone from the northbound shipping lanes. Future measurements collected at shorter range on the ECHO project’s underwater listening station in Georgia Strait could be used to fill in data gaps related to vessel source levels in the study area.

7. Conclusion

In summary, this study has developed a noise budget for the Salish Sea based on a model of cumulative vessel noise for the region. The model applied in this study takes regional, AIS-based vessel traffic data and whale watch vessel traffic data and propagates their noise emissions through the ocean environment to map the long-term cumulative distribution of vessel noise throughout the study area. The cumulative vessel noise maps were split into 11 categories to produce relative noise budgets for the entire region and also across six different sub-regions covering areas of critical Southern Resident Killer Whale (SRKW) habitat.

The results of this study indicate that vessels from the commercial sector (ferries, tugs, commercial deep-sea vessels) contribute the most underwater noise in the region. The noise contributions of other sectors (fishing, whale watching, recreational craft) are smaller, tend to be focused in specific sub-regions and have a strong seasonal component. Nonetheless, the localized noise contribution from smaller vessels may be important in critical habitat areas where their presence overlaps high-use areas for SRKW. Results from this study could be used to inform potential future noise mitigation efforts for different vessel sectors that operate in the region.

8. Acknowledgements

Editorial review of this report was provided by Katherine Williams (JASCO). Whale watch traffic density data for the study area was provided by Jason Wood (SMRU Consulting). The category assignments for vessels in the AIS dataset were developed in consultation with Jeffrey Pelton (Vancouver Fraser Port Authority, Operations). Orla Robinson (Vancouver Fraser Port Authority, ECHO Program) and Krista Trounce (Vancouver Fraser Port Authority, ECHO Program) provided many helpful comments and suggestions that were incorporated into this work.

Glossary

1/3-octave-band
Standard, non-overlapping frequency bands approximately one-third of an octave wide (see octave). Standard 1/3-octave band centre frequencies (f_c) are given by the formula $f_c = 10^{n/10}$ where n is an integer. Measured in the unit Hz.

automated identification system (AIS)
A radio-based tracking system whereby vessels regularly broadcast their identity, location, speed, heading, dimensions, class, and other information to nearby receivers.

broadband sound level
The total sound pressure level over the entire modelled or measured frequency range.

BC Albers
A standard map projection that is used by the province of British Columbia for representing spatial information with minimal distortion.

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

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

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

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

hydrophone
An underwater sound pressure transducer. A passive electronic device for recording or listening to underwater sound.

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

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

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

sound intensity
Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

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

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

$$\mathrm{SPL} = 10\log_{10}\left(p^2/p_0^2\right) = 20\log_{10}\left(p/p_0\right)$$

Unless otherwise stated, SPL refers to the root-mean-square sound pressure level (rms SPL).

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

source level (SL)
The sound pressure level at 1 meter distance from a theoretical point source that radiates the same total sound power as the actual source. Unit: dB re 1 µPa @ 1 m.

time-averaged sound level (Leq)
The decibel level of the mean square sound pressure over a specified time period.

transmission loss (TL)
The decibel reduction in sound level between a source and a receiver that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also called propagation loss. Measured in units dB re 1 m.

unweighted
Refers to a sound pressure level that has not been weighted according to the hearing sensitivity of any organism (i.e., raw SPL).

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Appendix A. AIS Vessel Category Assignments

The following table shows how vessel type codes from the Marine Traffic AIS dataset (left) were assigned to the vessel categories in the regional noise contributors model (right). Note that Clipper Line vessels travelling the Victoria-Seattle route, and roll-on/roll-off vessels in the Seaspan Ferries fleet were manually assigned to the Ferry category. Sailing vessels were excluded from the Recreational vessel category and were not included in the model (i.e., they were assumed not to be under power).

VESSEL_TYPE	Model Category
Cargo/Containership	Container
Container Ship	Container
Ro-Ro/Passenger Ship	Ferry
Factory Trawler	Fishing
Fish Carrier	Fishing
Fish Factory	Fishing
Fishing	Fishing
Fishing Vessel	Fishing
Trawler	Fishing
Buoy-Laying Vessel	Government
Fishery Patrol Vessel	Government
Fishery Research Vessel	Government
Law Enforce	Government
Logistics Naval Vessel	Government
Military Ops	Government
Patrol Vessel	Government
Replenishment Vessel	Government
Research/Survey Vessel	Government
Bulk Carrier	Merchant
Cargo	Merchant
Cargo - Hazard A (Major)	Merchant
Chemical Tanker	Merchant
General Cargo	Merchant
LPG Tanker	Merchant
Rail/Vehicles Carrier	Merchant
Reefer	Merchant
Ro-Ro Cargo	Merchant
Ro-Ro/Container Carrier	Merchant
Self Discharging Bulk Carrier	Merchant
Timber Carrier	Merchant
Vehicles Carrier	Merchant
Wood Chips Carrier	Merchant
Anti-Pollution	Miscellaneous

VESSEL_TYPE	Model Category
Cable Layer	Miscellaneous
Dive Vessel	Miscellaneous
Drill Ship	Miscellaneous
Heavy Lift Vessel	Miscellaneous
High Speed Craft	Miscellaneous
Hopper Dredger	Miscellaneous
Local Vessel	Miscellaneous
Other	Miscellaneous
Pilot Vessel	Miscellaneous
Port Tender	Miscellaneous
Reserved	Miscellaneous
SAR	Miscellaneous
Tender	Miscellaneous
Unspecified	Miscellaneous
Wing In Grnd	Miscellaneous
Passenger	Passenger
Passengers Ship	Passenger
Pleasure Craft	Recreational
Yacht	Recreational
Crude Oil Tanker	Tanker
Oil Products Tanker	Tanker
Oil/Chemical Tanker	Tanker
Tanker	Tanker
Anchor Handling Vessel	Tug
Fire Fighting Vessel	Tug
Multi Purpose Offshore Vessel	Tug
Offshore Supply Ship	Tug
Pollution Control Vessel	Tug
Pusher Tug	Tug
Towing Vessel	Tug
Tug	Tug

Appendix B. AIS Shipping Traffic Layers

The following figures show maps of shipping density (total seconds, log scale in the left hand images) and mean transit speed (in the right hand images) in January and July for the study area for all vessel categories, as calculated from the Marine Traffic AIS dataset. Density and speed values are given per 800 m × 800 m grid cell. The month and category (or sub-category) for each map is indicated in the plot title. Maps for January are presented first, followed by maps for July.

Vessels in the Seaspan fleet were captured in separate density and speed maps (SeaspanRoro and SeaspanTugs) because their categories designations had to be manually assigned based on MMSI rather than AIS vessel type code. Their noise contribution was included in the Ferries and Tug categories, respectively. The Whale Watch category was not included in the AIS dataset—density maps for this category are shown in Appendix C.

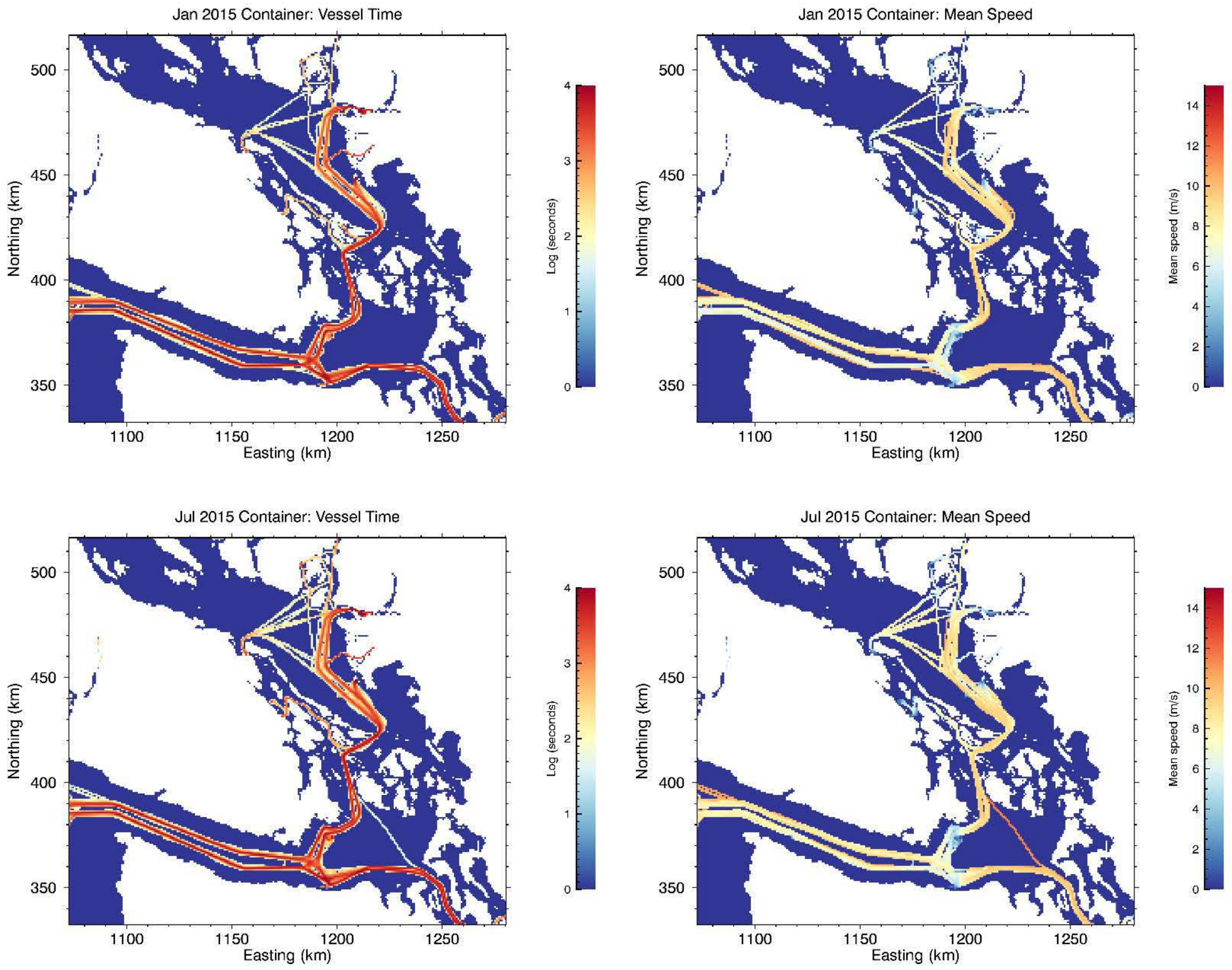

Figure B-1. Container category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

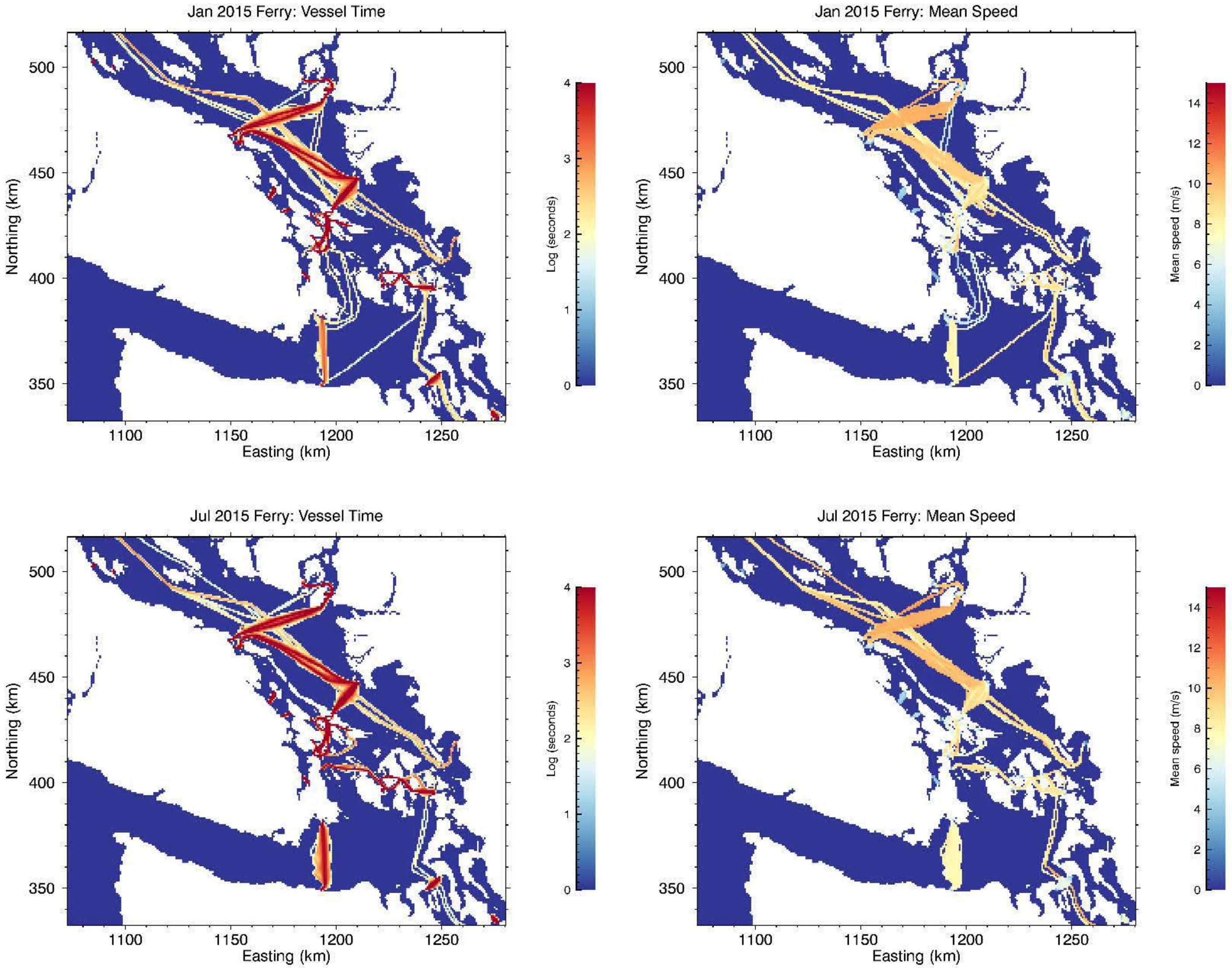

Figure B-2. Ferry category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

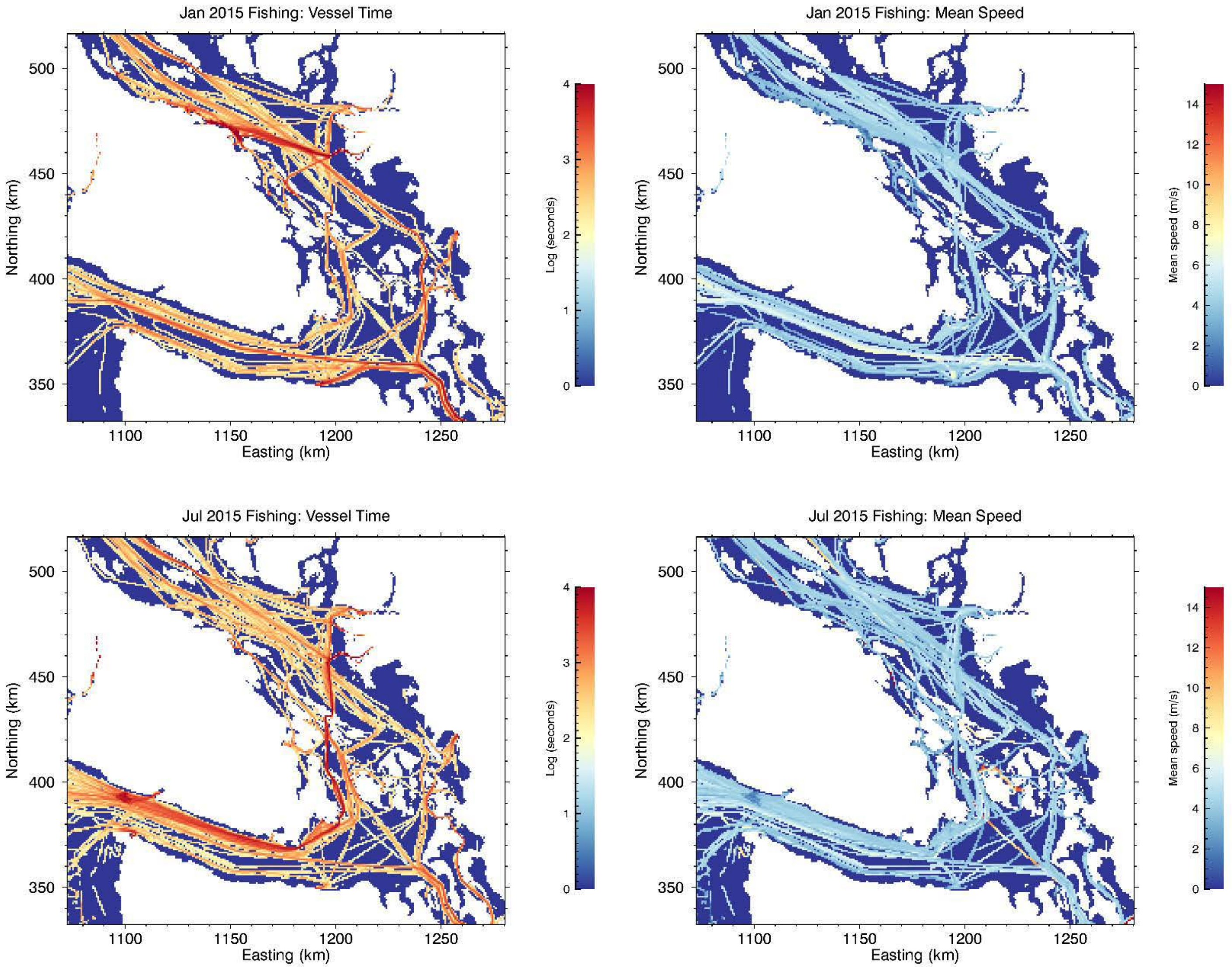

Figure B-3. Fishing category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

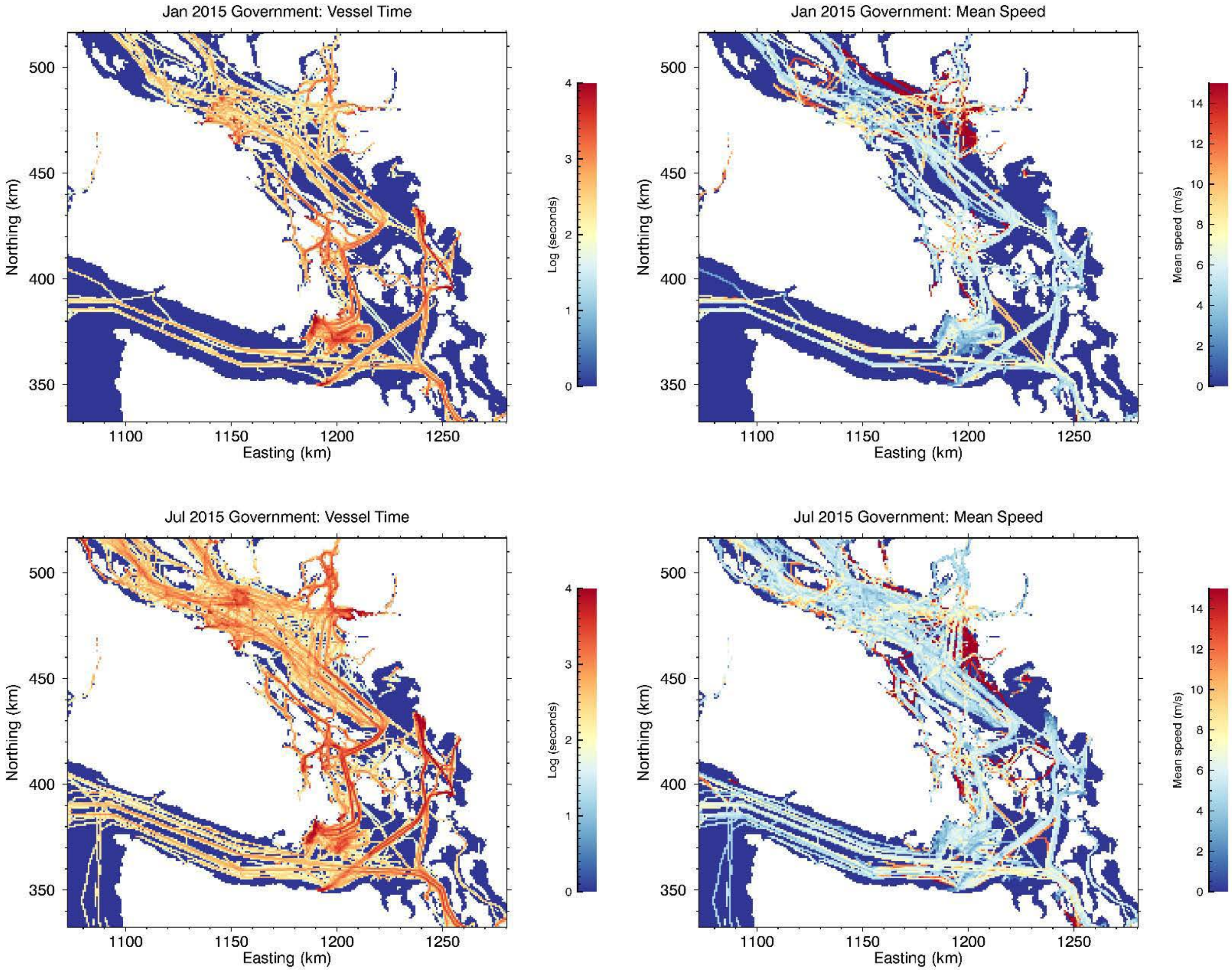

Figure B-4. Government category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

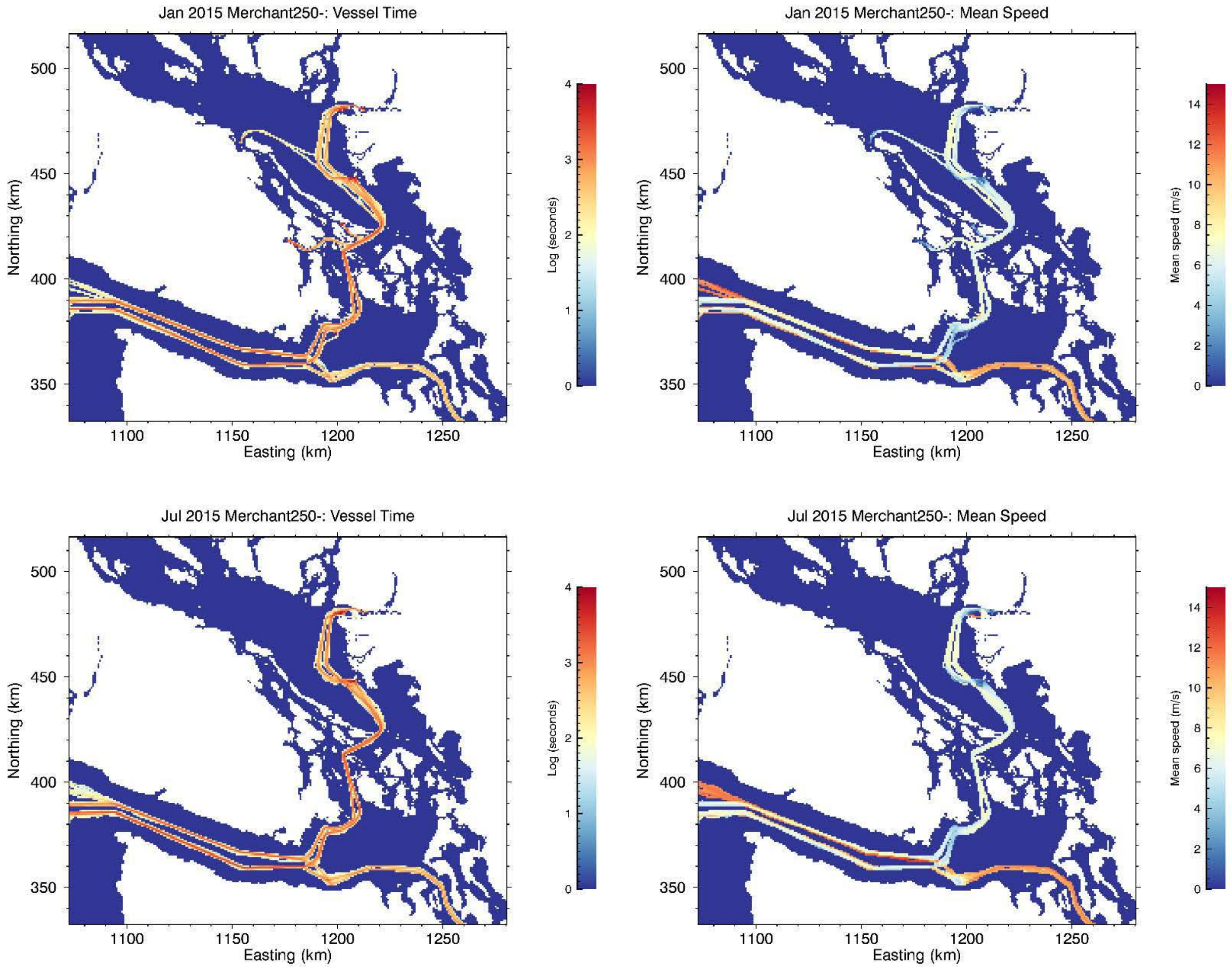

Figure B-5. Merchant (< 250 m) category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

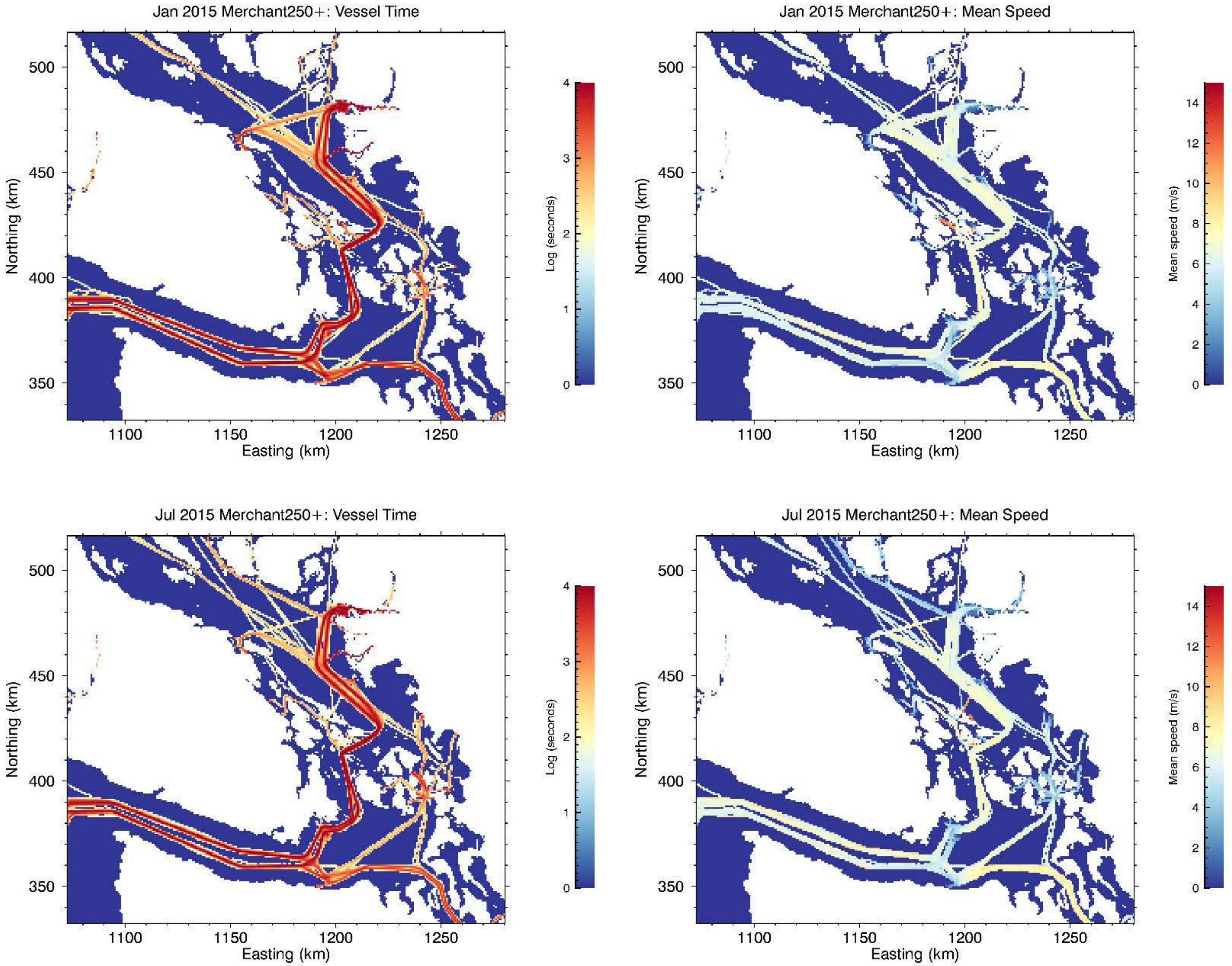

Figure B-6. Merchant (≥ 250 m) category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

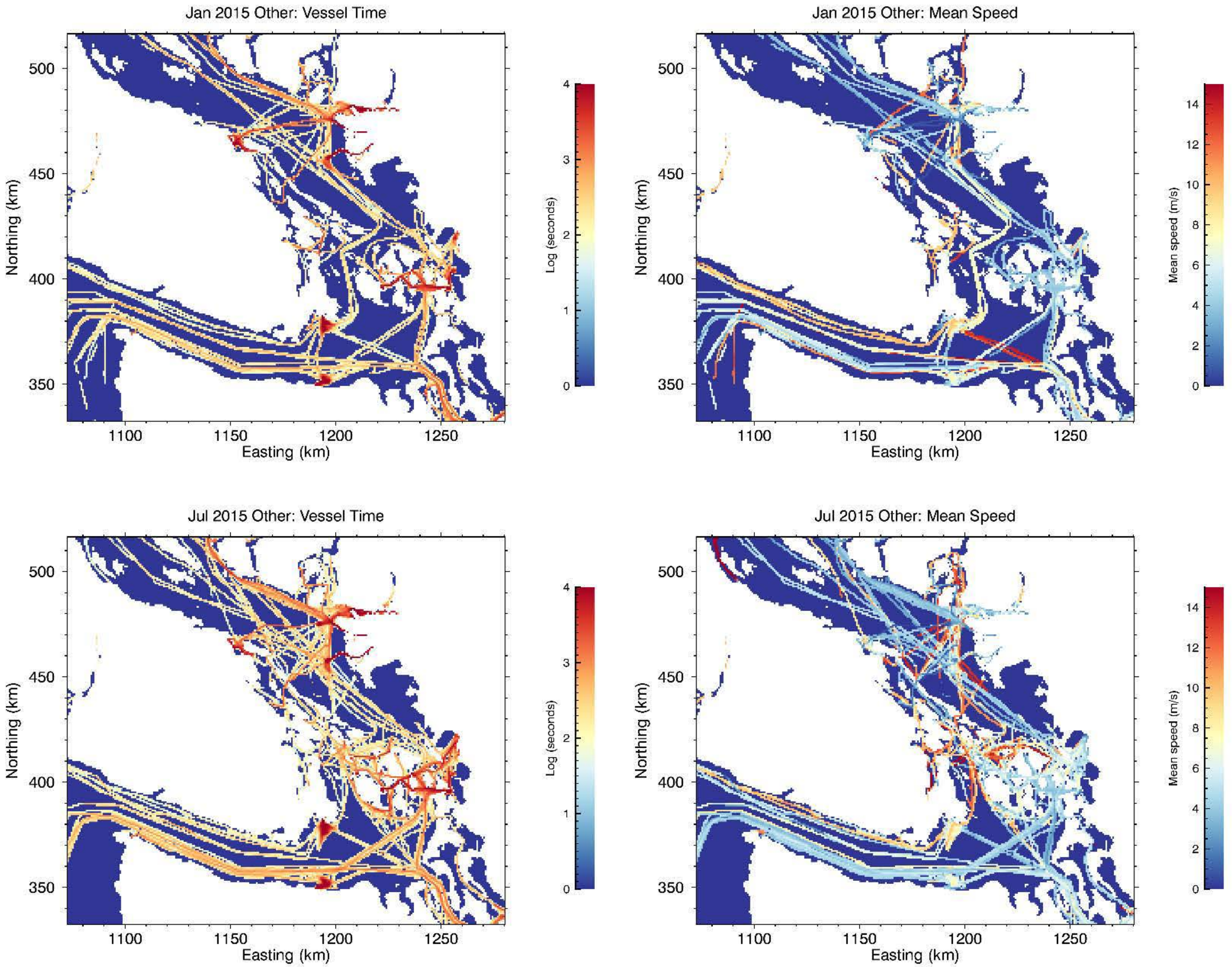

Figure B-7. Miscellaneous category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

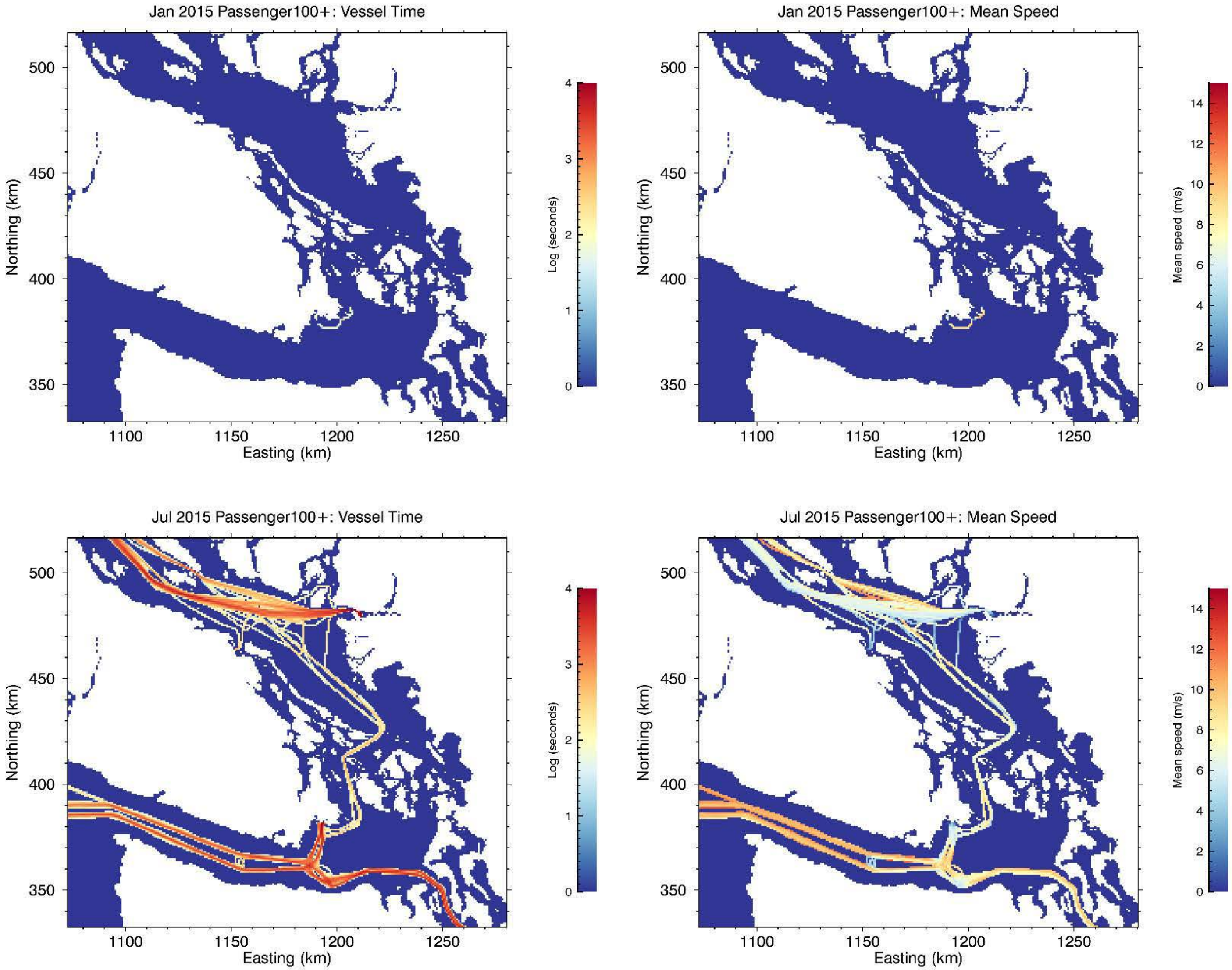

Figure B-8. Passenger (≥ 100 m) category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

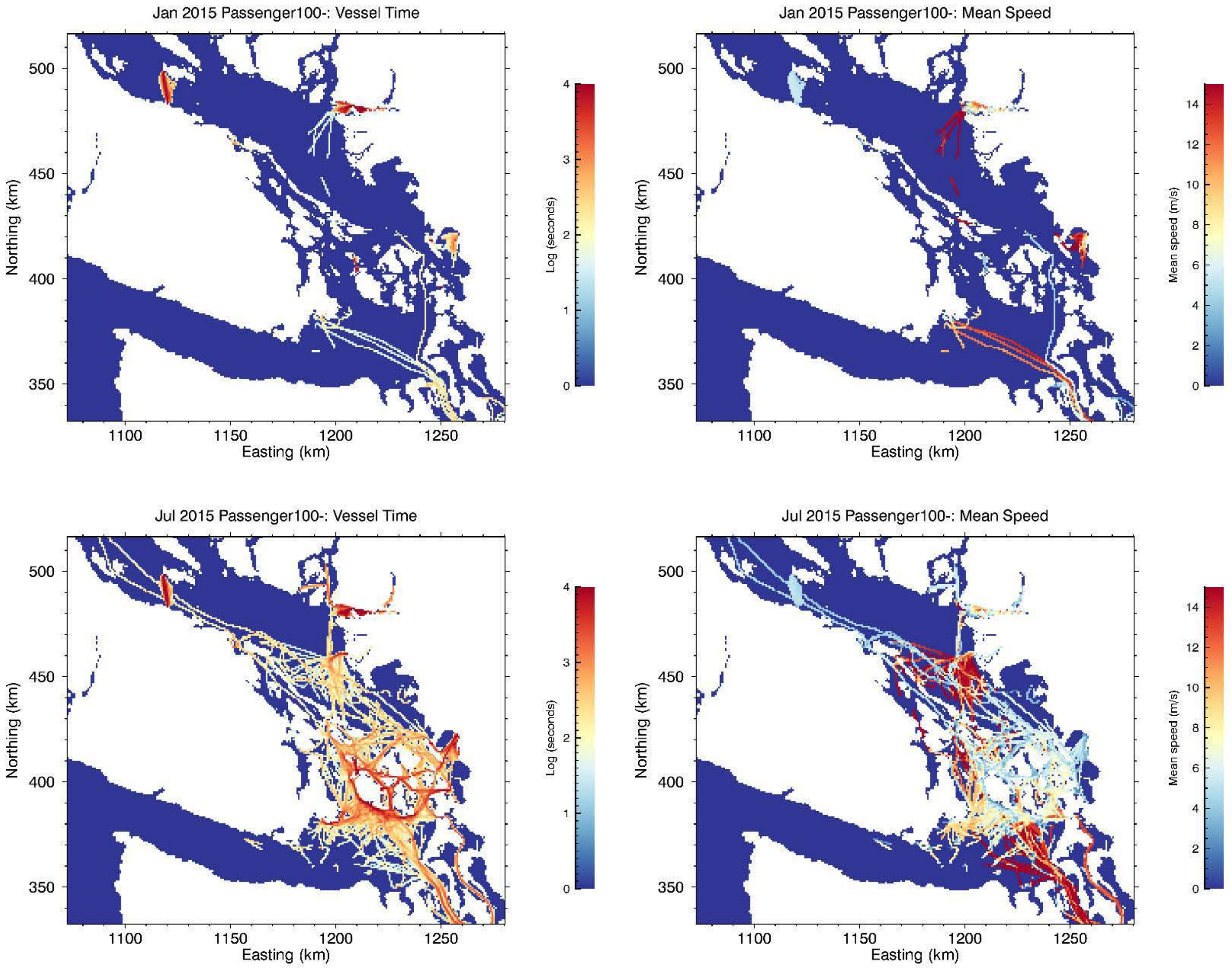

Figure B-9. Passenger (< 100 m) category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

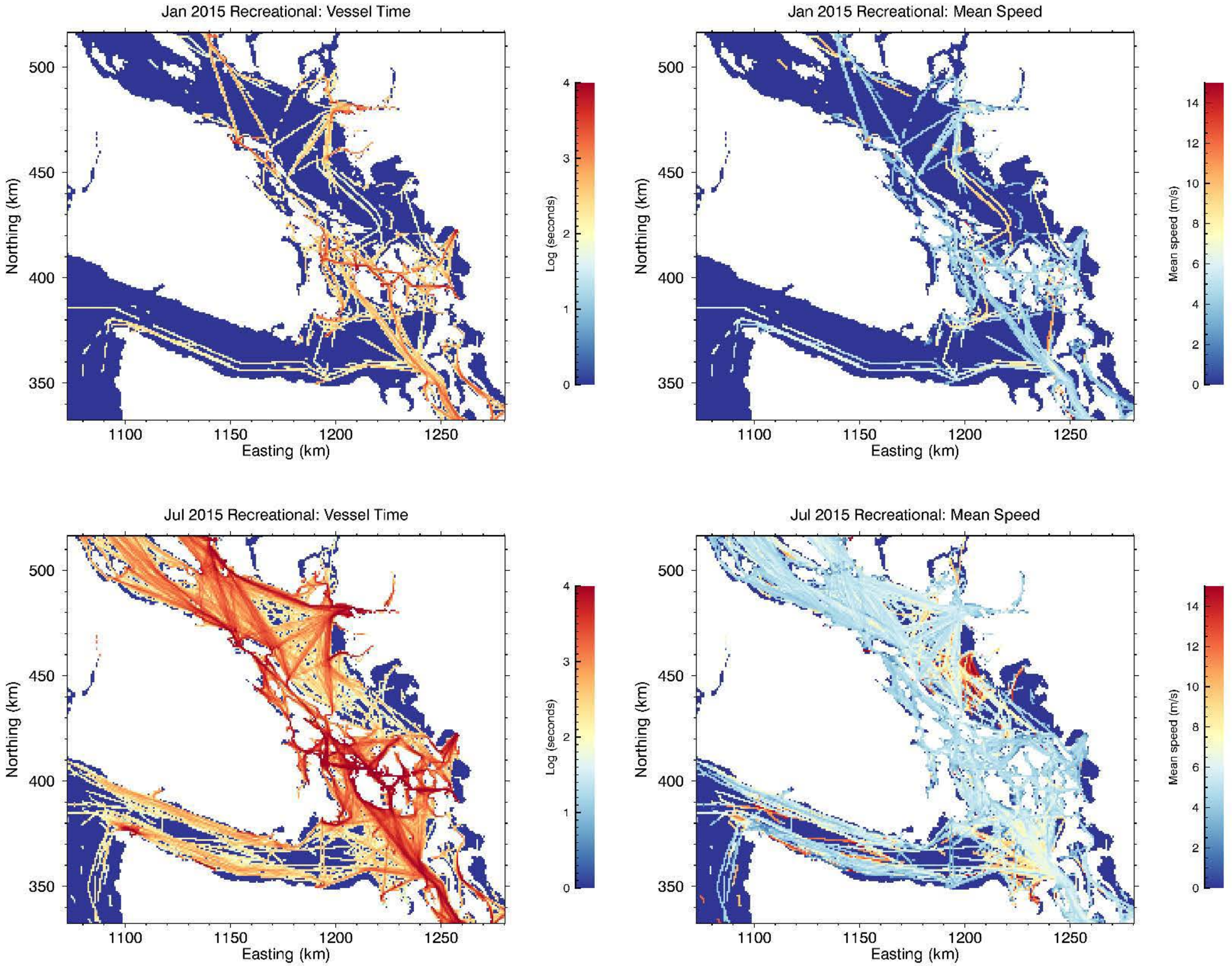

Figure B-10. Recreational category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

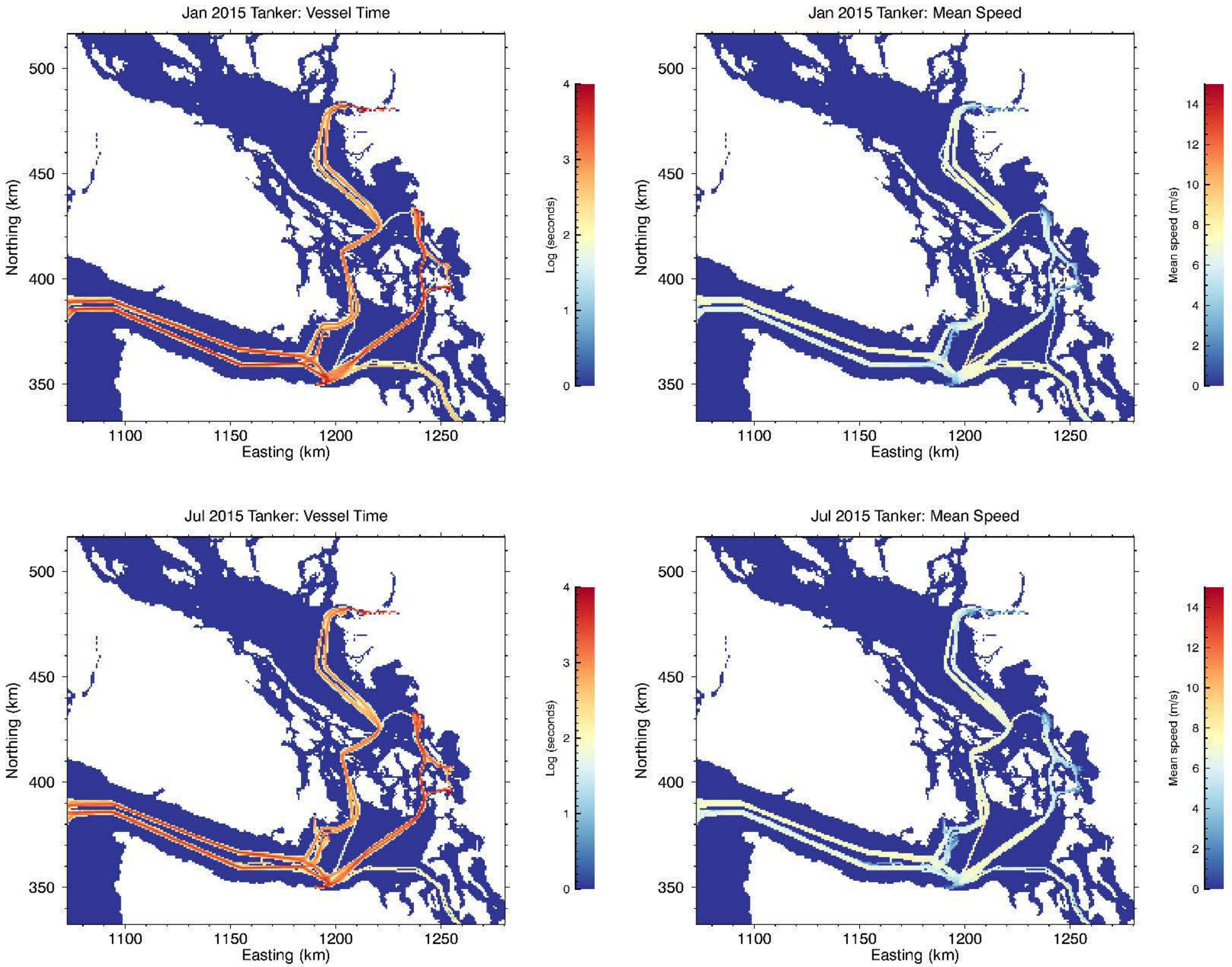

Figure B-11. Tanker category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

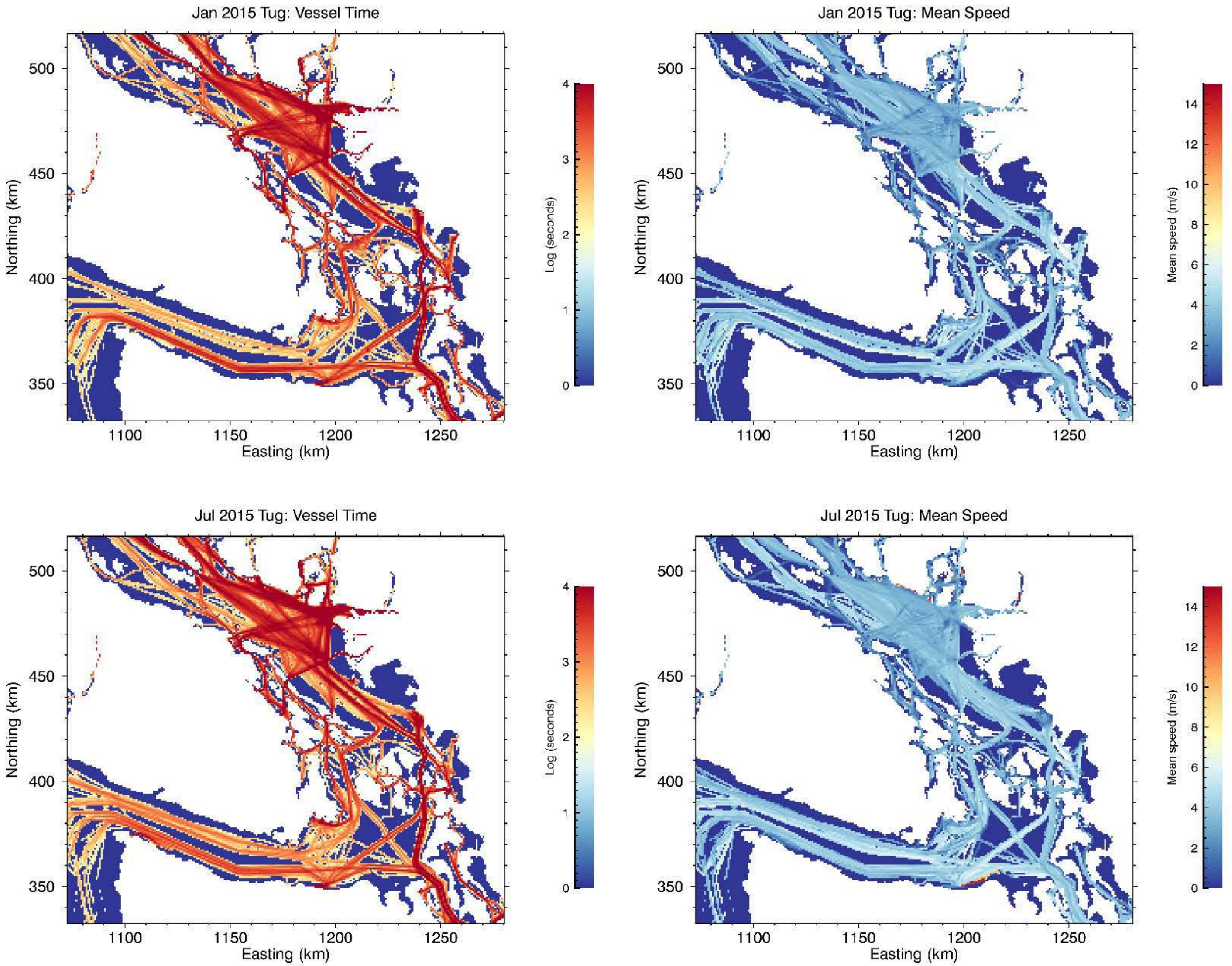

Figure B-12. Tug category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

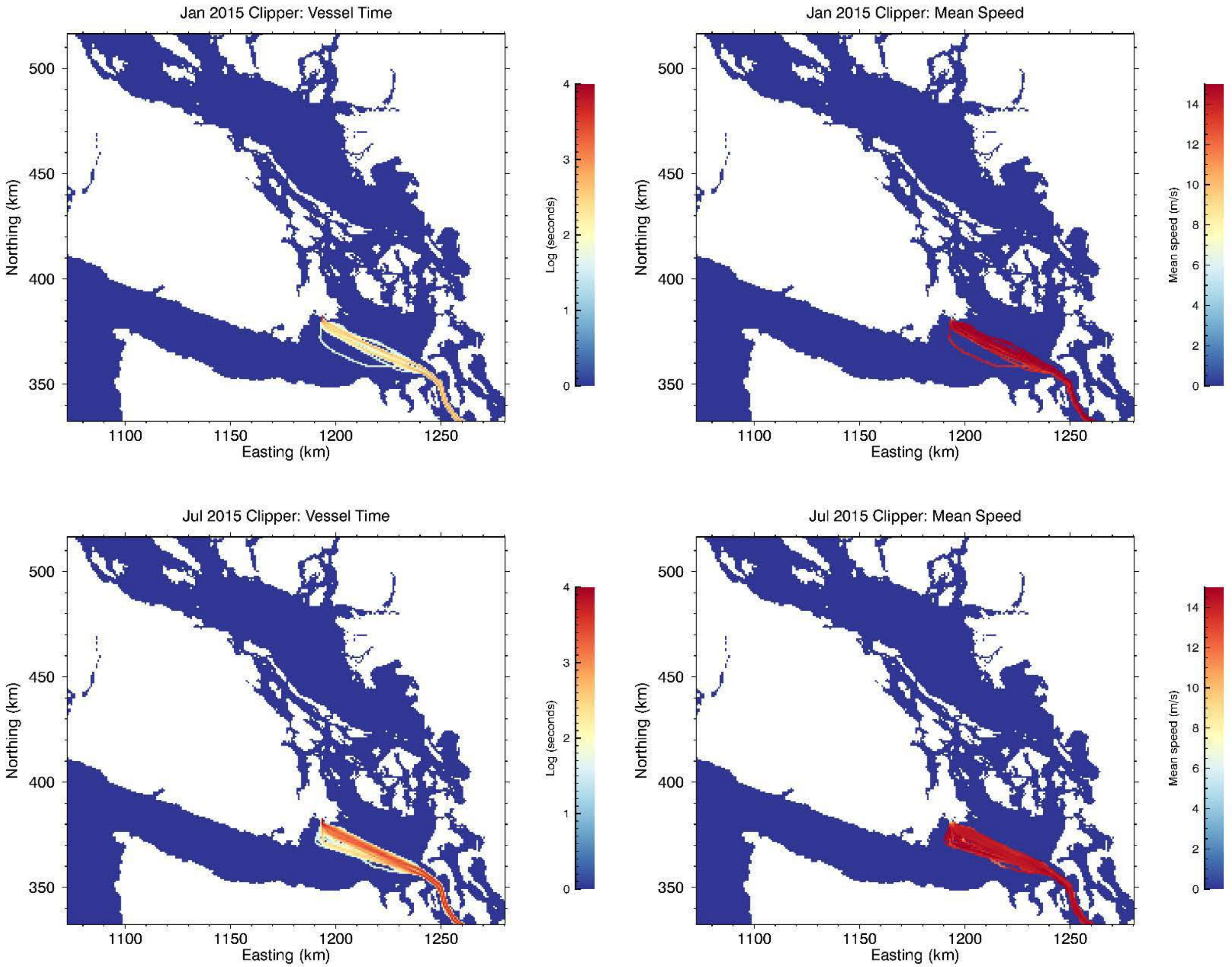

Figure B-13. Clipper category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

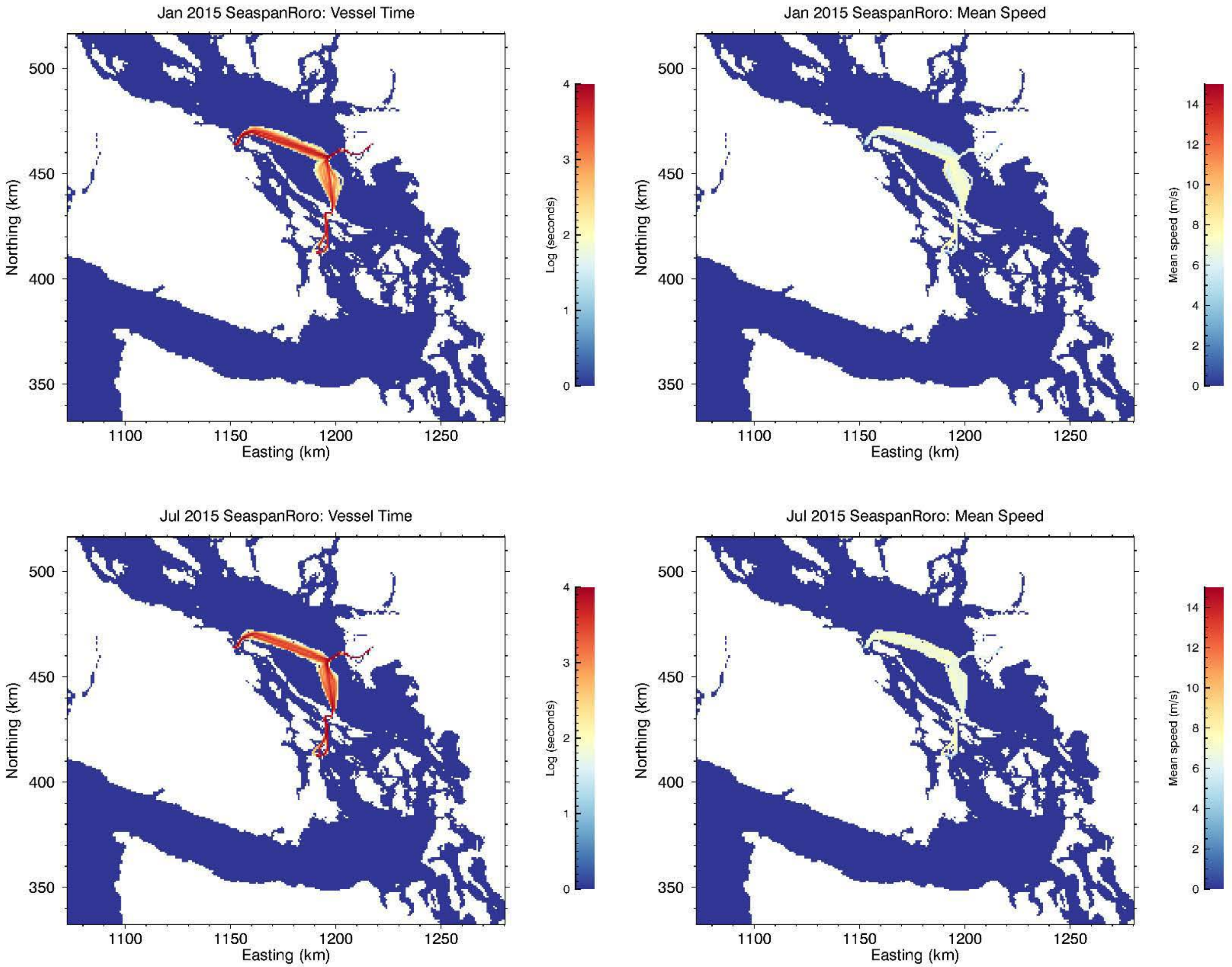

Figure B-14. Seaspan Ro-ro category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

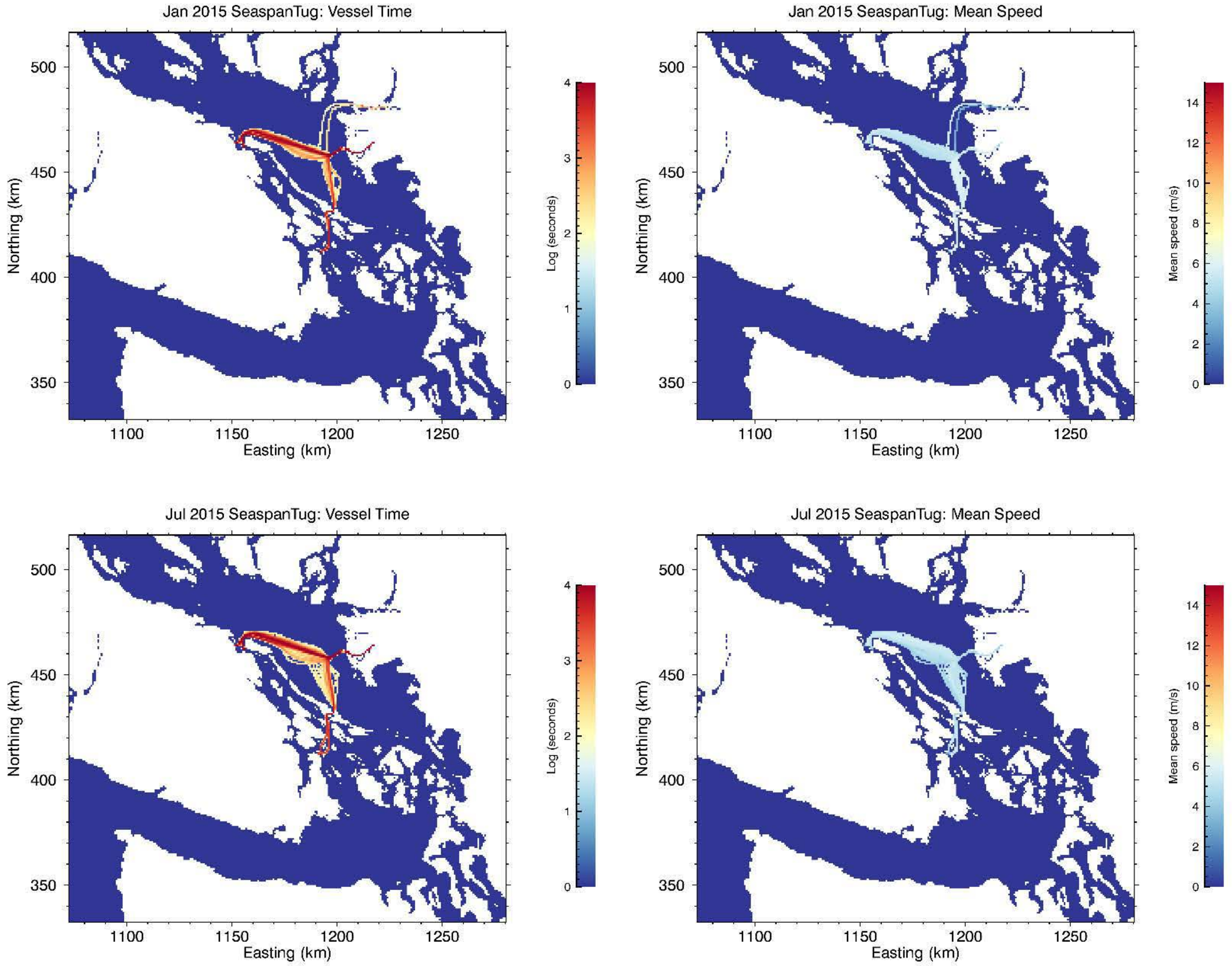

Figure B-15. Seaspan Tug category, total vessel time (left) and mean transit speed (right) in January (top) and July (bottom) 2015.

Appendix C. Whale Watch Vessel Traffic Analysis[1]

SMRU Consulting simulated whale watch boat traffic density for the month of July based on whale watch trip data from the Whale Museum's Soundwatch program. The simulated traffic density map was based on the total estimated effort for the Salish Sea whale watch fleet and the relative distribution of SRKW in the study area. The total whale watch effort for July was calculated according to the following assumptions:

1. Each whale watch trip lasts three hours.
2. There are 146 trips per day in the combined fleet (based on Soundwatch data) and 31 days in July.
3. Two hours of each trip is spent travelling (9052 hours total) and one hour is spent observing (4526 hours total).

A cost-distance analysis was conducted based on Soundwatch data on the home port of each whale watch vessel in the fleet and on assumptions on the typical range these boats venture from their home port during a whale watch trip (informed by discussions with members of the whale watch fleet). This resulted in a relative density of the combined fleet that has higher densities near home ports and successively lower densities the further one is from these home ports. This relative density was then scaled by the number of hours the boats were assumed to be on the water.

For the month of January, it was estimated that the whale watch fleet during the winter was 0.5% of their effort in the summer. This multiplier was then applied to the July Soundwatch data

SRKW relative density was generated from opportunistic sightings recorded by the BC Cetacean Sightings Network (from the Vancouver Aquarium) and the OrcaMaster dataset (from the Whale Museum). Based on the type of reporting party (e.g. whale watcher, coastal worker, population centers, etc.), the data were effort corrected to account for either the distance travelled or the amount of time spent on the water (Koshure and Wood 2014). This resulted in estimates of whale density per unit effort which were then scaled to a relative density from 0 to 1.

Transit speeds for whale watch vessels vary depending on hull design. It was estimated that 85% of the whale watch fleet (according to 2012 Soundwatch data) was of a faster planing-hull design, as opposed to a slower displacement-hull design. Since displacement-hull vessels only account for a small proportion of the fleet, and available source levels are for planing-hull vessels only, it was assumed for the purpose of this study that whale watch traffic consisted entirely of planing-hull vessels. Past measurements of whale watch boats in the study area suggest a typical transit speed for planing-hull vessels of 25 knots (Erbe 2002, Hunt 2007).

Observation speeds were estimated based on the average travelling speeds of the whales themselves since, to observe them, the boats will have to travel that speed as well. In the past, mean speeds of travelling whales have been estimated at 3.1 knots (Williams and Noren 2009), 5.8 knots (Ford 1989), and 4.3 knots (Vergara and Miller). For this study, the observing speed of whale watch boats was taken to be the average of these three estimates (4.4 knots).

The maps below show total whale watch traffic density (total seconds, log scale) in the study area for January (left) and July (right) while observing (top) and transiting (bottom). Density values are given per 800 m × 800 m grid cell.

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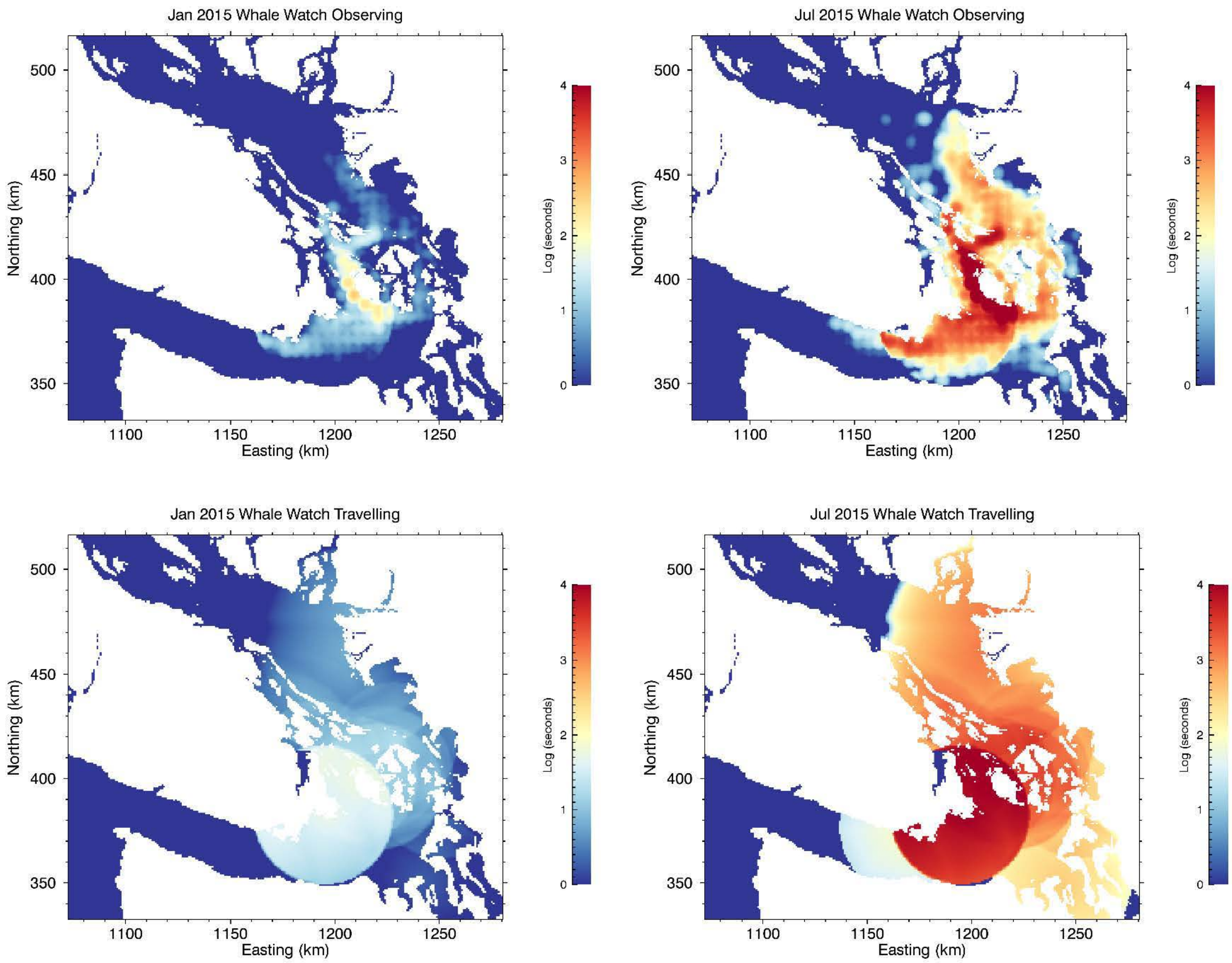
[1] Author: Jason Wood, SMRU Consulting.

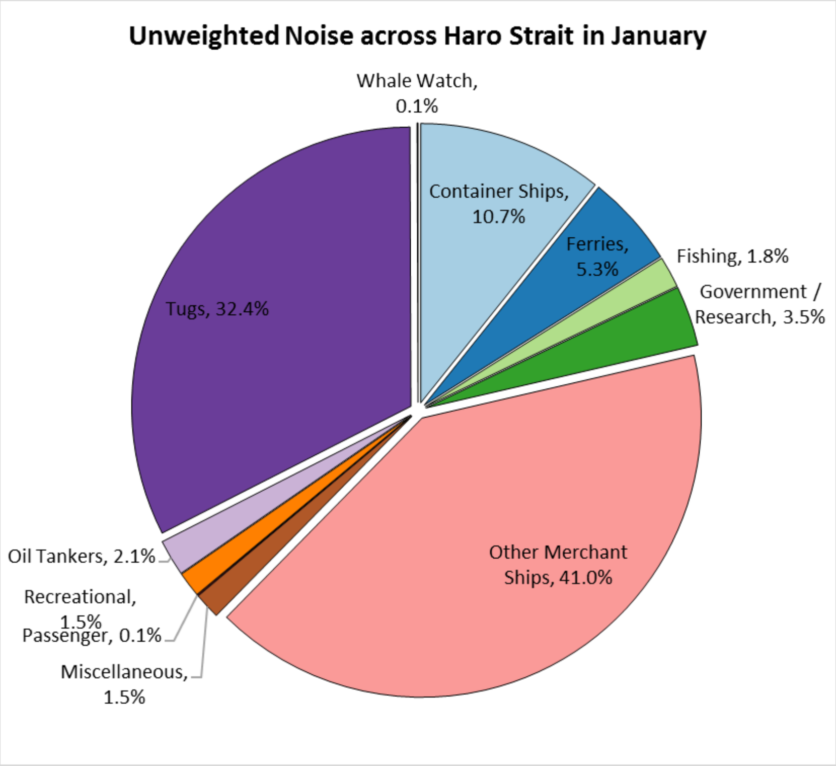


3

Figure C-1. Total vessel time for whale watch category under observing (top) and travelling (bottom) conditions in January (top) and July (bottom).

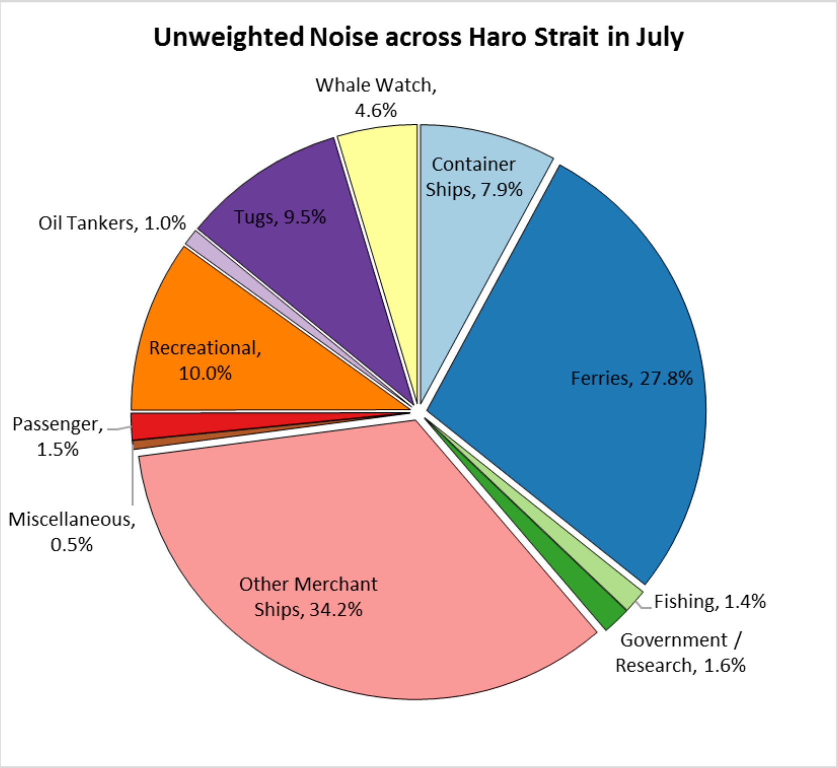
Appendix D. Noise Pie Charts by Sub-region

The following charts show noise budget pie charts for the six sub-region for January and July, in terms of mean square sound pressure. Tabular listings of the data shown in the pie charts are available in Table 3 and Table 4 (see Section 5).



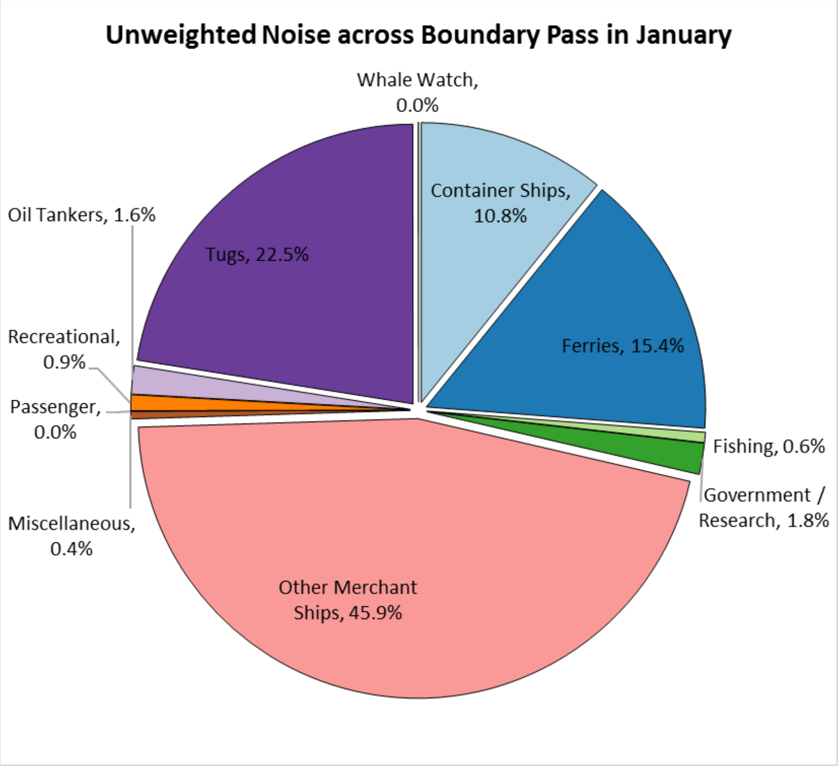
Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.05792	10.7%
Ferries	0.02874	5.3%
Fishing	0.00981	1.8%
Government / Research	0.01878	3.5%
Other Merchant Ships	0.22086	41.0%
Miscellaneous	0.00819	1.5%
Passenger	0.00034	0.1%
Recreational	0.00785	1.5%
Oil Tankers	0.01132	2.1%
Tugs	0.17486	32.4%
Whale Watch	0.00028	0.1%
All Categories	**0.53895**	**100.0%**

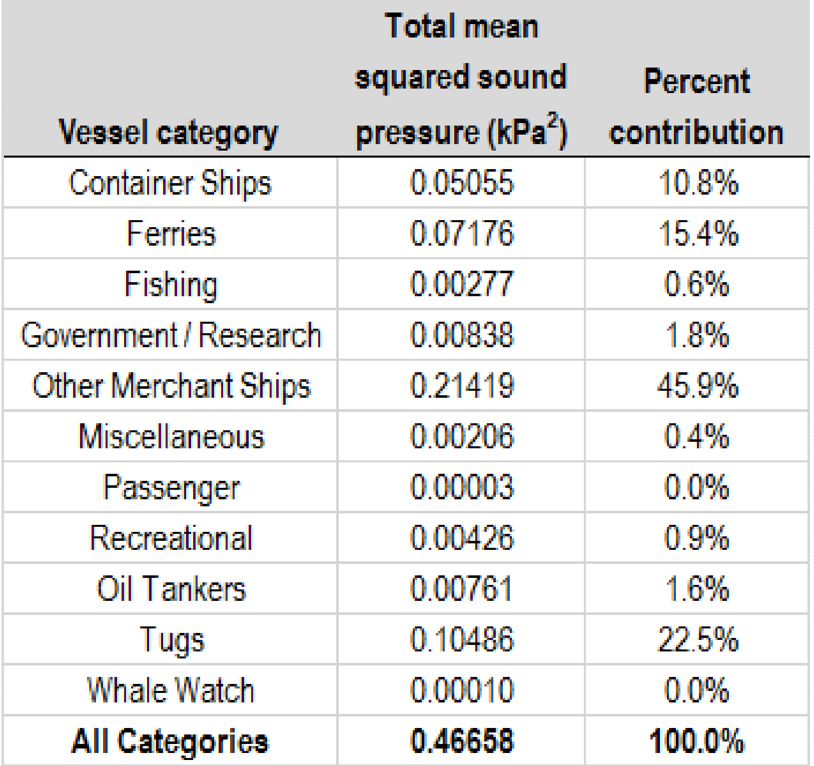
Figure D-1. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Haro Strait sub-region, for January. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.



Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.01589	7.9%
Ferries	0.05590	27.8%
Fishing	0.00278	1.4%
Government / Research	0.00327	1.6%
Other Merchant Ships	0.06873	34.2%
Miscellaneous	0.00102	0.5%
Passenger	0.00309	1.5%
Recreational	0.02004	10.0%
Oil Tankers	0.00192	1.0%
Tugs	0.01904	9.5%
Whale Watch	0.00932	4.6%
All Categories	**0.20101**	**100.0%**

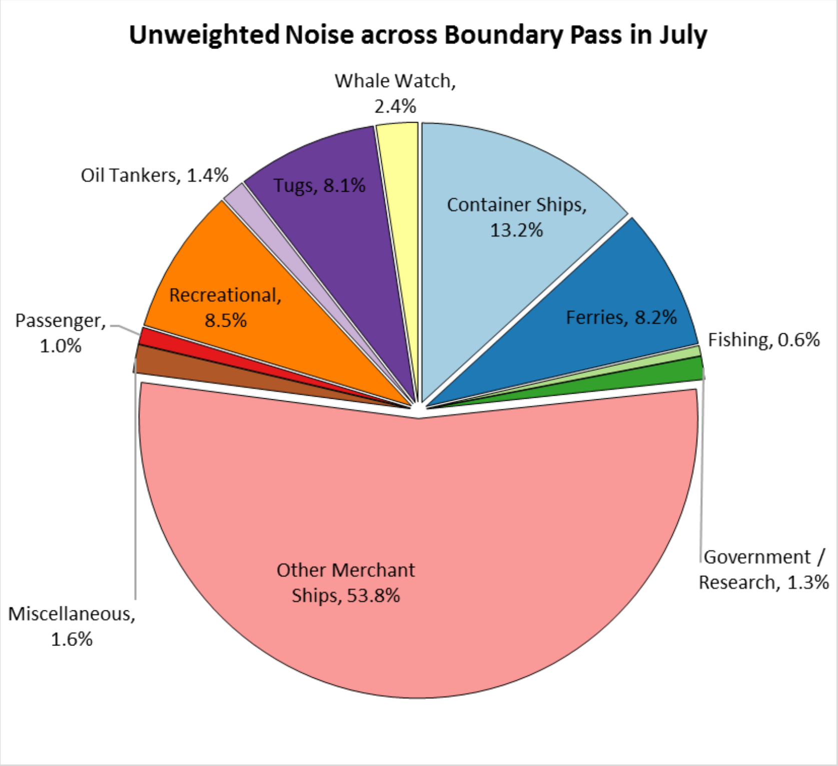
Figure D-2. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Haro Strait sub-region, for July. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.





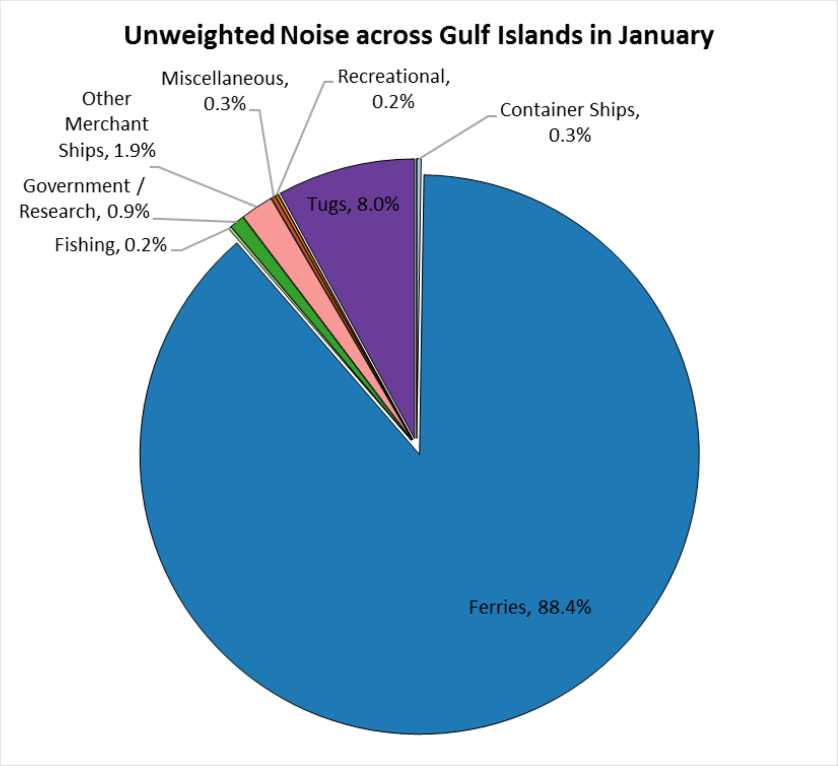
Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.05055	10.8%
Ferries	0.07176	15.4%
Fishing	0.00277	0.6%
Government / Research	0.00838	1.8%
Other Merchant Ships	0.21419	45.9%
Miscellaneous	0.00206	0.4%
Passenger	0.00003	0.0%
Recreational	0.00426	0.9%
Oil Tankers	0.00761	1.6%
Tugs	0.10486	22.5%
Whale Watch	0.00010	0.0%
All Categories	**0.46658**	**100.0%**

Figure D-3. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Boundary Pass sub-region, for January. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.



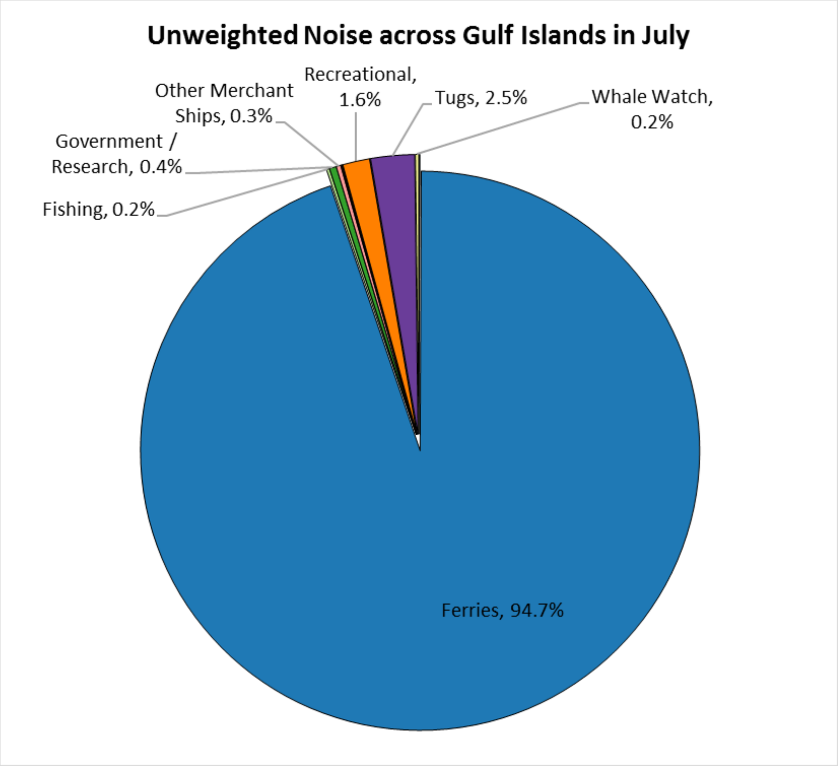
Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.01905	13.2%
Ferries	0.01182	8.2%
Fishing	0.00085	0.6%
Government / Research	0.00193	1.3%
Other Merchant Ships	0.07759	53.8%
Miscellaneous	0.00234	1.6%
Passenger	0.00140	1.0%
Recreational	0.01222	8.5%
Oil Tankers	0.00198	1.4%
Tugs	0.01169	8.1%
Whale Watch	0.00346	2.4%
All Categories	**0.14433**	**100.0%**

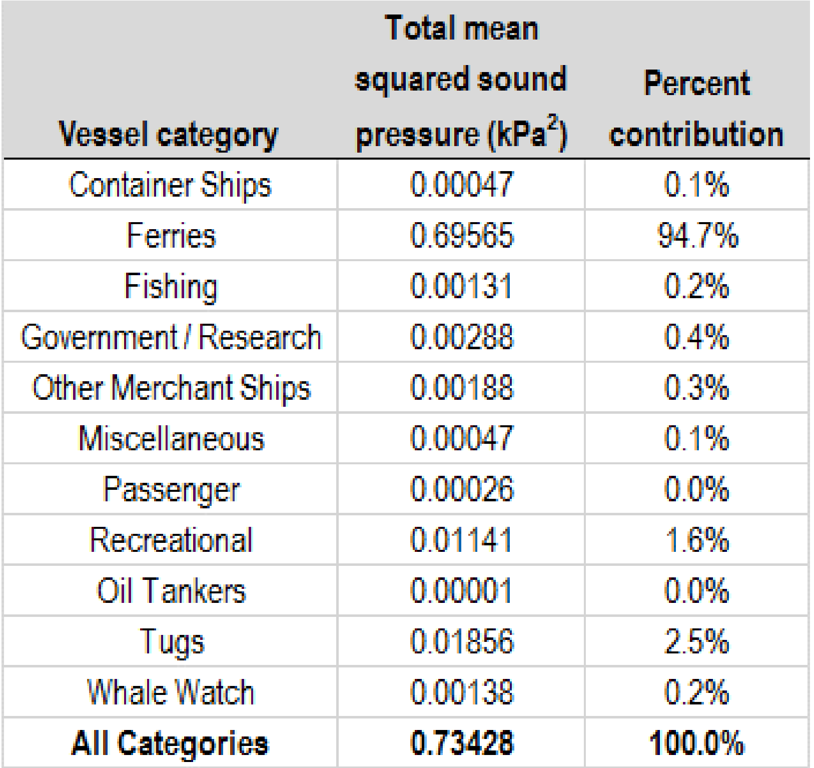
Figure D-4. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Boundary Pass sub-region, for July. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.



Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.00200	0.3%
Ferries	0.70429	88.4%
Fishing	0.00132	0.2%
Government / Research	0.00681	0.9%
Other Merchant Ships	0.01502	1.9%
Miscellaneous	0.00203	0.3%
Passenger	0.00001	0.0%
Recreational	0.00133	0.2%
Oil Tankers	0.00022	0.0%
Tugs	0.06350	8.0%
Whale Watch	0.00002	0.0%
All Categories	**0.79654**	**100.0%**

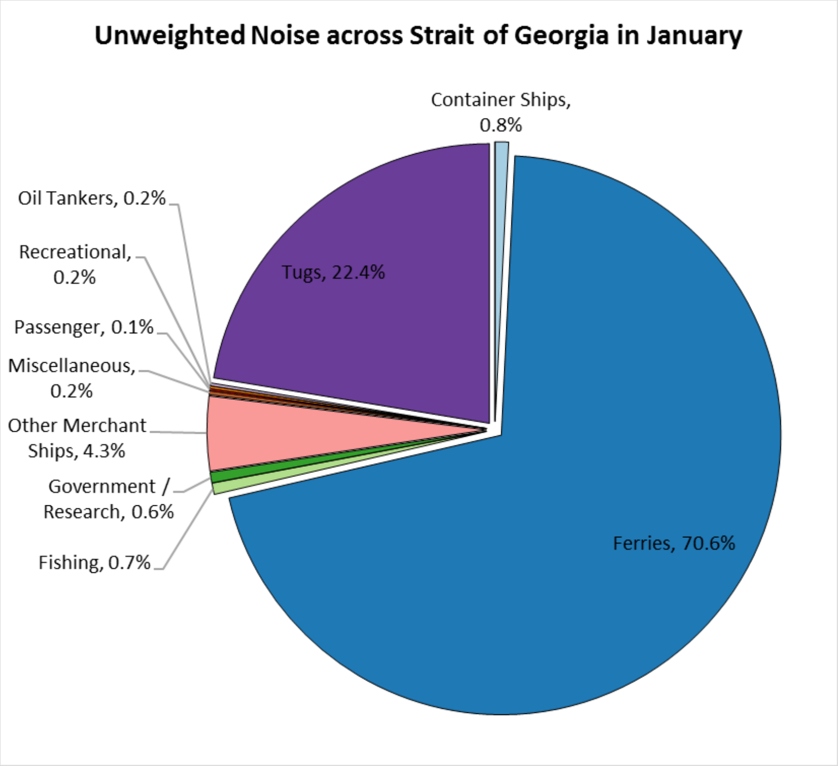
Figure D-5. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Gulf Islands sub-region, for January. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

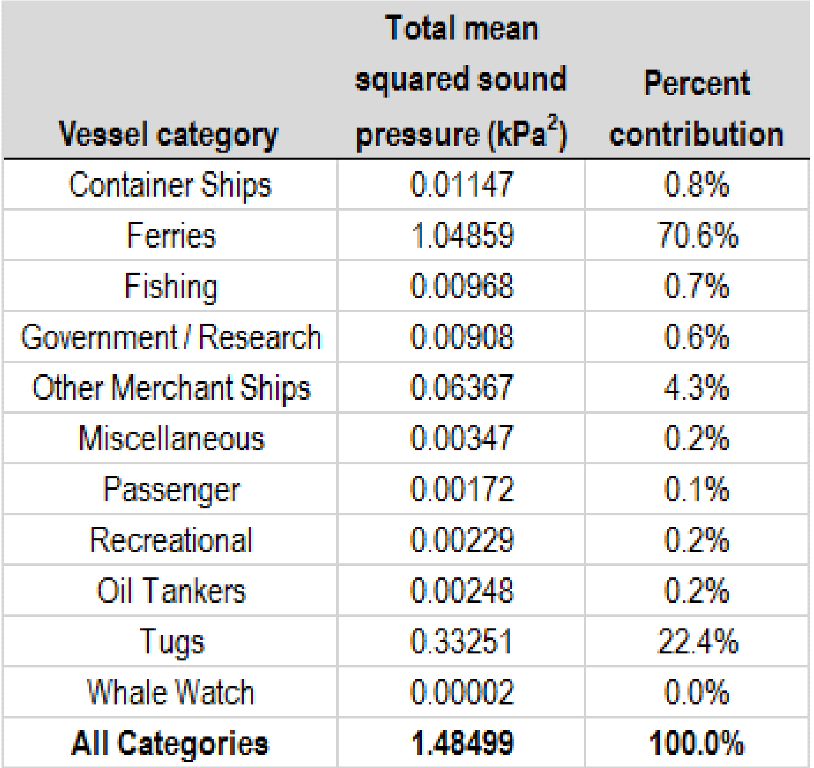




Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.00047	0.1%
Ferries	0.69565	94.7%
Fishing	0.00131	0.2%
Government / Research	0.00288	0.4%
Other Merchant Ships	0.00188	0.3%
Miscellaneous	0.00047	0.1%
Passenger	0.00026	0.0%
Recreational	0.01141	1.6%
Oil Tankers	0.00001	0.0%
Tugs	0.01856	2.5%
Whale Watch	0.00138	0.2%
All Categories	**0.73428**	**100.0%**

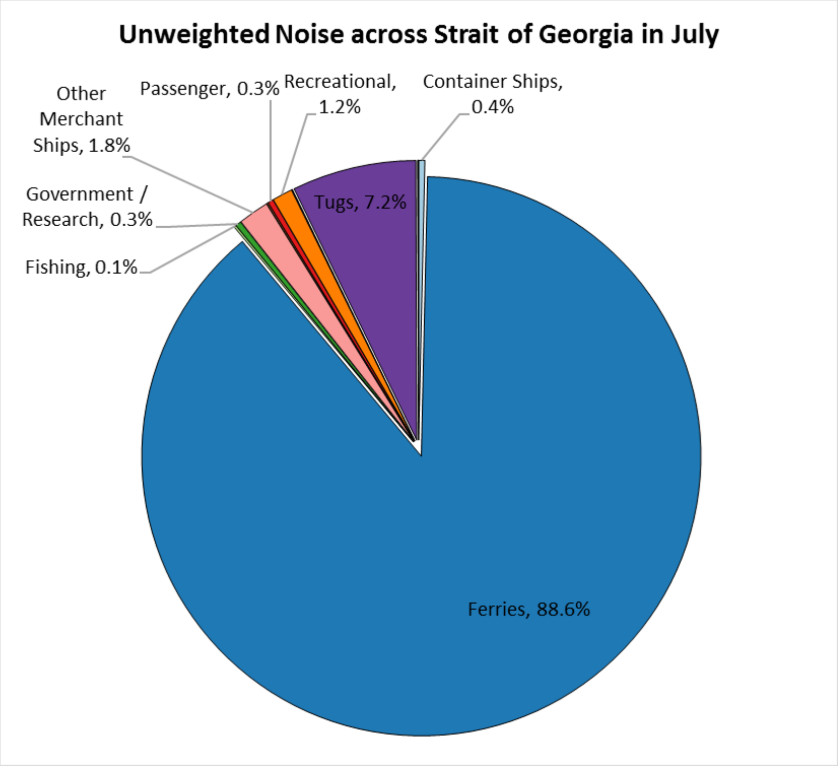
Figure D-6. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Gulf Islands sub-region, for July. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

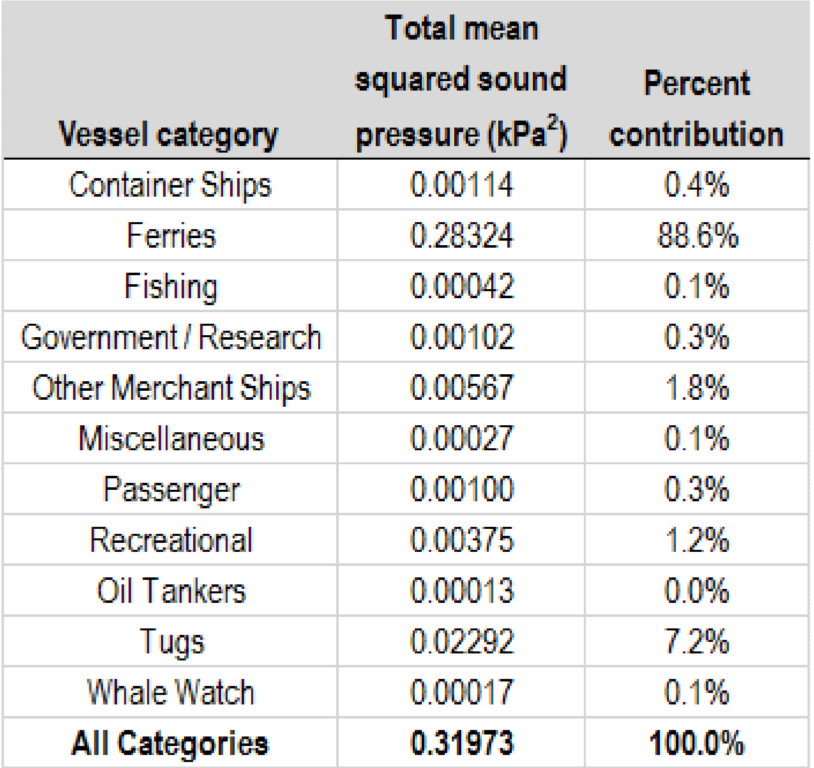




Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.01147	0.8%
Ferries	1.04859	70.6%
Fishing	0.00968	0.7%
Government / Research	0.00908	0.6%
Other Merchant Ships	0.06367	4.3%
Miscellaneous	0.00347	0.2%
Passenger	0.00172	0.1%
Recreational	0.00229	0.2%
Oil Tankers	0.00248	0.2%
Tugs	0.33251	22.4%
Whale Watch	0.00002	0.0%
All Categories	**1.48499**	**100.0%**

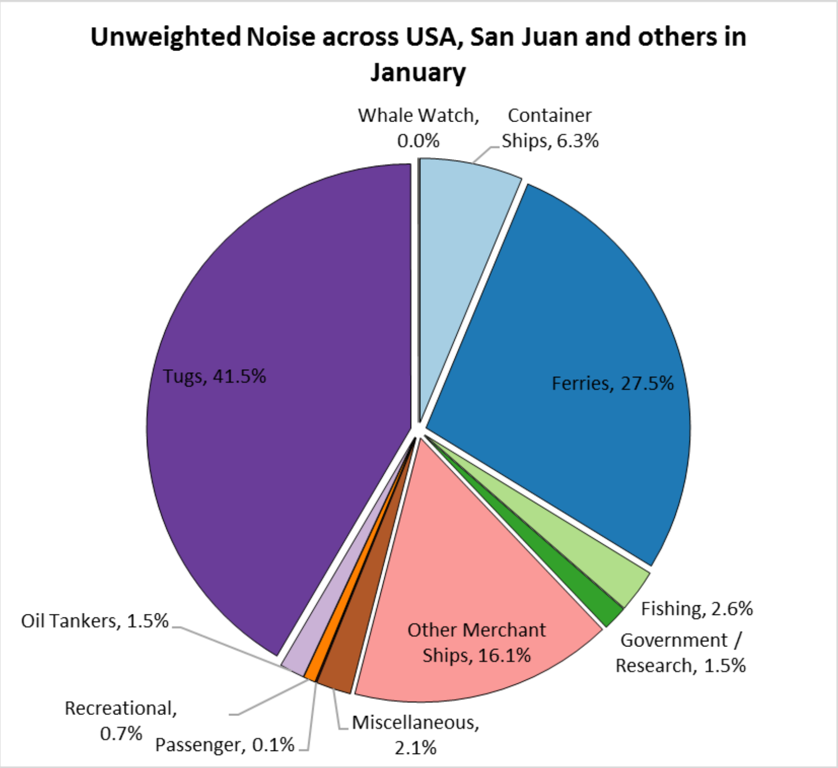
Figure D-7. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Strait of Georgia sub-region, for January. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.





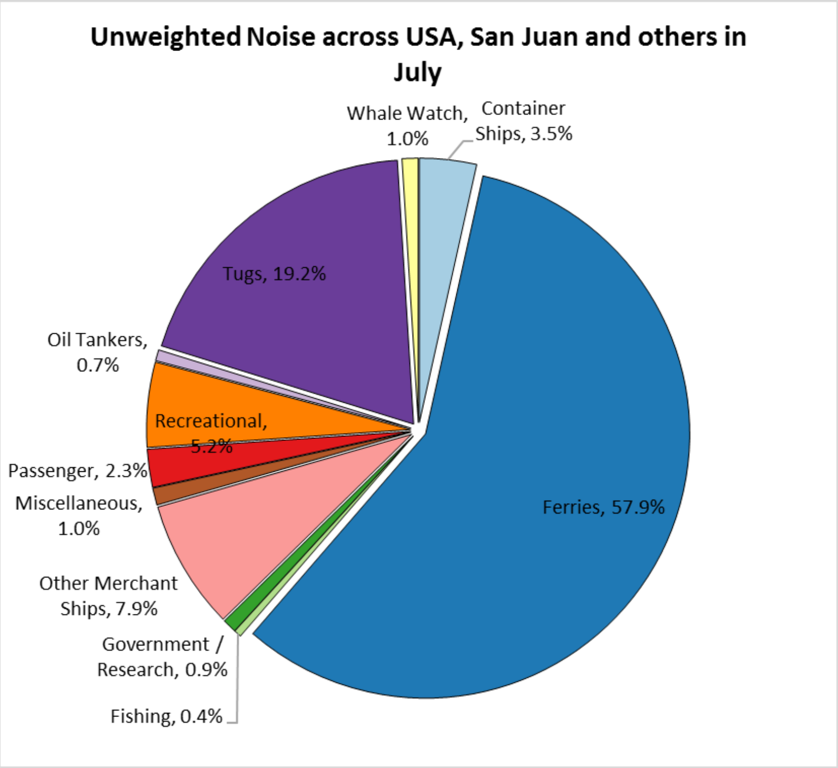
Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.00114	0.4%
Ferries	0.28324	88.6%
Fishing	0.00042	0.1%
Government / Research	0.00102	0.3%
Other Merchant Ships	0.00567	1.8%
Miscellaneous	0.00027	0.1%
Passenger	0.00100	0.3%
Recreational	0.00375	1.2%
Oil Tankers	0.00013	0.0%
Tugs	0.02292	7.2%
Whale Watch	0.00017	0.1%
All Categories	**0.31973**	**100.0%**

Figure D-8. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Strait of Georgia sub-region, for July. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.



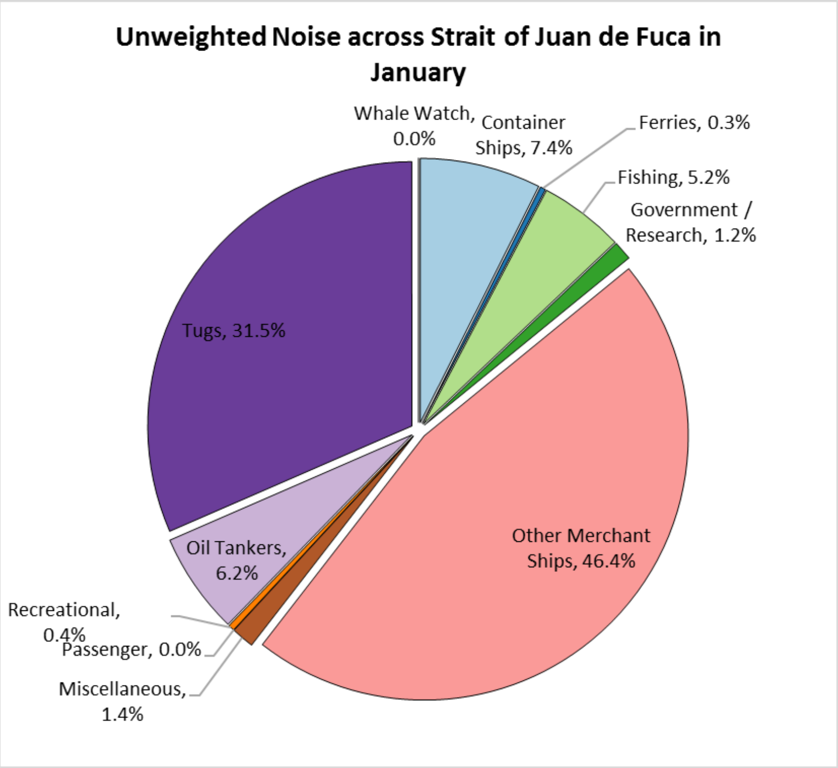
Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.03695	6.3%
Ferries	0.16111	27.5%
Fishing	0.01543	2.6%
Government / Research	0.00888	1.5%
Other Merchant Ships	0.09452	16.1%
Miscellaneous	0.01252	2.1%
Passenger	0.00042	0.1%
Recreational	0.00432	0.7%
Oil Tankers	0.00895	1.5%
Tugs	0.24362	41.5%
Whale Watch	0.00010	0.0%
All Categories	**0.58682**	**100.0%**

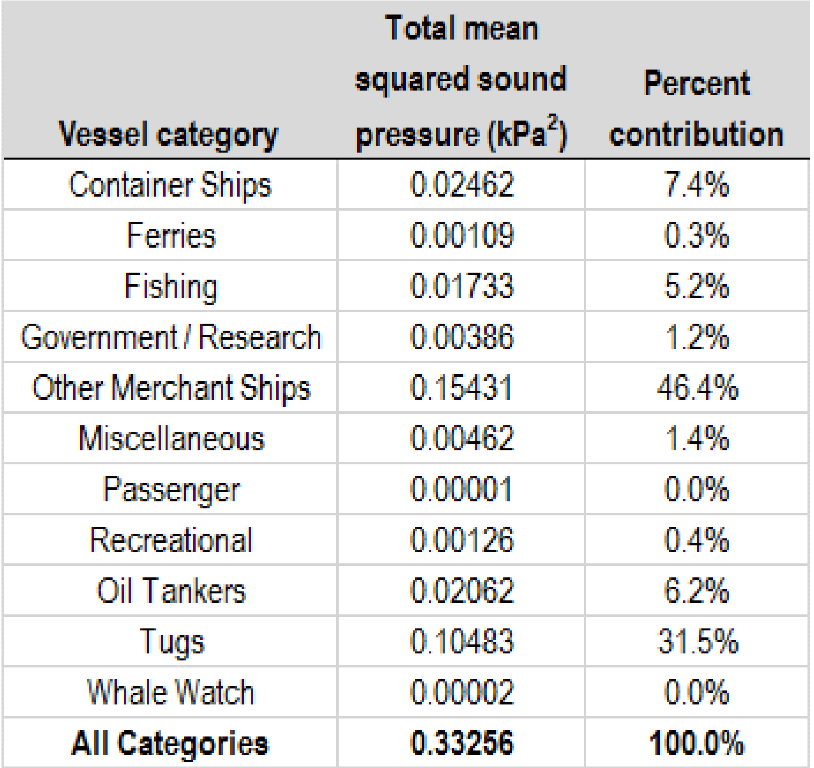
Figure D-9. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in USA, San Juans, and Other sub-region, for January. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.



Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.00839	3.5%
Ferries	0.13929	57.9%
Fishing	0.00108	0.4%
Government / Research	0.00207	0.9%
Other Merchant Ships	0.01900	7.9%
Miscellaneous	0.00252	1.0%
Passenger	0.00557	2.3%
Recreational	0.01250	5.2%
Oil Tankers	0.00162	0.7%
Tugs	0.04628	19.2%
Whale Watch	0.00237	1.0%
All Categories	**0.24069**	**100.0%**

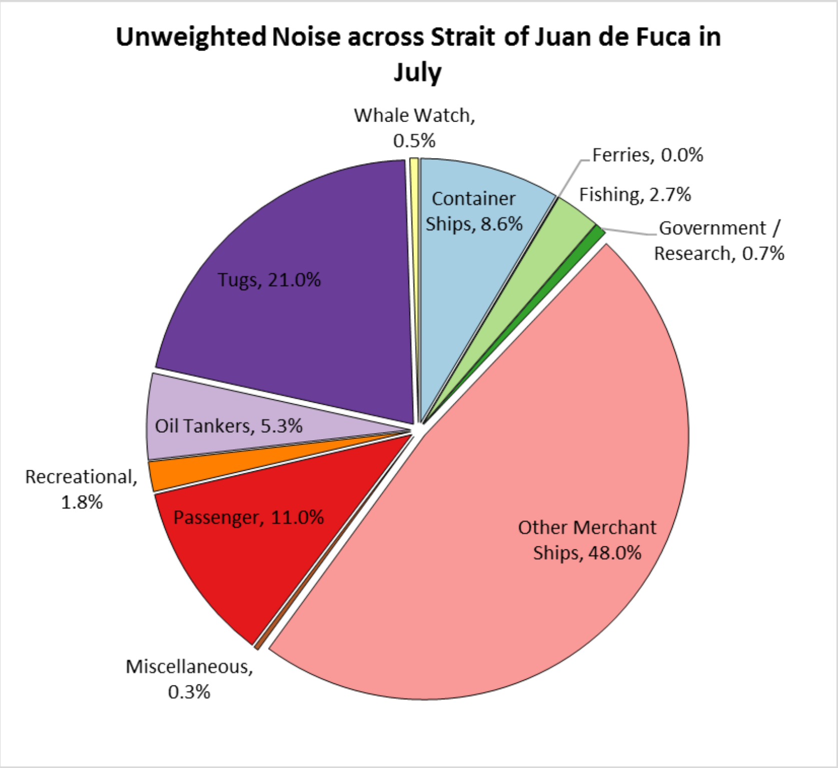
Figure D-10. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in USA, San Juans, and Other sub-region, for July. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

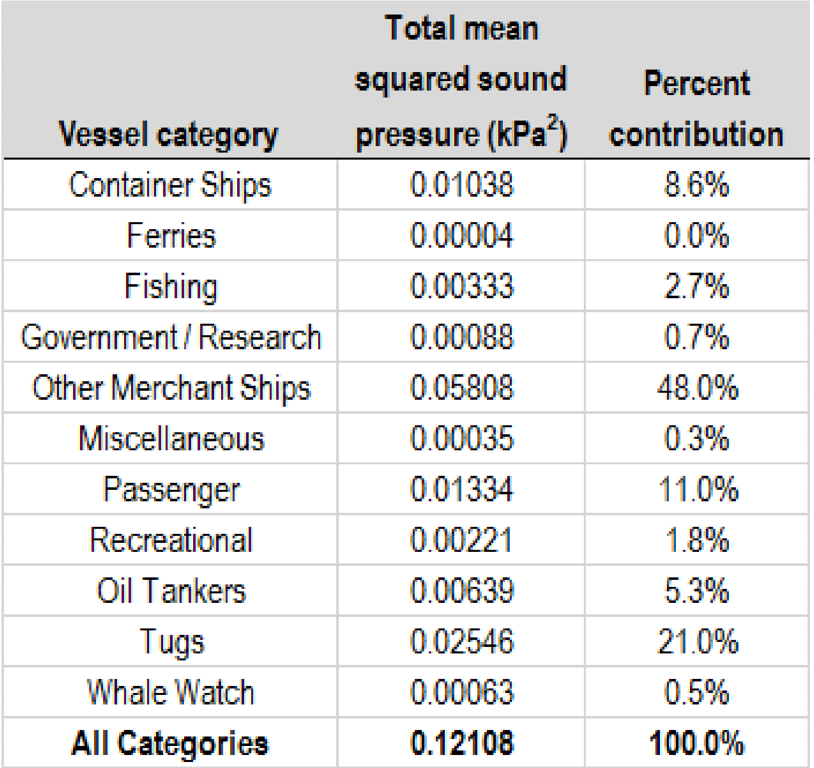




Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.02462	7.4%
Ferries	0.00109	0.3%
Fishing	0.01733	5.2%
Government / Research	0.00386	1.2%
Other Merchant Ships	0.15431	46.4%
Miscellaneous	0.00462	1.4%
Passenger	0.00001	0.0%
Recreational	0.00126	0.4%
Oil Tankers	0.02062	6.2%
Tugs	0.10483	31.5%
Whale Watch	0.00002	0.0%
All Categories	**0.33256**	**100.0%**

Figure D-11. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Strait of Juan de Fuca sub-region, for January. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.





Vessel category	Total mean squared sound pressure (kPa^2)	Percent contribution
Container Ships	0.01038	8.6%
Ferries	0.00004	0.0%
Fishing	0.00333	2.7%
Government / Research	0.00088	0.7%
Other Merchant Ships	0.05808	48.0%
Miscellaneous	0.00035	0.3%
Passenger	0.01334	11.0%
Recreational	0.00221	1.8%
Oil Tankers	0.00639	5.3%
Tugs	0.02546	21.0%
Whale Watch	0.00063	0.5%
All Categories	**0.12108**	**100.0%**

Figure D-12. Pie chart (left) and table (right) showing the relative noise contribution of all vessel categories in Strait of Juan de Fuca sub-region, for July. The contribution of each category is proportional to total number of vessels, the amount of time they spend in the region, and their source level.

IR4-06 Vessel Traffic Projections – Population

Information Source(s)

EIS Volume 5: Appendix 30-A, Appendix B, Table B-2

Marine Shipping Addendum: Appendix 6-A

Proponent Response to IR1-05 (CEAR Doc# 897)

Context

The Proponent, in Table B-2 of Appendix B of Appendix 30-A of the EIS and Appendix 6-A of the Marine Shipping Addendum, indicated that 80 Panamax bulkers (100,000 tons vessel capacity) and 500 cargo barges (16,000 tons vessel capacity) will call each year at the coal port planned at Fraser Surrey Docks to transport 8 million metric tonnes/year (MMT/year) of coal for each vessel type.

The annual amount of coal exported from the Fraser Surrey Docks Coal Transfer project would have a direct influence on the number of Panamax bulker and cargo barges movements through the south arm of the Fraser River and in the marine shipping area.

Updated information about the amount of coal exported from Fraser Surrey Docks and the number of vessels associated with the coal export operations at Fraser Surry docks is required.

Information Request

Confirm the amount of coal (MMT/year) which will be transported from Fraser Surrey Docks each year.

In accordance with what will be transported, indicate the number of Panamax Bulkers and cargo barges that will call each year at the coal port planned at Fraser Surrey Docks.

If a correction is needed, update the tables and figures in the Proponent's response to Review Panel information request IR1-05.

VFPA Response

Confirm the amount of coal (MMT/year) which will be transported from Fraser Surrey Docks each year.

On August 21, 2014, the VFPA issued a Project Permit (PP 2012-072) to Fraser Surrey Docks LP (FSD) for the development of a direct transfer coal facility to handle up to 4 million metric tonnes (MMT) of coal per year[1].

At the time of preparation of EIS Appendix 30-A, this project was under permit review by the VFPA and the tonnage was estimated to be 8.0 MMT (as described in Appendix B of EIS Appendix 30-A, based on available information from the VFPA (PMV 2013)). Subsequently, as shown in EIS Table 8-8, which was developed in 2014, the updated tonnage of 4.0 MMT was included.

In accordance with what will be transported, indicate the number of Panamax Bulkers and cargo barges that will call each year at the coal port planned at Fraser Surrey Docks.

As stated in its *Proposal for An Amendment to the Permit for the Direct Coal Transfer Facility* (FSD 2015a), FSD notes that changing commercial and market conditions prompted a shift in its shipping approach from barge-only transport to Texada Island (and subsequently via ocean-going Panamax bulkers) to the sole use of Panamax bulkers. As the proposed use of Panamax bulkers will provide increased operational flexibility for FSD, it is their intention to reduce or eliminate the number of barges required in their shipping operation (FSD 2015b). The number of Panamax bulkers and barges that will call at the FSD terminal will depend on the volume of coal shipped and the vessel shipping scenario. Assuming 4 MMT of coal is shipped annually, **Table IR4-06-1** presents five potential shipping scenarios and associated vessel calls proposed by FSD for Panamax bulkers and cargo barges (FSD 2015b).

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[1] On November 30, 2015, the VFPA issued a Project Permit amendment (PP 2012-072-1) to FSD to amend the original Project Permit (issued August 21, 2014). The amended permit authorised the addition of ship loading infrastructure at the site, but did not change the permitted volume of coal shipped (4 MMT). To clarify the statement on volume in the context of this information request, the unit of volume used throughout the EIS and Marine Shipping Addendum is metric 'tonnes' not imperial 'tons'.

Table IR4-06-1 Potential Shipping Scenarios at Fraser Surrey Docks Terminal

Potential Shipping Scenarios	Panamax Bulkers Calls per Year	Cargo Barge Calls per Year
Barge only	0	640
25% use of Panamax bulkers	20	480
50% use of Panamax bulkers	40	320
75% use of Panamax bulkers	60	160
100% use of Panamax bulkers	80	0

Source: From FSD (2015b). Note that loaded return-trip vessel movements described in this information source reflect annual calls for Panamax bulkers and cargo barges.

Although FSD would like to retain the ability to load barges at the terminal, the exclusive use of Panamax bulkers is the preferred operational scenario. As such, 100% use of Panamax bulkers, with 80 vessel calls (160 movements) per year is expected. As the FSD project is not operational as of June 2017, there is no actual ship call data to confirm this shipping scenario.

As described in EIS Table 8-8 and Appendix 6-A of the Marine Shipping Addendum, the FSD project was included as a certain or reasonably foreseeable project for the assessment of cumulative effects, and the assumption of vessel traffic associated with this project for coal transport included 500 cargo barges and 80 Panamax bulkers (based on original 8.0 MMT). Barges were assumed to transit between the terminal and a transfer facility on Texada Island, where it would be subsequently loaded onto bulkers for transport through the marine shipping area (Segments A to D).

If a correction is needed, update the tables and figures in the Proponent's response to Review Panel information request IR1-05.

In Table B-2 in Appendix B of EIS Appendix 30-A[2] for the FSD Project[3], 80 calls (160 movements) of Panamax vessels were included within the bulker category and 500 calls (1,000 movements) of cargo barges were included within the cargo barge category based on 8.0 MMT. Tables and figures in IR1-05[4] include the movements of FSD-related bulkers through the marine shipping area segments within the 1% per annum growth rate from 2012 to 2030 (refer to IR4-09 for more details), and therefore, corrections are not required. Note that revised Figures 4-2 and 4-3 included in IR1-05 have been superseded by Figures IR4-04-1 and IR4-04-2 in IR4-04, and Tables IR1-05-1 and IR1-05-2 in IR1-05 have been superseded by Tables IR4-04-1 and IR4-04-2 in IR4-04.

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[2] Note that at the time of undertaking the Quantitative Risk Assessment (provided in EIS Appendix 30-A), it was assumed that the FSD project would transport 8 MMT of coal annually (based on available information as of October 1, 2013, as outlined in Table B-2 in Appendix B of EIS Appendix 30-A).

[3] FSD Project also referred to as Texada Coal in Table B-2 in Appendix B of EIS Appendix 30-A.

[4] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

References

Fraser Surrey Docks LP (FSD). 2015a. Application for an Amendment to Permit No. 2012-072 Direct Transfer Coal Facility. Available at http://www.portvancouver.com/wp-content/uploads/2015/07/July-2015-Application-for-an-Amendment-to-Permit-No-2012-072-Fraser-Surrey-Docks-DTCF-Amendment.pdf. Accessed May 2017.

Fraser Surrey Docks LP (FSD). 2015b. Round 2 Public Consultation. Application to Amend Permit No. 2012-072 Direct Transfer Coal Facility. July 17 – August 21, 2015, Discussion Guide and Feedback Form. Available at http://www.fsd.bc.ca/_documents/amendment/FSD_DiscussionGuide_Round2.pdf. Accessed May 2017.

Port Metro Vancouver (PMV). 2013. Ongoing Projects. Available at http://portmetrovancouver.com/en/projects/OngoingProjects.aspx. Accessed September 2013.

IR4-07 Vessel Traffic Projections: Peak and Non-peak Ship Traffic Movements

Information Source(s)

EIS Volume 1: Section 4.4.2.2, Figure 4-27

Context

The Proponent, in Section 4.4.2.2 of the EIS, reported that due to seasonal fluctuations, import container traffic can cause the 2.4 million vessel TEUs per year terminal capacity target to be exceeded during certain peak days or weeks. The preliminary design of the wharf considered peak periods and terminal equipment was designed to be capable of handling 3.0 million vessel TEUs per year and maintaining the average 2.4 million vessel-TEU design capacity.

Figure 4-27 of the EIS reported the annual ship movements for 2012 and 2030 at the Roberts Bank terminals.

More detailed information about the weekly peak and non-peak ship traffic movements (highs and lows) at the four terminals at Roberts Bank is required.

Information Request

Provide a figure, similar to Figure 4-27, to illustrate the weekly peak and non-peak ship traffic movements (highs and lows) at the proposed Roberts Bank Terminal 2, Westshore Terminals, Deltaport Terminal and B.C Ferries Terminal for 2012 and 2030, with and without the Project.

VFPA Response

Appendix IR4-07-A provides traffic movements for Westshore Terminals, Deltaport Terminal, B.C. Ferries Terminal, and RBT2 where appropriate in the following figures:

- Figure IR4-07-A1 illustrates peak traffic movements with RBT2 for 2012 and 2030;
- Figure IR4-07-A2 illustrates non-peak traffic movements with RBT2 for 2012 and 2030;
- Figure IR4-07-A3 illustrates peak traffic movements without RBT2 for 2012 and 2030; and
- Figure IR4-07-A4 illustrates non-peak traffic movements without RBT2 for 2012 and 2030.

Weekly movements, except for B.C. Ferries, were calculated based on annual ship movements provided in EIS Appendix 4-D. For container terminals, weekly movements are independent of peak or non-peak terminal throughput as container vessels are on a scheduled service[1], as described in IR1-05 of CEAR Document #897[2]. Consignment sizes (i.e., the number of containers loaded or offloaded from a vessel) will vary between peak and off peak times, but the number of weekly ship movements will not change. As shown in EIS Appendix 4-D, peak daily ship movements were calculated based on the number of terminal berths times two (i.e., one arrival and one departure per day per berth[3]) as a worst-case scenario, and cannot be used to calculate weekly peak movements. This is because frequency of vessel movements is based on five scheduled calls (10 movements) per week and the number of vessels dedicated to each service dictate the frequency of vessels arriving at a terminal. For the Deltaport Terminal, it is assumed that split call service will not occur in 2030 as it was discontinued in spring 2017, as outlined in IR4-04.

For Westshore Terminals, there is no publicly available information to determine peak weekly movements. Market conditions for coal affect the competitiveness of Westshore's customers and, together with changes in customers' mine output, affect the volume of coal handled by Westshore (Westshore 2016) and, therefore, the number of vessels calling at the terminal (i.e., bulkers are not on scheduled service). Based on uncertainty in global market conditions, it is assumed that there is no difference between peak and non-peak weekly movements. As with container terminals, the peak daily ship movements shown in EIS Appendix 4-D were calculated based on the number of terminal berths times two (i.e., one arrival and one departure per day per berth) as a worst-case scenario, and cannot be used to calculate weekly peak movements.

For B.C. Ferries' vessels, movements in 2012 to 2030 were assumed to be the same, as illustrated on EIS Figure 4-27. Peak and non-peak weekly movements were calculated based on the ferry schedules for Tsawwassen-Swartz Bay, Tsawwassen-Duke Point, and Tsawwassen-Southern Gulf Islands (B.C. Ferries 2017). As the ferry schedules for these routes vary throughout the year and weekly depending on demand, non-peak weekly movements were calculated from the October to March sailing schedule and peak weekly movements were calculated from the June to September sailing schedule.

References

B.C. Ferries. 2017. Schedules. Available at http://www.bcferries.com/schedules/mainland. Accessed May 2017.

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[1] There have historically been between 15 and 20 services that call the Port of Vancouver on a weekly basis and each service has five to seven vessels dedicated to it to cover the five to seven week duration roundtrip (dependent on routing, transit speed, number of port calls, etc.) Refer to Figure IR1-05-3 in IR1-05 for an example.

[2] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

[3] The worst-case scenario of one arrival and one departure per day per berth represents three of the five calls per week, and thus cannot be multiplied by seven to get a weekly total.

Westshore. 2016. Westshore Terminals Investment Corporation Annual Report 2015. Available at http://www.annualreports.com/HostedData/AnnualReports/PDF/TSX_WTE.UN_2015.pdf. Accessed May 2017.

Appendices

Appendix IR4-07-A Figures: Peak and Non-peak Traffic Movements with and without RBT2

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APPENDIX IR4-07-A

FIGURES: PEAK AND NON-PEAK TRAFFIC MOVEMENTS WITH AND WITHOUT RBT2

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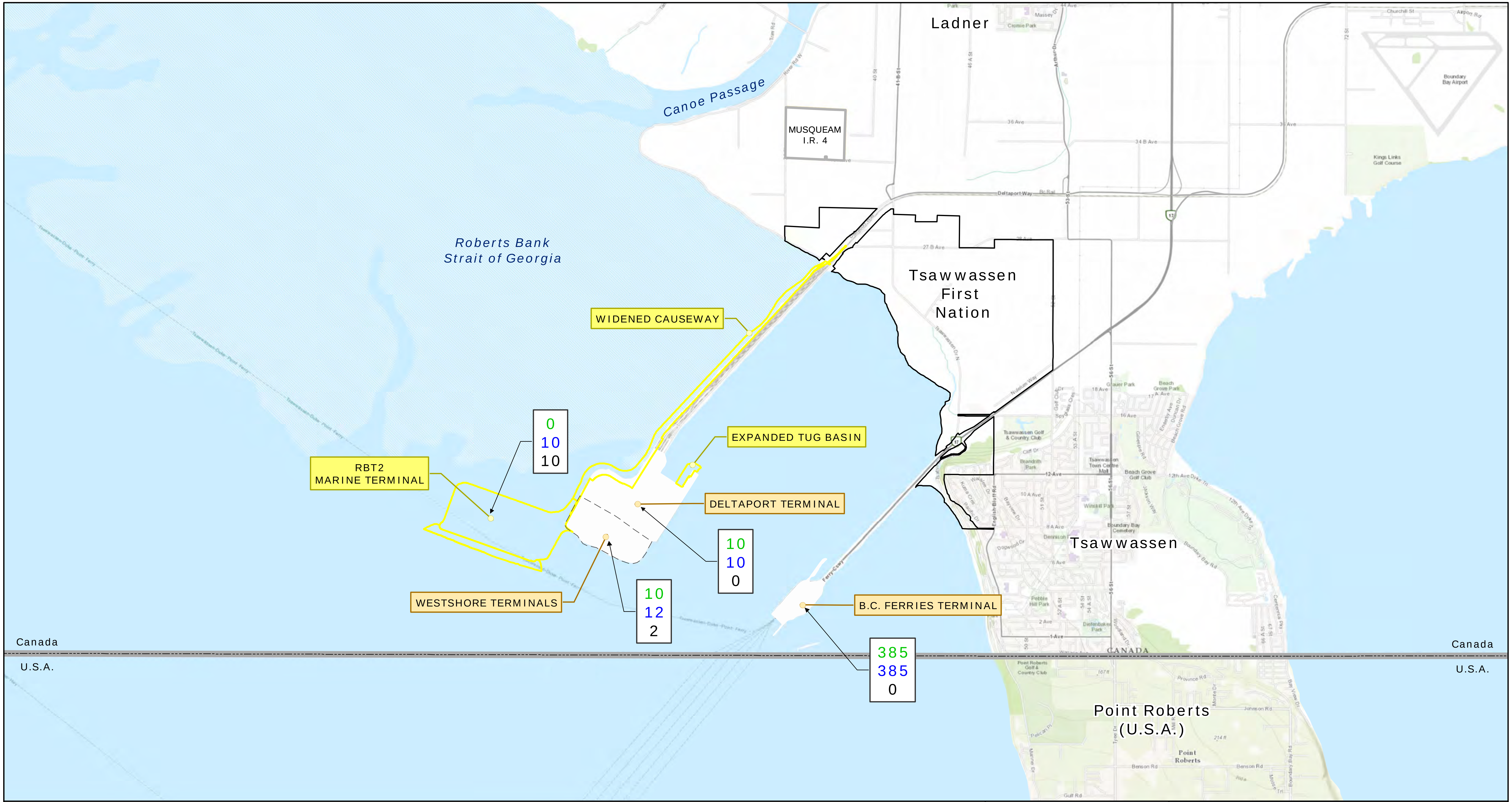

Legend

▭ BOUNDARY OF PROJECT AREA

▭ FIRST NATIONS RESERVE

┅ U.S.A.-CANADA BORDER

SHIP MOVEMENTS

2012
2030 Estimate
NET CHANGE

PROJECT COMPONENT

EXISTING LANDMARK

0 1 2
Kilometres
1:50,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

PEAK WEEKLY SHIP MOVEMENTS
WITH RBT2 FOR 2012 AND 2030

DATE: 07/20/2017

FIG No. IR4-07-A1

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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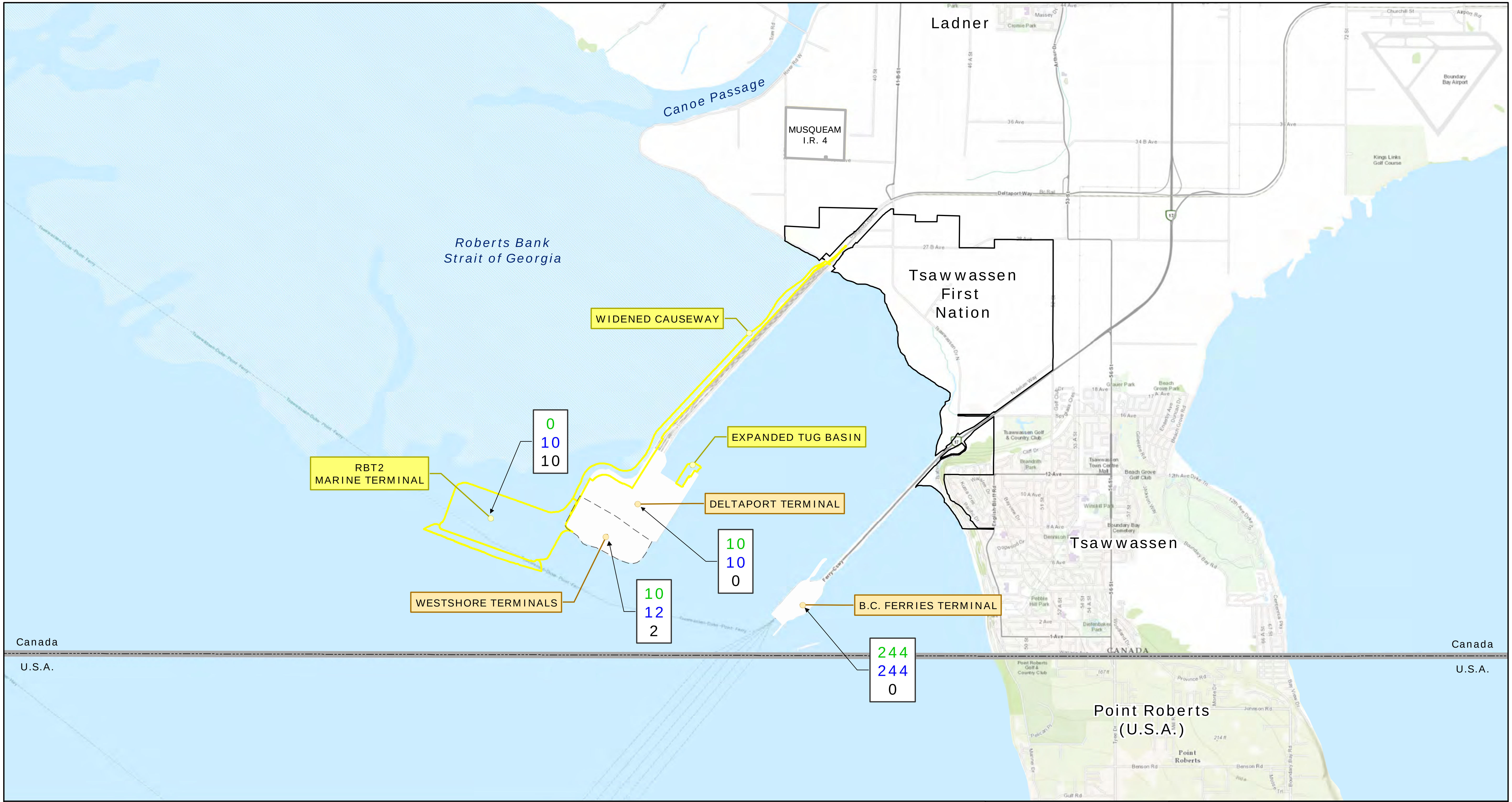

Legend

▭	BOUNDARY OF PROJECT AREA
▭	FIRST NATIONS RESERVE
- - -	U.S.A.-CANADA BORDER

SHIP MOVEMENTS

2012
2030 Estimate
NET CHANGE

PROJECT COMPONENT

EXISTING LANDMARK

0 1 2
Kilometres
1:50,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

NON-PEAK WEEKLY SHIP MOVEMENTS WITH RBT2 FOR 2012 AND 2030

DATE: 07/20/2017

FIG No. IR4-07-A2

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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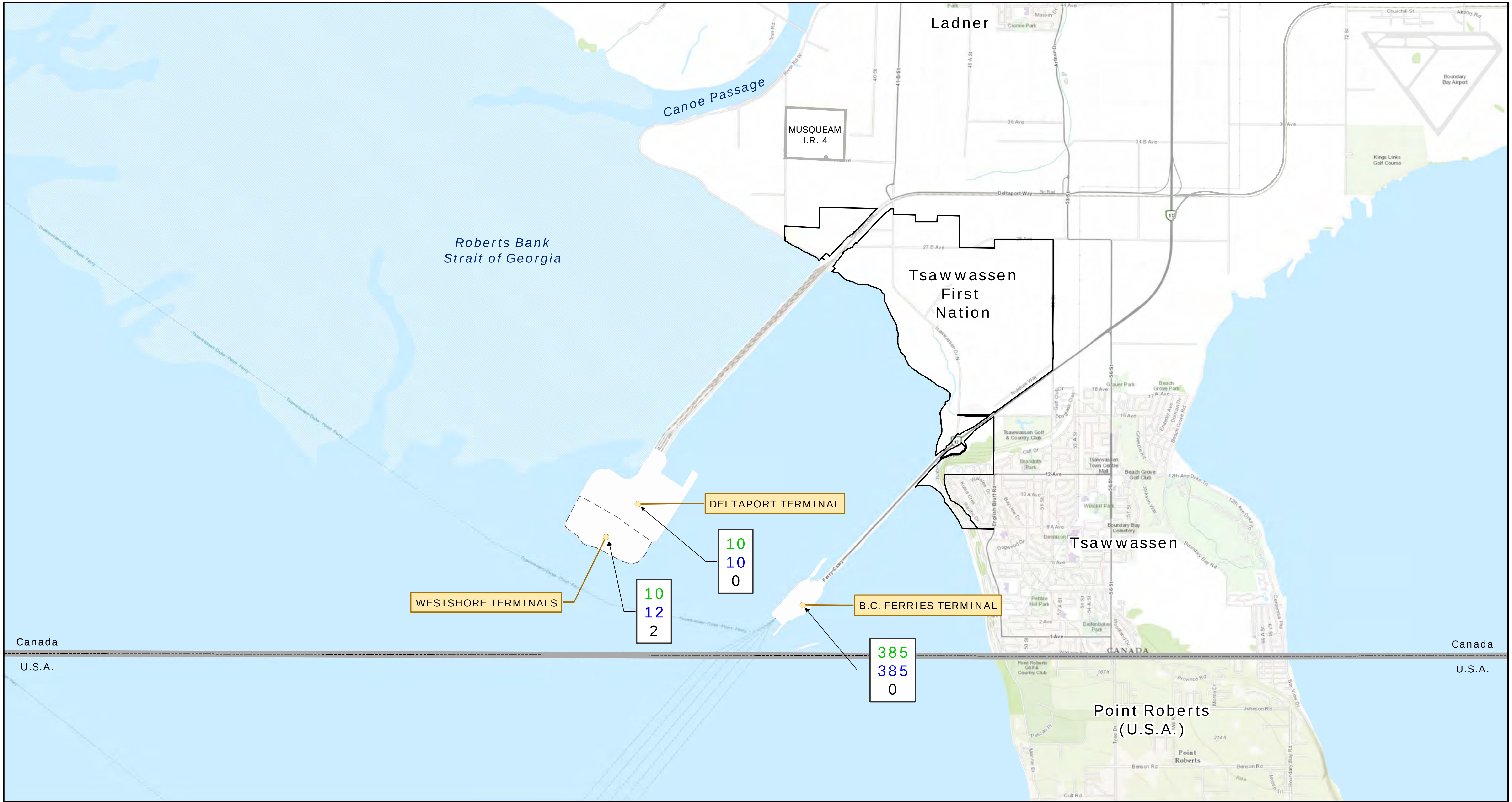

Legend

▭ FIRST NATIONS RESERVE

┅ U.S.A.-CANADA BORDER

SHIP MOVEMENTS

2012
2030 Estimate
NET CHANGE

EXISTING LANDMARK

0 1 2
Kilometres
1:50,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

PEAK WEEKLY SHIP MOVEMENTS WITHOUT RBT2 FOR 2012 AND 2030

DATE: 07/26/2017

FIG No. IR4-07-A3

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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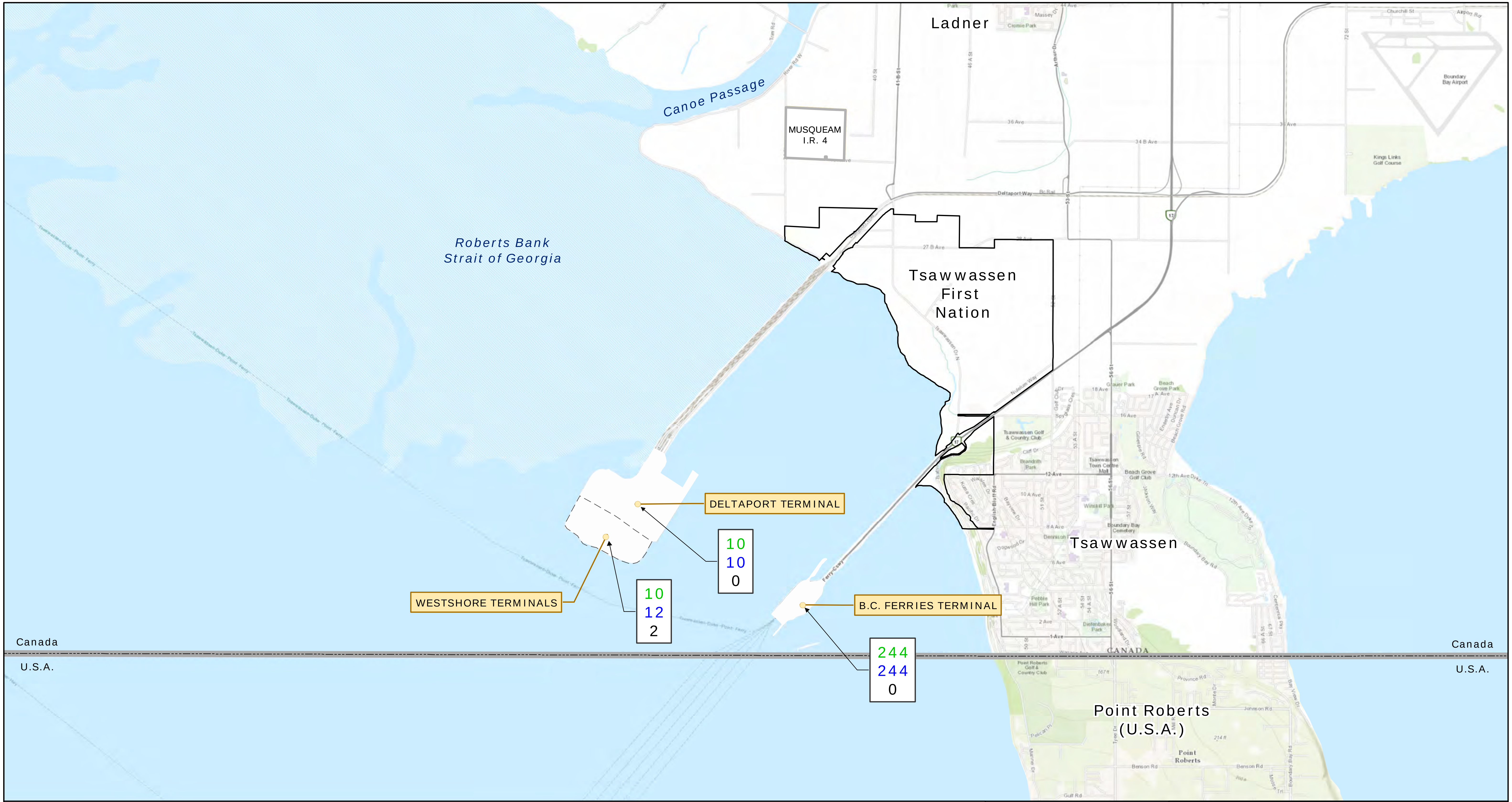

Legend

▭ FIRST NATIONS RESERVE

U.S.A.-CANADA BORDER

SHIP MOVEMENTS

2012
2030 Estimate
NET CHANGE

EXISTING LANDMARK

0 1 2
Kilometres
1:50,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

NON-PEAK WEEKLY SHIP MOVEMENTS
WITHOUT RBT2 FOR 2012 AND 2030

DATE: 07/26/2017

FIG No. IR4-07-A4

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

IR4-08 Vessel Traffic Projections: Tug Escort, Ferries

Information Source(s)

EIS Volume 1: Figure 4-27

Marine Shipping Addendum: Section 4.2.2.7; Appendix 10-A, Appendix A, Table A-3

Proponent Response to IR1-05 (CEAR Doc#897): Table IR1-05-1; Table IR1-05-2; Revised Figure 4-2 and Figure 4-3

Context

In Section 4.2.2.7 of the Marine Shipping Addendum, the Proponent stated that container ships do not require tugboat escort while transiting through Segments A to D. It is anticipated that the same will apply to the additional container ships associated with the proposed Project. All tugboat activity for the Project-associated container ships will be near the terminal. The Proponent in response to Review Panel information request IR1-05, provided information about vessel movements for various vessel types in Segment A-D and Segment F, for 2012 and 2030. For example, 4,592 tug movements were projected for Segment A in 2030. Information about the tug movements while acting as an escort vessel and on transit through the marine shipping area is required.

In response to the Review Panel information request IR1-05, the Proponent identified that the number of ferries movements in Segment A was adjusted by an additional 2,998 ferry traffic movements. This adjustment was made as a result of a slightly altered alignment of the cross-section used to calculated traffic in Segment A from the data gathered from the Trans Mountain Pipeline Project. In the information request response, it was reported that in Segment A, 8,632 movements of passenger vessel types (including ferries) occurred in 2012 and 9,570 passenger vessel movements (including ferries) would occur in 2030.

Information Request

Provide an explanation of which vessel types would require tugboat escort while moving through the marine shipping area. If tug escort is required for any vessel type, update movement tables for Segments A-G. The table should report the movements of each vessel type with and without tug escort and transiting tug movements.

Provide traffic movements for all existing small and large ferries operating in Segment A.

Clarify how the B.C. ferries movement data in Table A-3 in Appendix A of Appendix 10-A of the Marine Shipping Addendum is affected by the addition of 2,998 ferry traffic movements given in information request IR1-05 response.

Adjust Figure 4-27 of the EIS and Tables IR1-05-1, IR1-05-2 and revised Figures 4-2 and 4-3 of the Proponent's response to Review Panel information request IR1-05 as necessary.

VFPA Response

Provide an explanation of which vessel types would require tugboat escort while moving through the marine shipping area. If tug escort is required for any vessel type, update movement tables for Segments A-G. The table should report the movements of each vessel type with and without tug escort and transiting tug movements.

Tug escort is required for vessels over 40,000 deadweight tonnes (DWT) that carry liquids in bulk in excess of 6,000 tonnes that transit through Boundary Passage and Haro Strait (PPA 2015)[1], which are located in Segment B of the marine shipping area. For Segment B, escort tugs need to be tethered to such vessels from a position of two miles north of East Point to the vicinity of Race Rocks (Brotchie Ledge) or vice versa inbound (PPA 2015). These criteria apply to liquified natural gas (LNG) carriers, canola oil tankers, oil tankers, and chemical carriers (note that these vessels are included in the tanker vessel type category).

Movement data for Segments A to G includes tug escorts (for laden tankers and carriers) and tug transits (returning tugs) in the tug vessel type category for both 2012 and 2030 (refer to Figure IR4-04-2 in IR4-04 for information by segment).

As further explanation for 2030 projections, the following project information has been considered for transiting vessels requiring tug escort in Segments A to D of the marine shipping area:

- For the Kinder Morgan Trans Mountain Pipeline Expansion Project (note that this project is also referred to as Westridge Bitumen by the Panel in IR4-09), 360 tugs will be required for 360 oil tankers (i.e., one per vessel)[2];
- For the Pacific Coast Terminal Potash Handling System Project, 46 tugs will be required for 46 canola oil tankers[3];
- For the Vancouver Airport Fuel Delivery Project, 12 escort tugs will be required for 12 tankers (i.e., one per tanker) and no escort tugs will be required for the 26 tank barges[4] (barges will be towed by a tug so no additional 'escort' tug is required);
- For the WesPac Tilbury Marine Jetty Project, 540 tugs will be required for 180 LNG carriers (i.e., three escort tugs per carrier) and no escort tugs will be required for the

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[1] Escort tugs assist with navigation and are available to immediately respond or assist in the event of an emergency.

[2] Information from Table 4.4.1.2 of TMX (2013b), an information source used in Marine Shipping Addendum Appendix 10-A. Note that EIS Table 8-8 stated 344 tankers and 12 tank barges and Appendix B of EIS Appendix 30-A stated 350 tankers and 12 tank barges.

[3] Vessel projection information from VFPA Project Permit #2014-096 Project Review Report (PCT Potash Handling System) and VFPA Environmental Review Report and Schedule of Environmental Conditions for Project Permit #13-104 (Canola Oil Handling). Documents available upon request.

[4] Information from Vancouver Airport Fuel Facility Corporation (VAFFC 2016) states a tanker delivery per month and a barge delivery once every two weeks for the project. Note that the number of tank barges has decreased to 26 from the 48 assumed in EIS Table 8-8 and in EIS Appendix 30-A.

68 tank barges (barges will be towed by a tug so no additional 'escort' tug is required)[5]; and

- For the Woodfibre LNG Project, 120 escort tugs will be required for 40 LNG carriers (i.e., three escort tugs per carrier)[6].

For additional information for these projects including vessel movements and information sources, refer to Table IR4-09-A1 in Appendix IR4-09-A.

Table IR4-08-1 summarises the number of tugs required for tankers and barges associated with these certain and reasonably foreseeable projects with vessels transiting through Segments A to D. The table also summarises the vessel movements and associated escort and transit tug movements through Segments A to D.

Table IR4-08-1 Vessel and Tug Movements in Segments A to D for Certain and Reasonably Foreseeable Projects

Project	Vessel Type	Annual Calls	Annual Movements	Number of Tug Escort Movements	Number of Transiting Tug Movements	Total Number of Tug Movements
Kinder Morgan Trans Mountain Pipeline Expansion Project	Tanker	360	720	360	360	720
Pacific Coast Terminal Potash Handling System Project	Tanker	23	46	23	23	46
Vancouver Airport Fuel Delivery Project	Tanker Barge	12 26	24 52	12 0	12 52	24 52
WesPac Tilbury Marine Jetty Project	LNG Carrier (Tanker)	90	180	270	270	540
	Barge	34	68	0	68	68
Woodfibre LNG Project	LNG Carrier (Tanker)	40	80	120	120	240
Total				**785**	**905**	**1,690**

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[5] LNG carrier and barge vessel projection information from B.C. Environmental Assessment Office (2016).

[6] Information from Woodfibre LNG (2017) states that at least three tugboats will be deployed per LNG carrier.

The number of tugs associated with these projects were largely captured in the one percent increase annually over an 18-year period[7], even though at the time of the assessment there was no existing LNG carrier traffic through Segments A to D (and LNG facilities within the region were not yet proposed). For further explanation, refer to IR4-09.

Tug escorts were included in the tug vessel type movement data provided previously in IR1-05 of CEAR Document #897[8], and are also included in the tables and figures provided in IR4-04. There are no known certain and reasonably foreseeable projects anticipated to change the existing (2012) tug movements provided for Segments F and G in IR4-04.

To reiterate, the vessel traffic predictions in the EIS and Marine Shipping Addendum assumed there would be an increase in marine shipping traffic. As explained in Marine Shipping Addendum Information Request #6 (MSA IR-02.24.16-6 of CEAR Document #391[9]) and Marine Shipping Addendum Appendix 10-A: Section 2.4.2, a growth rate from 2012 traffic levels of between 1% to 2% per year to 2030 was assumed for most traffic sectors. Actual traffic growth rates may be lower than those assumed in the Marine Shipping Addendum, as increasing ship size is anticipated in nearly all traffic sectors in the future (i.e., increases in vessel size would lower the number of vessel calls (and associated tug escorts) compared to holding vessel size constant), and this has not been accounted for in the assumed future traffic projections (see Marine Shipping Addendum Appendix 10-A and IR4-09).

Provide traffic movements for all existing small and large ferries operating in Segment A.

Traffic movements for all B.C. Ferries operating out of the Tsawwassen ferry terminal are included in the EIS Figure 4-27 for an annual number. As requested in IR4-07, all B.C. Ferries movements operating out of the Tsawwassen ferry terminal are included in Figures IR4-07-1 to IR4-07-4 for weekly peak and non-peak numbers.

As clarified in the Marine Shipping Addendum Appendix 10-A: Appendix A, Section A 2-4, the Northern Route ferries operating between Tsawwassen and Duke Point are not included in the Segment A total since they do not transit through Segment A aside from the brief period when they depart the terminal. The ferries on this route cross the international shipping lanes north of Segment A. Segment A thus accounts for the B.C. Ferries that operate on the Southern routes between the Tsawwassen terminal and the island terminals at Swartz Bay and the Southern Gulf Islands and cross the international shipping lanes in Segment A.

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[7] Note that the tug movements incorporate the outbound trip while escorting a tanker, and while pulling a barge, plus the inbound trip returning to point of origin. As an example of tug movements in Segment A, the 2030 calculated incremental increase assumed for certain and reasonably foreseeable projects and activities was 1,355 movements per year (refer to Marine Shipping Addendum Appendix 10-A: Table 3-1 and IR4-04).

[8] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

[9] CEAR Document #391 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Marine Shipping Addendum Completeness Review - Responses to Additional Information Requirements (See Reference Document #386).

Clarify how the B.C. ferries movement data in Table A-3 in Appendix A of Appendix 10-A of the Marine Shipping Addendum is affected by the addition of 2,998 ferry traffic movements given in information request IR1-05 response.

The 2,998 ferry movements are already included in Table A-3 in Appendix A of Marine Shipping Addendum Appendix 10-A and in EIS Figure 4-27, and have been incorporated in the IR1-05 response (CEAR Document #897), as outlined in the note to Table IR1-05-1 "Compared to TMX 2013a, the Marine Shipping Addendum accounts for an additional 2,998 ferry traffic movements as a result of a slightly altered alignment of the cross-section used to calculated traffic in Segment A". As further clarification, there are no additional ferry movements that need to be updated for the content provided in previous documents. The cross-section alignment from TMX (2013a) was parallel to the B.C. Ferries route and did not adequately capture all the ferry traffic for the Southern routes between the Tsawwassen terminal and the island terminals at Swartz Bay and the Southern Gulf Islands. The realignment captured these movements.

Adjust Figure 4-27 of the EIS and Tables IR1-05-1, IR1-05-2 and revised Figures 4-2 and 4-3 of the Proponent's response to Review Panel information request IR1-05 as necessary.

No adjustments to EIS Figure 4-27 or tables or figures provided in IR1-05 (CEAR Document #897) are required as outlined above. Note that Figures 4-2 and 4-3 of the Marine Shipping Addendum, which were revised and included in IR1-05, have been superseded by Figures IR4-04-1 and IR4-04-2 in IR4-04, and Tables IR1-05-1 and IR1-05-2 in IR1-05 have been superseded by Tables IR4-04-1 and IR4-04-2 in IR4-04.

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IR4-09 Vessel Traffic Projections: Excluded Projects Reconciliation

Information Source(s)

EIS Volume 5: Appendix 30-A, Appendix B, Table B-2

Marine Shipping Addendum: Appendix 6-A; Appendix 10-A, Appendix A

Proponent response to Additional Information Requirements of April 8, 2016 (CEAR Doc#391): IR6; IR7, Table IR7-2

Proponent Response to IR1-05 (CEAR Doc#897): Table IR1-05-1; Table IR1-05-2; Revised Figure 4-2 and Figure 4-3

Context

Appendix 6-A of the Marine Shipping Addendum and Appendix B, Table B-2 of Appendix 30-A of the EIS differ in their list of projects included and ship population. For instance, Kinder Morgan Trans-Mountain Pipeline Expansion Project is presented in both documents but Appendix 6-A of the Marine Shipping Addendum adds 360 tugs. Gateway Pacific Bulk Terminal is excluded in Appendix 6-A of the Marine Shipping Addendum. Gateway Pacific Terminal at Cherry Point is not in Table B-2 of Appendix 30-A of the EIS. Further, Appendix A of Appendix 10-A of the Marine Shipping Addendum discusses the need for reconciliation of vessel traffic data used in Appendix 30-A of the EIS and Appendix 10-A of the Marine Shipping Addendum. Some projects are not included in either Appendix 6-A of the Marine Shipping Addendum or Appendix 30-A of the Environmental Impact Statement and information is required on these projects.

In Appendix 6-A of the Marine Shipping Addendum rationale provided for the exclusion of some projects in the assessment was that it was too early in the environmental review process to have the required information; others were not listed because they were not considered to be reasonably foreseeable.

Some of the excluded projects have passed the preliminary design stage and information is now available. Information is also required on all vessel traffic whether considered by the Proponent to be negligible or not.

Information Request

In a table, list, complete and reconcile the information given in Appendix 6-A of the Marine Shipping Addendum and Appendix B, Table B-2 of Appendix 30-A of the EIS in terms of vessel population, transits and movements for the relevant segments and categories of vessels for 2012 and 2030, with and without the Project.

Include, where appropriate, the following projects:

- Westpac Tilbury LNG Project

- Wespac Tilbury Marine Jetty Project
- Woodfibre LNG Project
- Centerm Terminal Expansion
- BURNCO Aggregate Project
- Lehigh Hanson Aggregate Facility
- Discovery LNG, Campbell River BC
- West Coast Reduction
- PMV Viterra Grain Terminal
- PMV Westridge bitumen Terminal
- Pacific Coast Terminals (canola)
- Steelhead Malahat LNG Project (Island Gas LNG)
- Shell refinery expansion, Anacortes WA
- Tesoro Refining, Anacortes WA
- Northwest Seaport Alliance Container Terminal, Seattle and Tacoma WA (data for existing and on-going expansions)

Adjust Tables IR-05-1 and IR1-05-2 and revised Figures 4-2 and 4-3 as necessary.

VFPA Response

In a table, list, complete and reconcile the information given in Appendix 6-A of the Marine Shipping Addendum and Appendix B, Table B-2 of Appendix 30-A of the EIS in terms of vessel population, transits and movements for the relevant segments and categories of vessels for 2012 and 2030, with and without the Project.

Include, where appropriate, the following projects: Westpac Tilbury LNG Project; Wespac Tilbury Marine Jetty Project; Woodfibre LNG Project; Centerm Terminal Expansion; BURNCO Aggregate Project; Lehigh Hanson Aggregate Facility; Discovery LNG, Campbell River BC; West Coast Reduction; PMV Viterra Grain Terminal; PMV Westridge bitumen Terminal; Pacific Coast Terminals (canola); Steelhead Malahat LNG Project (Island Gas LNG); Shell refinery expansion, Anacortes WA; Tesoro Refining, Anacortes WA; and Northwest Seaport Alliance Container Terminal, Seattle and Tacoma WA (data for existing and on-going expansions)

Information to respond to this information request is provided in several parts, as outlined below:

- A comparison of vessel movements (or transits) for the projects listed in the EIS Appendix B Table B-2 of Appendix 30-A and Marine Shipping Addendum (MSA) Appendix 6-A is provided. Updated information for these projects based on publicly available information as of July 1, 2017 is also provided;
- Clarification is provided on the approach used in the MSA to determine future vessel projections in segments of the marine shipping area—the approach involved the application of annual growth rate increases for vessel type categories, not future project-related increases; and
- Updated project status and vessel movement information is provided for the projects listed in this information request, plus other projects considered to be certain or reasonably foreseeable (as of July 1, 2017). Updated vessel movements based on incremental project-related increases are compared to vessel movements determined by the growth rate increase approach.

Comparison of Vessel Movement Information Provided in the EIS and MSA

A comparison of the vessel movements expected in 2030 for the seven projects listed in Table B-2 in Appendix B of EIS Appendix 30-A and the nine projects (i.e., those anticipated to contribute to future vessel traffic increases) listed in MSA Appendix 6-A is provided in **Table IR4-09-1**. Updated information (as of July 1, 2017) is also provided for each project in **Table IR4-09-1**. For comparison purposes, vessel traffic activity in 2030 is provided as incremental vessel movements (i.e., the difference between the forecast 2030 and actual 2012 vessel movement data).

As shown in **Table IR4-09-1**, the information provided in EIS and MSA was complete based on information available at the time of preparation of those documents. As vessel movements projections provided in the documents were comparable, reconciliation of the information is not required. Taking into consideration updated vessel movement projections, vessel movements for some projects have changed over time because of projects formally entering a project review process (e.g., Woodfibre LNG Project), project details being revised (e.g., Fraser Surrey Docks), or projects being cancelled (e.g., Gateway Pacific Bulk Terminal). Additional information is provided for each project in Table IR4-09-A1 in **Appendix IR4-09-A**, including project location, project status, vessel movements by vessel type, and information sources.

Table IR4-09-1 Comparison of Annual Incremental Vessel Movements Provided in the EIS and MSA, and Updated Information for Nine Certain or Reasonably Foreseeable Projects

Project	Vessel Type	Predicted Annual Vessel Movements by 2030		
		EIS[a]	MSA[b]	Updated Projections[c]
Fraser Surrey Docks Direct Transfer Coal Facility Project	Cargo barge	1,000	1,000	0
	Bulker	160	160	160
Richardson Grain Storage Capacity Project	Bulker	24	24	0
Neptune Terminals Coal Handling – Replacement Stacker Reclaimer	Bulker	120	120	73
Vancouver Airport Fuel Delivery Project	Tanker	24	24	24
	Barge	96	96	52
	Escort Tug	0	0	24
Kinder Morgan Trans-Mountain Pipeline Expansion Project	Tanker	700	720	720
	Escort Tug	0	720	720
Gateway Pacific Bulk Terminal	Bulker	50 (980)[d]	974	0[d]
Pacific Coast Terminals (PCT) (Canola Oil Handling Project	Bulker[e]	208	208	88
	Tanker[e]			46

Project	Vessel Type	Predicted Annual Vessel Movements by 2030		
		EIS[a]	MSA[b]	Updated Projections[c]
and Potash Handling System Project)	Escort Tug	0	0	46
Deltaport Terminal Road and Rail Improvement Project (DTRRIP)	Container	86[f]	86	86
Woodfibre LNG Project	Tanker (LNG Carrier)	0[g]	0[g]	80
	Tug	0[g]	0[g]	240

Notes:

a. Vessel movements based on number of ships (calls) listed in Table B2 in Appendix B of EIS Appendix 30-A.
b. Vessel movements based on predicted annual increase in calls listed in MSA Appendix 6-A.
c. For project details and sources of information, refer to Table IR4-09-A1 in **Appendix IR4-09-A**.
d. As described in Section 3.3.4 of EIS Appendix 30-A, 50 bulker movements was based on 5% of vessels moving northward (total number of vessels estimated at 490). This project was recently withdrawn from the federal permit review process, as outlined below.
e. At the time of EIS preparation, vessel movements associated with the PCT project were unknown, and the vessel projection was based on a five-year trend for the chemical carriers calling at PCT (see Appendix B in EIS Appendix 30-A). The increase in bulkers and tankers to transport potash and canola oil was listed as an increase in chemical carriers in both the EIS and MSA.
f. Although DTRRIP was not listed in Table B-2 of Appendix B in EIS Appendix 30-A, existing and future ship calls for terminals at Roberts Bank were provided in Table 3-2 of EIS Appendix 30-A.
g. This project was not yet proposed publicly at the time of preparation of the EIS Appendix 30-A. As stated in MSA Appendix 6-A, due to the early stage of the project, vessel numbers were released publicly after traffic projections for the marine shipping assessment were completed.

The increase in future vessel traffic in segments of the marine shipping area was not based on anticipated traffic increases associated with certain or reasonably foreseeable projects. As previously explained in MSA Appendix 10-A (Section 2.4.2) and the response to Marine Shipping Addendum Information Request #7 (MSA IR-02.24.16-7 of CEAR Document #391[1]), the approach taken to forecast future traffic levels involved applying a growth rate from 2012 traffic levels of between 1% to 2% per year to 2030 for most vessel type categories[2]. Additional vessel information was incorporated as necessary to accurately reflect existing or future conditions (see IR4-04 for further explanation by segment). A comparison of projected vessel movements using the growth rate approach to a project-based approach is provided below for segments of the marine shipping area relevant to the projects listed in this request plus for other certain and reasonably foreseeable projects.

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[1] CEAR Document #391 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Marine Shipping Addendum Completeness Review - Responses to Additional Information Requirements (See Reference Document #386).

[2] The growth rates used were from the published projections from Seaport Consultants Canada (2013) in a report prepared for the Trans Mountain Expansion Project. The 2012 vessel movement estimates for the marine shipping area were based on published vessel movements from the Kinder Morgan Trans Mountain Expansion Project TERMPOL Reports (TMX 2013).

Comparison of Vessel Projection Approaches

Vessels associated with the projects listed in this request, except the BURNCO Aggregate Project, will transit either through Haro Strait (Segment B) or Rosario Strait (Segment F). The BURNCO Aggregate Project, a proposed sand and gravel mine, processing plant, and marine barge loading facility located in Gibsons, B.C., involves the transport of aggregate via barges through Howe Sound to existing BURNCO facilities in Burnaby or Langley via the Fraser River. Vessels will not transit through the marine shipping area and, therefore, this project is not included in either of the comparisons provided below.

Segment B Haro Strait Vessel Movement Comparison

Table IR4-09-2 provides projected incremental vessel movements in 2030 by vessel type through Segment B (Haro Strait) based on publicly available vessel traffic information for certain or reasonably foreseeable projects as of July 1, 2017. Projects shown in bold in the table were listed in the request, and additional projects (in plain text) have also been included to provide a complete list of certain and reasonably foreseeable projects anticipated to contribute to changes in future vessel traffic. The total number of movements by vessel type is provided at the bottom of the table along with the incremental vessel movements[3] determined from vessel type growth rate increases from 2012 Automatic Identification System (AIS) data at cross-section 2. Additional information is provided for each project in Table IR4-09-A1 in **Appendix IR4-09-A**.

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[3] Incremental increases were determined by subtracting 2012 AIS vessel movement data from 2030 vessel movement projections that were provided for Segment B in Figure IR4-04-2 in IR4-04.

Table IR4-09-2 Segment B (Haro Strait) Incremental Vessel Movements in 2030 by Vessel Type for Certain and Reasonably Foreseeable Projects Compared to Growth Rate Vessel Movement Projections

Project	Projected Incremental Vessel Movements in 2030 by Vessel Type							
	Cargo/Carrier	Container	Tug	Service	Passenger	Tanker	Other/Unknown	Fishing
Centerm Terminal Expansion		120						
Deltaport Terminal Road and Rail Improvement Project		86						
Deltaport Terminal - Discontinued Split Call Service		-208						
Discovery LNG			UNK			UNK		
Fibreco Export Terminal Enhancement	-6							
Fraser Grain Terminal Project	160							
Fraser Surrey Docks Direct Coal Transfer Facility	160	-154[a]						
G3 Western Grain Terminal	178							
Lehigh Hanson Aggregate Facility			0					
Neptune Phosphate Rock Handling	0							
Neptune Terminals Coal Handling Capacity Expansion	73							
Northwest Seaport Alliance		0[b]						
Pacific Coast Terminals (PCT) (**Canola Oil Handling Project** and Potash Handling System Project)	88		46			46		
Richardson International Grain Storage Capacity Project	0							
Roberts Bank Terminal 2 (RBT2)		520						
Steelhead Malahat LNG Project (Island Gas LNG)			UNK			UNK		
Vancouver Airport Fuel Delivery Project			76			24		
Viterra Grain Terminal - Shiploading System Upgrade at Pacific Terminal	85							
WesPac Tilbury LNG Project (Fortis LNG Plant, Fortis Expansion)								

Project	**Projected Incremental Vessel Movements in 2030 by Vessel Type**							
	Cargo/Carrier	**Container**	**Tug**	**Service**	**Passenger**	**Tanker**	**Other/Unknown**	**Fishing**
WesPac Tilbury Marine Jetty Project			608			180		
West Coast Reduction - Railcar Unloading Facility Improvement Project	0							
Westridge Marine Terminal (Kinder Morgan Pipeline Expansion Project, or Trans Mountain Expansion Project)			720			720		
Westshore Terminals - Equipment Replacement and Upgrade	60							
Woodfibre LNG Project			240			80		
Project-based Approach - Total Vessel Movements	**798**	**364**	**1,690**	**0**	**0**	**1,050**	**0**	**0**
Growth Rate Approach - Total Vessel Movements	**522**	**362**	**911**	**167**	**99**	**887**	**269**	**0**

Notes: Bolded projects are those specifically listed in the information request. UNK = unknown vessel movement projections based on lack of publicly available information as of July 1, 2017.

a. Fraser Surrey Docks is undergoing significant redevelopment over the coming years, and as they re-purpose from their diminishing opportunity in container capacity to other commodities, container volume is expected to continue to reduce from 154 movements per year (based on actual 2014 vessel call data, as provided in IR4-03) to near zero.

b. For two projects proposed by the Northwest Seaport Alliance, a decrease of 188 container vessel movements per year is predicted (refer to Table IR4-09-A1 in **Appendix IR4-09-A** for details). This decrease has not been included in the project-based approach total in order to be consistent with the EIS and MSA assumption that vessel numbers will remain constant in the future, regardless of the increasing container vessel size trend.

Compared to the project-based approach, the growth rate approach resulted in similar vessel movement projections for the container category (less than 1% difference) and higher vessel movement projections through Segment B for the service, passenger, and other/unknown categories. The project-based approach resulted in higher vessel movement projections for the cargo/carrier, tug, and tanker categories, primarily as a result of two new grain terminal projects and the introduction of proposed LNG facilities to the B.C. coast.

At the time of EIS preparation, which reflects projects and associated activities that were certain and reasonably foreseeable as of October 1, 2013, future LNG carrier movements were not available publicly. As outlined in Table B-3 in Appendix B of EIS Appendix 30-A, there were no LNG carriers transiting through the marine shipping area in 2012, and hence, the growth rate approach for Segment B cannot be used for this newly-introduced vessel type (i.e., it is not possible to apply a percentage increase to zero traffic). For the cargo/carrier and container vessel categories, increasing ship size is anticipated in the future, which would result in lower vessel movements compared to holding the vessel size constant. As examples, the projects proposed by the Northwest Seaport Alliance are expected to result in a decrease of 188 container vessel movements per year and Westshore Terminals also anticipates that increasing ship size could decrease projected movements (refer to Table IR4-09-A1 in **Appendix IR4-09-A** for project details). The project-based approach to estimate cargo/carrier and container vessel movements, therefore, conservatively assumes more vessel movements (and that all proposed projects will proceed).

Segment F Rosario Strait Vessel Movement Comparison

Oil refining in Washington State involves marine transport through Segment F of both crude oil and refined petroleum products to and from the major petroleum refineries including BP Cherry Point and Phillips 66 near Ferndale, Shell Oil near Anacortes, and Tesoro on March Point.

The status of projects proposed at these refineries has changed since the submission of the MSA, except for Phillips 66 (excluded as a reasonably foreseeable project, as outlined in the response to MSA IR-02.24.16-7 of CEAR Document #391). Regarding the Gateway Pacific Bulk Terminal at Cherry Point, which was considered a reasonably foreseeable project in the EIS and MSA, in February 2017, the proponent withdrew all permit applications after the US Army Corps of Engineers denied the application for Federal permits until impacts to treaty fishing rights can be resolved. The 487 to 490 vessel calls (974 to 980 movements) associated with this project that were anticipated in 2030 (as outlined in EIS Appendix 30-A and Marine Shipping Addendum Appendix 6-A; see **Table IR4-09-1**) are no longer considered reasonably foreseeable. Figure IR4-04-2 in IR4-04 provides revised 2030 vessel projections in Segment F to incorporate this project change.

Table IR4-09-3 provides incremental vessel movements in Segment F based on a hybrid approach that combined growth rate increases and projected project-specific vessel movements[4]. Additional information is provided for each project in Table IR4-09-A2 in **Appendix IR4-09-A**.

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[4] Vessel traffic for Segment F for 2012 was calculated by subtracting cross-section 2 data from cross-section 3 for vessels following international shipping lanes for most vessel categories, and 684 tanker movements and 1,368 tug movements were added for the BP Cherry Point Marine Terminal Dock (Segment F data provided in Figure IR4-04-1 in IR4-04). For 2030, percentage growth rate increases were applied to all categories, and 840 tanker movements and 1,680 escort tug movements were added for the BP Cherry Point Marine Terminal Dock. Passenger and other/unknown vessel types were not calculated as data relevant to Segment F are not captured at these cross-sections.

Table IR4-09-3 Segment F (Rosario Strait) Incremental Vessel Movements in 2030 by Vessel Type for Certain and Reasonably Foreseeable Projects Compared to Growth Rate Vessel Movement Projections

Project	Projected Incremental Vessel Movements in 2030 by Vessel Type							
	Cargo/Carrier	Container	Tug	Service	Passenger	Tanker	Other/Unknown	Fishing
BP Cherry Point Marine Terminal Dock			312			156		
Shell Refinery Expansion (Shell Puget Sound Refinery)			0			0		
Tesoro Refining			-30			-30		
Project-based Total Vessel Movements	**0**	**0**	**282**	**0**	**0**	**126**	**0**	**0**
Hybrid Growth Rate-based Vessel Movements	**156**	**0**	**756**	**91**	**n/a**	**156**	**n/a**	**0**

Notes: Bolded projects are those specifically listed in the information request. n/a = not available; passenger and other/unknown vessel types were not calculated as data relevant to Segment F are not captured by the cross-sections used in the calculations.

Compared to the project-based approach, the hybrid growth rate approach resulted in higher vessel movement projections through Segment F for all vessel type categories. As container vessels do not transit through Rosario Strait (refer to IR1-05 of CEAR Document #897[5] for more information), the comparison provided above is applicable for future conditions for both the with, and without, Project scenario.

Given the uncertainty associated with proposed projects proceeding through permitting or proceeding once permitted, the growth rate approach provides reasonable future vessel traffic projections, and is an accepted approach for the assessment of marine shipping activities. The approach taken has been reviewed by Transport Canada's Economic Analysis (TEA) team (see CEAR Document #982[6]). In CEAR Document #962[7], the Panel requested that Transport Canada "Provide a detailed discussion of the analysis that lead Transport Canada to conclude that the Project projections regarding container percentages, forecasted volumes, and projected dates by when new container terminal capacity will be required, seem reasonable and accurate." As stated in CEAR Document #982, while TEA cannot claim to validate the

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[5] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

[6] CEAR Document #982 From Transport Canada to the Review Panel re: Response to Information Requests issued by the Review Panel on May 10, 2017 (See Reference Document 962).

[7] CEAR Document #962 From the Review Panel to Transport Canada re: Information Requests to Transport Canada regarding the Roberts Bank Terminal 2 Project.

forecasts and capacity needs of the West Coast Ports, they reviewed the information provided by the VFPA and "regard it to be broadly reasonable based on the most recent publicly available data."

Adjust Tables IR-05-1 and IR1-05-2 and revised Figures 4-2 and 4-3 as necessary.

IR4-04 updates information previously provided in Tables IR1-05-1 and IR1-05-2 and revised Figures 4-2 and 4-3 (refer to Tables IR4-04-1 and IR4-04-2 and figures provided in Appendix IR4-04-A). Based on the growth rate approach to project future vessel movements used in the assessment of marine shipping associated with the Project, further updates are not required.

References

Seaport Consultants Canada, Inc. 2013. Projections of Vessel Movements Report. Prepared for Kinder Morgan Trans Mountain Pipeline Expansion Project. Vancouver, B.C.

Trans Mountain Pipeline ULC (TMX). 2013a. Trans Mountain Pipeline Expansion Project: An Application Pursuant to Section 52 of the National Energy Board Act. Volume 8C: Volume 8C TERMPOL Reports. Available at https://docs.neb-one.gc.ca/lleng/llisapi.dll?func=ll&objId=2451003&objAction=browse&viewType=1. Accessed October 2016.

Appendices

Appendix IR4-09-A Supporting Tables

APPENDIX IR4-09-A
SUPPORTING TABLES

Appendix IR4-09-A:

Table IR4-09-A1 Segment B: Project Information for Certain and Reasonably Foreseeable Projects, including Anticipated Annual Incremental Vessel Movements by Vessel Type

Project	Project Location	Project Status as of July 1, 2017	Cargo/ Carrier	Container	Tug	Service	Passenger	Tanker	Other/ Unknown	Fishing
Centerm Terminal Expansion[a]	Vancouver, B.C.	Project permit (File no. 15-012) currently under review by the VFPA. Proposed improvements include increasing annual terminal capacity from 900,000 TEUs to 1.5 million TEUs. Should it be approved, construction of the project is anticipated to start in 2017 and be completed in late 2019. Existing vessel calls average of 5 per week (480 movements annually), and with expansion vessel calls will increase to an average of 6 per week (600 movements annually), an increase of 120 vessels movements per annum.		120						
Deltaport Terminal Road and Rail Improvement Project (DTRRIP)[b]	Delta, B.C.	Road and rail infrastructure project to increase container capacity at the Deltaport Terminal from 1.8 MTEUs to 2.4 MTEUs through improvements to existing port infrastructure within the existing terminal, road and rail footprints. Construction work to reconfigure the intermodal yard is currently underway and is expected to be complete by 2017 (VFPA Project Permit #15-029).		86						
Deltaport Terminal - Discontinued Split Call Service[c]	Delta, B.C.	As of April 1, 2017, with the establishment of new container shipping alliances, the split call service at Deltaport Terminal, which was assumed to continue in 2030 as stated in prior documentation (i.e., EIS and Marine Shipping Addendum, from assumptions provided in Appendix A of CEAR Document #667[1]) has been discontinued. As four movements are associated with the weekly split call service, a decrease of 208 movements is anticipated in 2030.		-208						
Discovery LNG[d]	Campbell River, B.C.	Project includes building and operating natural gas liquefaction, storage, and on-loading facilities to convert produced natural gas primarily from B.C. into LNG for export to Asia. An export licence was issued by the National Energy Board (NEB) in June 2015, but as outlined in Marine Shipping Addendum Information Request #7 (MSA IR-02.24.16-7 of CEAR Document #391[2]), the issuance of an export licence does not indicate the project is certain or even likely to proceed. A feasibility study has not been completed and an environmental assessment has not been submitted—vessel projections are unknown.			Unknown			Unknown		
Fibreco Export Terminal Enhancement[e]	North Vancouver, B.C.	The Fibreco Terminal Enhancement Project proposes to enhance the terminal's current wood pellet operations, add new grain export operations and remove the woodchip exporting infrastructure. In April 2017, Fibreco submitted a project permit application (VFPA File no. 16-268). Project construction is anticipated to be completed by the end of 2018. For 2012, annual vessel movements were 136 and upon project completion, vessel movements are anticipated to decrease by six movements annually to 130 movements.	-6							
Fraser Grain Terminal Project[f]	Surrey, B.C.	The project involves the construction of a grain export facility with a throughput of 4 Mt/year. The project permit application is currently under preliminary review by the VFPA (File no. 15-041). Based on preliminary information, the terminal will see between one to three bulk vessels per week or approximately 160 movements per year.	160							
Fraser Surrey Docks (FSD) Direct Coal Transfer Facility[g]	Surrey, B.C.	The VFPA approved the FSD project to build and operate a direct transfer coal facility to handle up to 4 million tonnes of coal within its existing lease area (Project Permit 12-072-01). As outlined in IR4-06, it is anticipated that coal will be loaded directly to ocean-going vessels (i.e., barges no longer required). Since FSD will be re-purposed from a container terminal to a bulk terminal, container traffic is expected to reduce from 154 movements annually (based on 2014 actual call data) to zero.	160	-154						

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[1] CEAR Document #667 From the Vancouver Fraser Port Authority to the Review Panel re: Orientation Session #2 Undertaking #1: Estimate of the number of ultra-large ships that would call on Roberts Bank Terminal 2.

[2] CEAR Document #391 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Marine Shipping Addendum Completeness Review - Responses to Additional Information Requirements (See Reference Document #386).

Project	Project Location	Project Status as of July 1, 2017	Cargo/ Carrier	Container	Tug	Service	Passenger	Tanker	Other/ Unknown	Fishing
G3 Western Grain Terminal[h]	North Vancouver, B.C.	In 2012, there were 158 movements associated with the existing break bulk terminal. The project proposal includes partially repurposing the facility to include a grain export facility with operation in 2019, reaching capacity in 2023. At capacity, vessel movements are expected to be 336 per year (a difference of 178 movements per year). On May 30, 2016, VFPA Project Permit 15-180 was issued. Construction has been underway since March 2, 2017 and is slated for completion in 2020.	178							
Lehigh Hanson Aggregate Facility[i]	Richmond, B.C.	In June 2012, Lehigh submitted a proposal to the VFPA for review under the Project and Environmental Review Process to construct an aggregate processing facility in Richmond, including a wash plant, aggregate material stockpiles, reclaimer, rail and truck loading facilities, and two marine berths for loading and unloading barges. The project is no longer considered to be reasonably foreseeable, as the proponent has withdrawn its application for review and approval from the VFPA process.			0					
Neptune Phosphate Rock Handling[j]	North Vancouver, B.C.	The VFPA issued Project Permit 12-041 in August 2012 to build a storage and handling facility for phosphate rock at the existing Neptune Terminals. This project included the replacement and upgrade of terminal infrastructure for the storage of imported phosphate rock, used for production of fertilizer. Project construction was completed in 2013. Vessel traffic increases are negligible, and any increases are assumed to be included within projections provided for the Neptune Coal Handling Capacity Expansion Project (see below).	0							
Neptune Terminals Coal Handling Capacity Expansion[k]	North Vancouver, B.C.	Expansion upgrades include: a second railcar dumper, a conveyor to transport the steelmaking coal from the new dumper to the storage area, replacement of a quadrant shiploader, and foundation reinforcement at berth one. Neptune received VFPA Project Permits 12-066 and 12-097 to increase its coal-handling capacity to 18.5 million tonnes a year from 8.5 million. The number and size of ships will vary depending on the requirements of individual customers, but on average it is estimated that terminal improvement and expansion projects will result in approximately 0.7 additional ships per week, or 73 movements per year.	73							
Northwest Seaport Alliance[l]	Seattle and Tacoma, WA	The ports of Seattle and Tacoma have formed the Northwest Seaport Alliance (NWSA) to manage the two ports' marine cargo terminal investments, operations, planning, and marketing to strengthen the Puget Sound gateway and attract more marine cargo for the region. Two projects are currently under review: 1. Pier 4 Reconfiguration Project - Pier 4 at the Husky Terminal is being reconfigured to align with the adjacent Pier 3 to create one contiguous berth capable of serving two 18,000-TEU container ships (current usage is limited to 6,500 TEU vessels). As of June 1, 2017, construction is about halfway completed and is anticipated to be completed in 2018. Upon project completion cargo capacity will increase from 767,000 TEUs annually to an estimated 1.3 million TEUs. Fewer vessels calls are needed under the "with project" condition because more containers are expected to be moved per vessel call (i.e., for 2030, 94 calls are projected without the project, and 52 calls are projected with project completion), or 188 to 104 movements per annum (reduction of 84 movements per year). 2. Terminal 5 Cargo Wharf Rehabilitation, Berth Deepening, Improvements Project- Final EIS was submitted under the state environmental review process in October 2016. The proposed Project includes rehabilitation of an existing facility in order to serve larger vessels, and construction completion is expected by 2019. With project completion vessel calls are projected to decrease from six per week (existing traffic) to four per week, or 312 to 208 movements per annum (reduction of 104 movements per year). The total decrease in vessel movements with these two projects is 188 per year. As vessel size has been held constant for projections for VFPA container terminals, this decrease has not been incorporated in the project-based approach total (i.e., calls to VFPA terminals would also decrease due to schedule service to both regions).		0						

Project	Project Location	Project Status as of July 1, 2017	Cargo/ Carrier	Container	Tug	Service	Passenger	Tanker	Other/ Unknown	Fishing
Pacific Coast Terminals (PCT) (Canola Oil Handling Project and Potash Handling System Project)[m]	Port Moody, B.C.	The proposed facility expansion to handle canola oil and potash involved infrastructure modifications including: a railcar unloading facility, conveyors with dust collection systems, a potash storage shed, rail track modifications in the PCT yard, foreshore extension between PCT and Reed Point Marina, and shiploader modifications. As outlined in MSA IR-02.24.16-7 (CEAR Document #391), vessel traffic levels stated in the EIS and MSA associated with the conversion of PCT capacity to handle new commodities assumed 104 vessel calls (208 movements) as chemical carrier tankers, not tankers and bulkers. At the time of EIS preparation, vessel movements associated with the PCT project were unknown, and the vessel projection was based on a five-year trend for the chemical carriers calling at PCT. Future traffic levels for chemical commodities were assumed to accommodate the traffic levels associated with the conversion of terminal capacity to handle new commodities. Based on VFPA Project Permit 14-096 Project Review Report for the potash handling, project completion would result in 88 bulker movements per year. Based on VFPA Environmental Review Report for File 13-104 for the canola oil handling, project completion would result in 46 tanker movements and 46 tug movements per year at full capacity utilisation based on escort tug rules in Haro Strait.	88		46			46		
Richardson International Grain Storage Capacity Project[n]	North Vancouver, B.C.	On April 15, 2013, the VFPA issued a project permit (PP 2012-099) for the project and an extension of the permit was granted in June 2016. The project involves the construction of two 40,000 metric tonne concrete storage annexes, as well as the installation of conveyors and automatic dust filter systems. Richardson's Vancouver terminal is currently operating at maximum capacity, handling approximately 3 million metric tonnes (MMT) of grains and oilseeds each year. Richardson expects to handle in excess of 5 MMT of grains and oilseeds annually with the additional storage capacity in Vancouver. There are no increases to vessel traffic due to this development as the smaller vessels currently servicing the terminal will be replaced by larger vessels (Panamax 70,000 MT).	0							
Roberts Bank Terminal 2 (RBT2)[o]		RBT2 is a proposed new three-berth container terminal that would provide 2.4 million TEUs of container capacity, and is anticipated to generate 260 container ship calls per year when the terminal reaches its design capacity around 2030 (520 Project-associated vessel movements per year). The frequency of ships calling on the Project is anticipated to decrease as container vessel sizes increase in the future (as fewer ships will be required to carry the same number of containers)—refer to IR4-02 for further details.		520						
Steelhead Malahat LNG Project (Island Gas LNG)[p]	Mill Bay, B.C.	A liquefied natural gas project that would include floating liquefaction facilities (with up to 6 million tons per annum capacity) moored to the shoreline and supporting land-based facilities. As the project is currently in the preliminary engineering and design stage, provincial and federal regulators have not commenced an environmental review of the proposed project. An export licence was issued by the NEB in October 2015, but as outlined in MSA IR-02.24.16-7 (CEAR Document #391), the issuance of an export licence does not indicate the project is certain or even likely to proceed.			unknown			unknown		
Vancouver Airport Fuel Delivery Project (YVR)[q]	Richmond, B.C.	The proponent is building an aviation fuel delivery system to serve YVR, which will include a Marine Terminal and Fuel Receiving Facility on the South Arm of the Fraser River and a 13-kilometre underground pipeline to YVR. Construction of the new system is expected to be completed by Spring 2018. One tanker delivery per month and a barge delivery once every two weeks for the project is expected; each tanker will have two associated tug movements. As the project has advanced the number of tank barges has decreased to 26 from the 48 assumed in EIS Table 8-8 and in EIS Appendix 30-A. Refer to Table IR4-03-1 in IR4-03 for a breakdown of tugs requirements.			76			24		
Viterra Grain Terminal (Viterra Inc Shiploading System Upgrade at Pacific Terminal)[r]	Vancouver, B.C.	The project involves operational improvements and upgrades at its existing Pacific Terminal - activities include dredging, structural, seismic and electrical upgrades, ship loading system upgrade, modernisation of dust control systems. The final project approval was issued by the VFPA on July 2, 2015. Based on VFPA Project Permit No. 2014-081 Viterra Inc — Shiploading System Upgrade at Pacific Terminal, the approved works must be complete no later than July 31, 2017. The new shiploading system will support a proposed increase in facility throughput from 1,900,000 metric tonnes per year (2013) to 5,000,000 MT per year (2023), resulting in an increase of ship movements from 78 to 163 per year.	85							

Project	Project Location	Project Status as of July 1, 2017	Cargo/ Carrier	Container	Tug	Service	Passenger	Tanker	Other/ Unknown	Fishing
WesPac Tilbury LNG Project (Fortis LNG Plant, Fortis Expansion)[s]	Delta, B.C.	Project includes construction of a new storage tank and additional liquefaction equipment. The expanded facility will be able to liquefy an additional 34,000 GJ of natural gas per day and will add 1.1 million GJ of additional storage capacity. This project is not associated with an increase in vessel numbers in the Fraser River, but it is adjacent to the proposed WesPac Tilbury Marine Jetty Project (for vessel information see below).								
WesPac Tilbury Marine Jetty Project[t]	Delta, B.C.	WesPac proposes to construct and operate a liquefied natural gas marine jetty at Tilbury Island on the Fraser River, adjacent to the existing Fortis BC Tilbury LNG Plant. The proposed project includes a dock and loading platform with a berth for docking a single LNG barge or carrier to be loaded with LNG for local or offshore delivery. WesPac received approval of the Application Information Requirements (AIR) from the B.C Environmental Assessment Office in November 2016, which specifies the information required in its Application for provincial and federal environmental assessment processes (not yet submitted). As the project has advanced, the number of LNG carriers has been reduced from 120 to 90 (180 movements) and number of barges has been reduced from 90 to 34 (68 movements). The total number of tugs is based on one tug per barge and three escort tugs for each LNG carrier.			608			180		
West Coast Reduction - Railcar Unloading Facility Improvement Project[u]	Vancouver, B.C.	The expansion of rail unloading and handling facilities at the West Coast Reduction port storage and export facility was completed in April 2015 (under VFPA Project Permit 12-122). The expansion was aimed at increasing its export of canola oil by at least 25% by allowing for 24 tank cars per rail delivery (up from 16). An increase in vessel traffic is not expected with this project.	0							
Westridge Marine Terminal (Kinder Morgan Pipeline Expansion Project, or Trans Mountain Expansion Project)[v]	Vancouver, B.C.	The approved expansion project will create a twinned pipeline increasing the nominal capacity of the system from 300,000 barrels per day to 890,000 barrels per day, and will include approximately 980 km of new pipeline, new pump stations, new tanks, and expansion with three new berths at the Westridge Marine Terminal. The construction start date is September 2017, with operations commencing December 2019. Tanker traffic is expected to increase from approximately 5 to 34 vessels per month, or to 360 vessels per year (720 movements), and one escort tug per tanker is required through Segment B.			720			720		
Westshore Terminals - Equipment Replacement and Upgrade[w]	Delta, B.C.	On January 31, 2014, the VFPA issued Project Permit PP13-144 to replace two stacker reclaimers and consolidate existing office and operations facilities to allow for increased coal storage by approximately 135,000 metric tonnes (MT). Annual capacity for the terminal is expected to increase by 3 million MT to 36 million MT following completion of construction, resulting in a potential increase of up to 30 ships per year arriving at the terminal (or 60 ship movements per annum). The incremental increase will be less, however, if ship size continues to increase as it has done in recent years.	60							
Woodfibre LNG Project[x]	Squamish, B.C.	The proponent proposes to build an LNG processing and export facility at the former Woodfibre pulp mill site. The site is licensed to export about 2.1 million tonnes of LNG per year for 40 years. Natural gas will be delivered to Woodfibre through the existing FortisBC pipeline, where it will be liquefied and loaded into LNG carriers for shipment. Woodfibre LNG anticipates that there would be approximately 3 to 4 LNG carriers per month calling at the terminal, or about 40 carriers per year (80 movements) with three escort tugs required for each LNG carrier.			240			80		
		Total Incremental Vessel Movements	**798**	**364**	**1,690**	**0**	**0**	**1,050**	**0**	**0**

Notes: Bolded projects are those specifically listed in the information request. Unknown = unknown vessel movement projections based on lack of publicly available information as of July 1, 2017.

Information Sources:

a. Centerm: Discussion Guide and Feedback Form. 2017. https://www.portvancouver.com/wp-content/uploads/2017/02/CEP_Application-Review-Phase-Round-1_Discussion-Guide-and-Feedback-Form_FINAL_Feb-20-2017.pdf.
b. DTRRIP: Project status: https://www.portvancouver.com/development-and-permits/status-of-applications/deltaport-terminal-road-and-rail-improvement-project/. Vessel projections: Table 4-D.1 in EIS Appendix 4-D and Table 3-2 in EIS Appendix 30-A.
c. Deltaport Split Call Service: VFPA personal communication. Container Shipping Alliance information: www.icontainers.com/us/2017/03/21/new-shipping-alliances-what-you-need-to-know.
d. Discovery: Project status: http://www.discoverylng.com.

e. Fibreco: Project status and vessel projections: https://www.portvancouver.com/development-and-permits/status-of-applications/fibreco-export-inc-fibreco-terminal-enhancement-project/ and https://www.portvancouver.com/wp-content/uploads/2017/03/VFPA-Permit-Application-Form-December-2016.pdf.

f. Fraser Grain: Project status and vessel projections: https://www.portvancouver.com/wp-content/uploads/2016/10/Fraser-Grain-Terminal_Input-Consideration-Report_March_2017_FINAL.pdf.

g. FSD: Project status: http://www.fsd.bc.ca/index.php/project-updates/. Vessel projections: http://www.fsd.bc.ca/_documents/amendment/FSD_DiscussionGuide_Round2.pdf.

h. G3: Project status: http://g3terminalvancouver.ca/ and vessel projections: https://www.portvancouver.com/wp-content/uploads/2015/12/November-5-2015-Permit-Application-Appendix-R_Environmental-Air-Assessment-with-modelling_G3.pdf.

i. Lehigh: Project status: Letter from VFPA to City of Richmond March 30, 2016 regarding Project Permit #2009-076.

j. Neptune Phosphate Rock Handling. VFPA Project Review Report 2012-041.

k. Neptune Terminals Coal Handling Capacity Expansion. Project status and vessel projections: https://www.portvancouver.com/wp-content/uploads/2015/03/january-2013_final_neptune-project-input-consideration-memo.pdf and Neptune Replacement Stacker Reclaimer Project Review Report (PP#2012-097) – available from the VFPA upon request.

l. Northwest Seaport Alliance. Pier 4 Project status: https://www.nwseaportalliance.com/about/strategic-plan/pier4, and https://www.nwseaportalliance.com/sites/default/files/pier-4-1p-2017.pdf, and vessel projections: https://www.portoftacoma.com/sites/default/files/2015BCA.pdf; Terminal 5 Project vessel projections: http://www.portseattle.org/Environmental/Environmental-Documents/Documents/T5_feis_2016_oct/T5_FEIS_volume_II_Appx_G.pdf.

m. PCT: Project status and vessel projections: VFPA Project Permit #2014-096 Project Review Report (PCT Potash Handling System) and VFPA Environmental Review Report and Schedule of Environmental Conditions for Project Permit #13-104 (Canola Oil Handling); Tug escort requirements for canola tanker: http://www.ppa.gc.ca/text/notice/Notice%20to%20Industry_2015-10_Rules%20for%20vessels%20carrying%20liquids%20in%20bulk.pdf.

n. Richardson: Project status and vessel projections: https://www.portvancouver.com/wp-content/uploads/2015/03/n-2013-04-15-richardson-2012-099-decision-backgrounder.pdf.

o. RBT2: EIS Sections 1.0 and 4.0, and MSA Section 4.0.

p. Steelhead Malahat: http://malahatlng.com/the-project/#_theopportunity.

q. YVR: Vessel numbers: http://www.vancouverairportfuel.ca/files/VAFFC%20May%202016%20Brochure%20-%20Web.pdf.

r. Viterra: Project status and vessel projections: https://www.portvancouver.com/wp-content/uploads/2015/05/2015-07-02-PP2014-081-Project-permit-Shiploading-System-Upgrade-at-Pacific-Terminal_FINAL.pdf.

s. WesPac/Fortis: Project information: https://www.fortisbc.com/About/ProjectsPlanning/GasUtility/NewOngoingProjects/Pages/Tilbury.aspx.

t. WesPac Tilbury Marine Jetty: Project and vessel projection information: EAO Working Group #3 Meeting Notes. 2016. https://projects.eao.gov.bc.ca/api/document/5886b1bce036fb01057695fb/fetch.

u. West Coast: Project status: https://www.pressreader.com/canada/vancouver-sun/20150408/281947426367265.

v. Westridge: Project status: https://www.transmountain.com/expansion-project and https://www.tc.gc.ca/media/documents/mosprr/Trans_Mountain_Pipeline_Kinder_Morgan_rev.pdf; Vessel projections: http://transmountain.s3.amazonaws.com/application/V8A_1_of_4_1_TO_4.2.9_MAR_TRANS_ASSESS.pdf.

w. Westshore: Project status: https://www.portvancouver.com/development-and-permits/status-of-applications/westshore-terminals-equipment-replacement-and-upgrade-project/; Vessel projections: https://www.portvancouver.com/wp-content/uploads/2015/03/here1.pdf.

x. Woodfibre: Project status and vessel projections: https://www.woodfibrelng.ca/the-project/about-the-project/.

Table IR4-09-A2 Segment F: Project Information for Certain and Reasonably Foreseeable Projects, including Anticipated Annual Incremental Vessel Movements by Vessel Type

Project	Project Location	Project Status as of July 1, 2017	Cargo/ Carrier	Container	Tug	Service	Passenger	Tanker	Other/ Unknown	Fishing
BP Cherry Point Marine Terminal Dock (BP)[a]	Cherry Point, WA	A second dock (north wing) was added to the existing BP Cherry Point Marine Terminal dock (south wing) in 2001. As required by a court-ordered review of a previous permitting action, a draft EIS was prepared by the US Army Corps of Engineers to assess the incremental environmental effects. It was issued May 2014 and has not been finalised. Vessel numbers are not anticipated to increase in the future (i.e., 2030) as the dock has been in operation since 2001, but for the purposes of IR1-05 of CEAR Document #897[3], IR4-04, and this information request, maximum vessel forecast numbers were considered in 2030 to be conservative. Existing vessel movements for 2012 are approximately 684 annually, and estimated maximum annual vessel numbers are 840 annually for 2030, a difference of 156 tanker movements (and 312 accompanying tug escorts) per annum.			312			156		
Shell Refinery Expansion (Crude-by-Rail Project)[b]	Anacortes, WA	The project involved building an unloading facility and rail spur from an existing BNSF Railway line. The expansion would have allowed for delivery of crude from six trains a week. A draft Environmental Impact Statement was released by Skagit County and the Washington Department of Ecology in October 2016 laying out proposed conditions for building the crude-by-rail unloading facility at the existing refinery. Shell subsequently withdrew its permit applications due to non-economic conditions. Should Shell decide to restart the project, the company would need to re-apply for permits, which would trigger the environmental review process.			0			0		
Tesoro Refining (Clean Products Upgrade Project)[c]	Anacortes, WA	The project includes construction and upgrades of onshore facilities and systems to permit the shipment of mixed xylenes from the refinery and deliveries of reformate to the refinery. Based on a March 2016 Vessel Traffic Assessment Technical Report, tanker traffic is expected to decrease from 176 movements in 2012 to 146 movements in the future (assessment based on 2020 projections), and no changes in barge traffic are anticipated.			-30			-30		
		Total Incremental Vessel Movements	**0**	**0**	**282**	**0**	**0**	**126**	**0**	**0**

Notes: Bolded projects are those specifically listed in the information request.

Information Sources:

a. BP: Project information and vessel projections: http://www.nws.usace.army.mil/Portals/27/docs/regulatory/NewsUpdates/BPDock2014/BP%20Cherry%20Point%20Dock%20DEIS%20May%202014.pdf.
b. Shell: Project status: http://www.shell.us/about-us/projects-and-locations/puget-sound-refinery/puget-sound-refinery-news-events/crude-by-rail-project-suspended.html and http://www.ecy.wa.gov/geographic/anacortes/shelloil.html.
c. Tesoro: Project information and vessel projections: https://tesoroanacorteseis.blob.core.windows.net/media/Default/Library/CH2M%20Hill_%202016_Vessel%20Traffic%20Report%20CPUP.pdf.

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[3] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

IR4-10 Underwater Noise – ECHO Program

Information Source(s)

Marine Shipping Addendum: Section 8.2

Proponent Response to IR1-01 (CEAR Doc#897)

Context

In Section 8.2 of the Marine Shipping Addendum, the Proponent identified a series of initiatives that were being considered by the Enhancing Cetacean Habitat and Observation (ECHO) Program. In Chapter 14 of the Port Information Guide provided as part of the response to Review Panel IR1-01, the Proponent indicated that the long-term goal of the ECHO program is to develop mitigation measures that will lead to a quantifiable reduction in potential threats to whales as a result of shipping activities. Underwater noise is identified as a priority study area of the ECHO Program.

Additional information is required regarding the expected outcomes of the ECHO Program initiatives and to determine how these outcomes could inform the development and application of mitigation measures considered in the Roberts Bank Terminal 2 environmental assessment.

Information Request

Describe the objectives and main findings of initiatives that have been undertaken, and are currently being undertaken as part of the ECHO Program.

Describe any mitigation measures that have been proposed in ECHO Program initiatives that may be appropriate to mitigate the potential effects of the proposed Project and marine shipping associated with the Project.

VFPA Response

The following response provides an overview of the VFPA-led Enhancing Cetacean Habitat and Observation (ECHO) Program, followed by responses to the two sub-requests in the Panel’s information request.

ECHO Program Overview

Much of the commercial vessel activity within the southern coast of B.C. transits critical habitat for endangered southern resident killer whales (SRKWs), as well as areas known to be of importance to other at-risk whales. The VFPA is committed to conducting operations in a responsible and sustainable manner to enable Canada’s trade objectives, ensuring safety, environmental protection, and consideration for local communities. Although the regulated care and control of vessels calling at the Port of Vancouver is limited to its marine jurisdiction, it is recognised by the VFPA that to adequately address and understand the potential existing cumulative threats posed by commercial vessel activities to at-risk whales, a larger, regional-scale approach was required. In 2014, the VFPA-led ECHO Program was developed as a collaborative initiative aimed at better understanding and managing the impact of shipping activities on at-risk whales throughout the southern coast of B.C. The long-term goal of the ECHO Program is outlined below:

- Understand the potential cumulative effects of commercial vessel traffic on at-risk whales through the southern coast of B.C.; and
- Develop voluntary, practical, and effective mitigation measures that will lead to quantifiable reduction in threats to whales as a result of shipping activities.

The VFPA-led ECHO Program engages and involves key regional interested parties to maximise program success and help ensure that mitigation and management measures developed through the program are informed by social, cultural, economic, and environmental sustainability interests. The ECHO Program is guided by the advice and input of an advisory working group[1], and supported by a federal government advisory committee and associated technical committees (see **Appendix IR4-10-A** for a full list of ECHO members and collaborators).

Through engagement and consultation with stakeholders, the ECHO Program has initiated or supported short-term projects, scientific studies, and educational initiatives to fill knowledge gaps necessary to inform the development of credible, science-based threat reduction solutions and management options to reduce cumulative effects of shipping to at-risk whales in the region.

As the program advances (see **Figure IR4-10-1** below; taken from ECHO Program 2016 Annual Report (**Appendix IR4-10-A**)), multiple projects have been or will be executed with the intention of developing voluntary management options which will be implemented from 2017 onwards.

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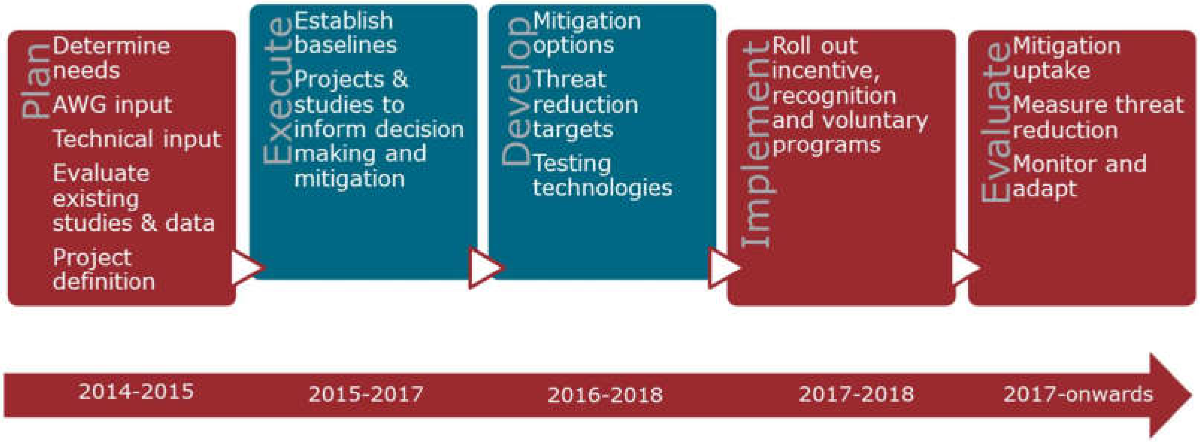
[1] Members of the advisory working group include the BC Coast Pilots, B.C. Ferries, Chamber of Shipping of B.C., Cruise Lines International Association (North West and Canada), Aboriginal individuals, Fisheries and Oceans Canada (DFO), Hemmera Envirochem Inc., U.S. National Oceanic and Atmospheric Administration, Pacific Pilotage Authority, Shipping Federation of Canada, Transport Canada, the VFPA, Vancouver Aquarium, Washington State Ferries, and World Wildlife Fund - Canada.

Figure IR4-10-1 ECHO Program Road Map



EcoAction Program and ECHO Program

The VFPA EcoAction Program (see **Appendix IR4-10-B**; separate from the ECHO Program) recognises positive environmental practices while vessels operate within the VFPA's jurisdiction and offers discounted harbour due rates to vessels that have implemented emission reduction measures, other environmental practices, and as of 2017, underwater noise reduction technologies. Vessels may qualify for one of three levels: gold, silver, or bronze.

In 2016, the ECHO Program conducted a desktop study identifying three quiet ship classifications and three propeller technologies shown to reduce underwater noise in support of new criteria for the EcoAction Program.[2] Effective January 1, 2017, the EcoAction Program includes new incentive criteria to provide harbour due rate discounts for quieter ships[3] (i.e., ship classification society quiet vessel notations, cavitation/wake flow reduction technologies), making Canada the first country in the world, and Port of Vancouver the first port, with a marine underwater noise reduction incentive. Since the VFPA launched its new EcoAction underwater noise reduction criteria in 2017, 12 vessels took actions to reduce their underwater noise levels and received a bronze level incentive resulting in reduced harbour due rates.

As it relates to RBT2, container ships calling on RBT2 that qualify under the EcoAction Program by meeting incentive criteria for reducing underwater noise levels, informed by ECHO initiatives, will reduce potential effects to at-risk whales. These reductions in underwater noise would occur in the southern coast of B.C. due to both marine shipping associated with the Project along shipping lanes, and when container ships are calling at RBT2.

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[2] The report summarising this study is available at portvancouver.com/echo.

[3] Vessels with one of three propeller technologies shown to reduce underwater noise are eligible for a bronze level discount of 24%.

Describe the objectives and main findings of initiatives that have been undertaken, and are currently being undertaken as part of the ECHO Program.

The objectives and main findings of initiatives that have been undertaken, and are currently being undertaken, as part of the ECHO Program are summarised below and described more fully in the 2015 and 2016 ECHO annual reports publicly available on the VFPA's ECHO Program webpage, and appended to this response (**Appendix IR4-10-A**), and associated study reports also publicly available on the VFPA's ECHO Program webpage. The timeline for these initiatives are as follows:

- **2014 to 2017**: Plan and execute projects to inform mitigation measures;
- **2016 to 2017:** Develop and pilot potential mitigation solutions, targets, and incentives; and
- **2017 onwards:** Implement incentive/voluntary programs; monitor and manage for measurable reduction in threats.

The ECHO Program has initiated or provided support to 17 projects in three vessel-related threat categories that are identified in DFO's Species at Risk Recovery and Action Plans for at-risk whales: acoustic disturbance (underwater noise), physical disturbance (vessel strikes), and environmental contaminants.[4] The ECHO Program's advisory working group identified underwater noise as a priority focus area based on impacts to species-at-risk, in particular SRKWs. In its recent review of the Recovery Strategy for SRKW, DFO (2017a) stated that VFPA ECHO projects are addressing numerous recovery objectives outlined in the SRKW Action Plan (DFO 2017b).

With input and advice from the acoustic technical committee, a work plan was defined and specific projects and studies were advanced through the ECHO Program to fill the above data gaps, including monitoring of existing underwater noise with hydrophones in multiple locations, measurements of individual commercial vessels at a dedicated 'listening station', modelling of underwater noise produced by commercial vessel traffic sectors, and predictions of potential effects to SRKWs (see Table IR4-10-C1 in **Appendix IR4-10-C** and ECHO Program 2016 Annual Report (**Appendix IR4-10-A**)), the following initiatives/projects have been conducted or are ongoing:

- Regional ambient acoustic monitoring;
- Regional ocean noise contributors;
- Vessel noise reduction options;
- The underwater listening station;
- Underwater noise education initiatives;
- Summary paper on underwater noise impacts to whales;
- Estimating the effects of noise from commercial vessels and whale watch boats on SRKW;
- Effect of ship noise on vocal behaviour of humpback whales in B.C.;

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[4] Availability of prey is identified as another key threat category for at-risk whales. While this threat category is not a focus area for the ECHO Program, the VFPA manages a separate Habitat Enhancement Program, which contributes towards enhancing fish habitat.

- Underwater listening station sea trials;
- Voluntary vessel slowdown trial;
- Feasibility study of underwater listening station locations in the Salish Sea (hull cleaning);
- Large whale vessel strike risk assessment;
- DFO whale tagging and additional aerial transect surveys;
- Mariner's Guide to Whales of Western Canada;
- Whale sightings notification system;
- Vancouver Aquarium PollutionTracker Project; and
- Management of contaminants during underwater hull cleaning.

Underwater Noise

In 2015, upon recommendation of the ECHO advisory working group, an acoustic technical committee was developed with the purpose of offering expert advice on specific project approaches, goals and objectives related to underwater noise. The ECHO acoustic technical committee is composed of individuals bringing expertise from relevant fields of study, backgrounds, perspectives, and interests. The advisory working group requested that the acoustic technical committee examine identified data gaps, as follows:

- Underwater noise levels coming from different vessels in the region;
- Underwater noise contributions from various vessel sectors to overall regional ocean noise;
- Existing regional ambient underwater noise conditions;
- Potential effects of existing underwater noise from vessels to at-risk whales, specifically SRKW; and
- Potential options to reduce underwater noise levels, and the implications of these options.

In parallel to trying to better understand the existing levels of underwater noise from shipping traffic and the potential effects to SRKWs, the ECHO Program has been exploring the technical and economic feasibility of identified options to reduce existing underwater noise levels. Options explored to reduce underwater noise levels included quietening vessel technologies, designs and ship classification notations, vessel maintenance (i.e., for example hull cleaning, propeller maintenance), and changes to vessel operation (i.e., for example vessel speeds or route changes).

Screening of potential vessel underwater noise management options involved consultation with many experts and stakeholders from the advisory working group, including naval architects, pilots, captains, shipping companies, port operators, acousticians, Aboriginal individuals, and biologists, and considered their potential effectiveness and feasibility. The ECHO Program identified four categories (below) of potential vessel based mitigation measures. The following four mitigation measure categories were developed through compilation of potential options (and related benefits and implications) followed by a screening evaluation and ranking of these options by the advisory working group:

- Vessel slow downs;

- Route alterations;
- Training / mitigation banking / vessel size; and
- Vessel convoying.

The ECHO advisory working group feedback on the above four mitigation categories suggested vessel slowdowns and route alterations be considered the more practical options and vessel convoying the least practical. Based on this feedback the voluntary vessel slowdown trial was proposed. As a result of these studies, discussions, and the ongoing guidance of the advisory working group, the following actions are currently being implemented by the ECHO Program.

Voluntary Vessel Slowdown Trial

After evaluating a number of potential voluntary operational vessel noise reduction options in consultation with the advisory working group (e.g., route changes, vessel convoying, no-go areas, vessel operator training), the vessel slowdown option was considered to be a potentially feasible and implementable voluntary vessel noise reduction option. A slowdown research trial was proposed to gather data to explore all aspects of this potential option. As described in the ECHO 2016 Annual Report (**Appendix IR4-10-A**) and **Appendix IR4-10-D**, the ECHO Program is conducting a voluntary trial between August 7 and October 6, 2017 to slow down commercial vessels within Haro Strait with the goal of studying the relationship between slower vessel speeds, underwater noise levels, and effects on SRKW. Haro Strait is an area of high summer use by SRKW in its critical habitat where they regularly are sighted feeding on key salmon prey.

During the trial period, all vessels transiting Haro Strait are requested to voluntarily reduce speeds to 11 knots[5] through the water for approximately 16 nautical miles between Discovery Island at the southern end, and Henry Island at the northern end (**Appendix IR4-10-D**).

During the trial period, hydrophones will monitor both vessel source levels at slower speeds, as well as total underwater noise levels and automated vessel tracking will be used to monitor vessel speed. Computer modelling (first developed to inform the RBT2 EIS), will then be used to simulate the resultant benefits to SRKW behaviour.

As of July 2017, 54 organisations have confirmed their intention to participate in the trial, where operationally and technically feasible. The 54 organisations represent 100% participation from container ships and cruise ships, and a significant amount of bulker vessels that transit Haro Strait when calling on the Port of Vancouver. Of additional note, all members of the Chamber of Shipping, Shipping Federation of Canada, and Cruise Line International Association Northwest and Canada have confirmed their intent to participate.

The ECHO Program team, in conjunction with industry experts, will also evaluate the potential economic benefits and implications to the shipping industry as a result of slowing vessels down. Once the trial is over and data has been compiled, the management option of slowing

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[5] Average vessel speeds through this area range from 18 knots for container vessels and cruise ships to 13 knots for bulk vessels.

vessels down will be evaluated for its efficacy in reducing underwater noise levels and providing benefits to SRKW.

Vessel Strikes

Since 2015, the ECHO Program has been supporting DFO on a project to evaluate the distribution and habitat of large baleen whales, and the potential for vessel strikes along shipping lanes off the west coast of Vancouver Island. In 2017, DFO published a report that detailed the use of whale distribution data obtained through aerial surveys in a modelling exercise to assess the risk of lethal ship strikes to humpback and fin whales in this area. The ECHO Program continues to support the DFO-led project through funding of aerial surveys and satellite tagging. In the 2016 field season, nine temporary satellite tags were deployed on fin whales, six of which successfully transmitted data. Five additional aerial transect surveys were also completed. This work was conducted to collect fine scale habitat use and behaviour data for fin whales and humpback whales. Additional tags will be deployed in the 2017 field season.

In relation to training, the ECHO Program, in collaboration with input from ports and other partners from the marine transportation industry, developed the *Mariner's Guide to Whales, Dolphins, and Porpoises of Western Canada*[6] (**Appendix IR4-10-E**). This new guide for mariners was produced to inform mariners and raise awareness about the risk of collisions between vessel and marine life, and to help minimise vessel disturbance. Data collected by the B.C. Cetacean Sightings Network, supplemented by data sets from DFO and Pacific Northwest LNG, have been used to create maps that give a sense of high density areas for various species of cetaceans found off the coast of B.C., and where encounters are likely to occur. The guide will also help vessel crew members identify key cetacean species, understand the threats their vessels pose, and take action to minimise those threats. The guide has been distributed to commercial vessel captains, coastal pilots, B.C. Ferries, and other professional mariners.

Environmental Contaminants

Marine mammals, in particular SRKWs, are vulnerable to accumulating high concentrations of persistent organic pollutants because they are long-lived animals that feed high in the food web (DFO 2011). As a part of the Vancouver Aquarium's PollutionTracker project, the Vancouver Aquarium successfully sampled ten ECHO Program-funded locations in and around the VFPA's jurisdiction and SRKW critical habitat.

The PollutionTracker project aims to establish a baseline of environmental conditions in B.C. coastal waters through the sampling of sediment and shellfish. These sampling media

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[6] The Mariner's Guide was produced by the Vancouver Aquarium's Coastal Ocean Research Institute in partnership with the VFPA and the Prince Rupert Port Authority. The guide was developed with input from ports and other partners from the marine transportation industry. Along with the ports of Prince Rupert and Vancouver, contributors included DFO, B.C. Ferries, B.C. Chamber of Shipping, Shipping Federation of Canada, Pacific Pilotage Authority, BC Coast Pilots, ROMM (Réseau D'Observation De Mammifères Marins), and Cruise Lines International Association.

represent the health of the habitat and food web for at-risk whale species in the region. Samples of sediment and mussels will be analysed for an extensive suite of chemicals to help determine current contaminant loadings, identify priority contaminants and sources, and provide a baseline for assessing trends into the future. The ECHO Program-funded sites are part of a coast-wide project, for which the Vancouver Aquarium will publish a report in 2018.

Describe any mitigation measures that have been proposed in ECHO Program initiatives that may be appropriate to mitigate the potential effects of the proposed Project and marine shipping associated with the Project.

The objective of the ECHO Program relates to better understanding cumulative impacts of commercial vessel noise to at-risk whales and identification of regional (southern coast of B.C.) voluntary mitigation measures, not mitigation measures specific to the Project[7]. However, any voluntary mitigation and management options informed by the ECHO Program's collaborative work and ultimately implemented in the region (e.g., the VFPA's incentives for quieter vessels, potential future vessel slowdown areas) may indirectly reduce potential effects to marine mammals from the proposed Project and marine shipping associated with the Project. While these measures are not mandatory, any vessels meeting the VFPA's EcoAction vessel noise reduction criteria will qualify for incentives and help reduce underwater noise in the region. Container ships calling on RBT2 that qualify under the EcoAction Program by meeting incentive criteria for reducing underwater noise levels, informed by ECHO initiatives, will reduce potential effects to marine mammals. These reductions in underwater noise would occur in the regional study area due to both marine shipping associated with the Project along shipping lanes, and when container ships are calling at RBT2.

References

DFO. 2011. Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca)* in Canada. Species at Risk Act Recovery Strategy Series, Fisheries & Oceans Canada, Ottawa, ix + 80 pp.

DFO. 2017a. Southern Resident Killer Whale: A Science-Based Review of Recovery Actions for Three At-Risk Whales. 73 p.

DFO. 2017b. Action Plan for the Northern and Southern Resident Killer Whale (*Orcinus orca*) in Canada. Species at Risk Act Action Plan Series. Fisheries and Oceans Canada, Ottawa. v + 33 pp.

Appendices

Appendix IR4-10-A 2015 and 2016 ECHO Program Annual Reports

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[7] Marine shipping associated with RBT2 is outside the scope of the Project as defined by the Canadian Environmental Assessment Agency (CEA Agency). A Marine Shipping Addendum (CEAR Document #316) was provided as requested by the CEA Agency in 2015, to provide additional information to the Government of Canada regarding the potential effects of marine shipping associated with the Project. Management of potential effects from Project shipping identified in the Marine Shipping Addendum is not under jurisdiction of the VFPA.

Appendix IR4-10-B	EcoAction Program Description Brochure
Appendix IR4-10-C	Supporting Table
Appendix IR4-10-D	ECHO Program Voluntary Vessel Slowdown Trial Backgrounder
Appendix IR4-10-E	Mariner’s Guide to Whales, Dolphins, and Porpoises of Western Canada

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APPENDIX IR4-10-A

2015 AND 2016 ECHO PROGRAM ANNUAL REPORTS

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PORT of
vancouver

Enhancing Cetacean Habitat and Observation (ECHO) Program

2015 Annual Report

Canada

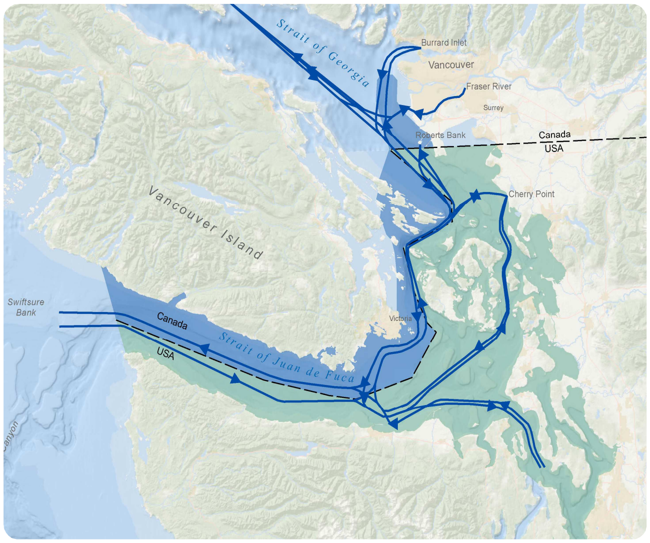
Table of contents

Introduction

Program rationale

British Columbia has a dynamic and growing international trade gateway. It also has a productive coastal ecosystem that sustains populations of whales, porpoises and dolphins (cetaceans). Fisheries and Oceans Canada (DFO) has published *Species at Risk Act* recovery strategies and action plans for a number of at-risk whale species in the region. Some of the key threats to whales in this region include: acoustic disturbance (e.g. underwater noise from vessels), physical disturbance (e.g. vessel collisions), environmental contaminants, and the availability of prey.

Much of the commercial vessel activity in the southern coast of B.C. transits DFO-designated critical habitat for endangered southern resident killer whales, as well as areas known to be of importance to other at-risk whales. The human population of the Metro Vancouver area is predicted to grow by one million people by 2040, and with increased trade demands and a number of potential marine projects coming on line in Canadian and American waters, commercial vessel traffic through designated critical habitat is predicted to increase significantly over the same time. Vancouver Fraser Port Authority is committed to conducting operations in a responsible and sustainable manner that safeguards and promotes continual protection of the environment. For these reasons, the Enhancing Cetacean Habitat and Observation (ECHO) Program was developed.



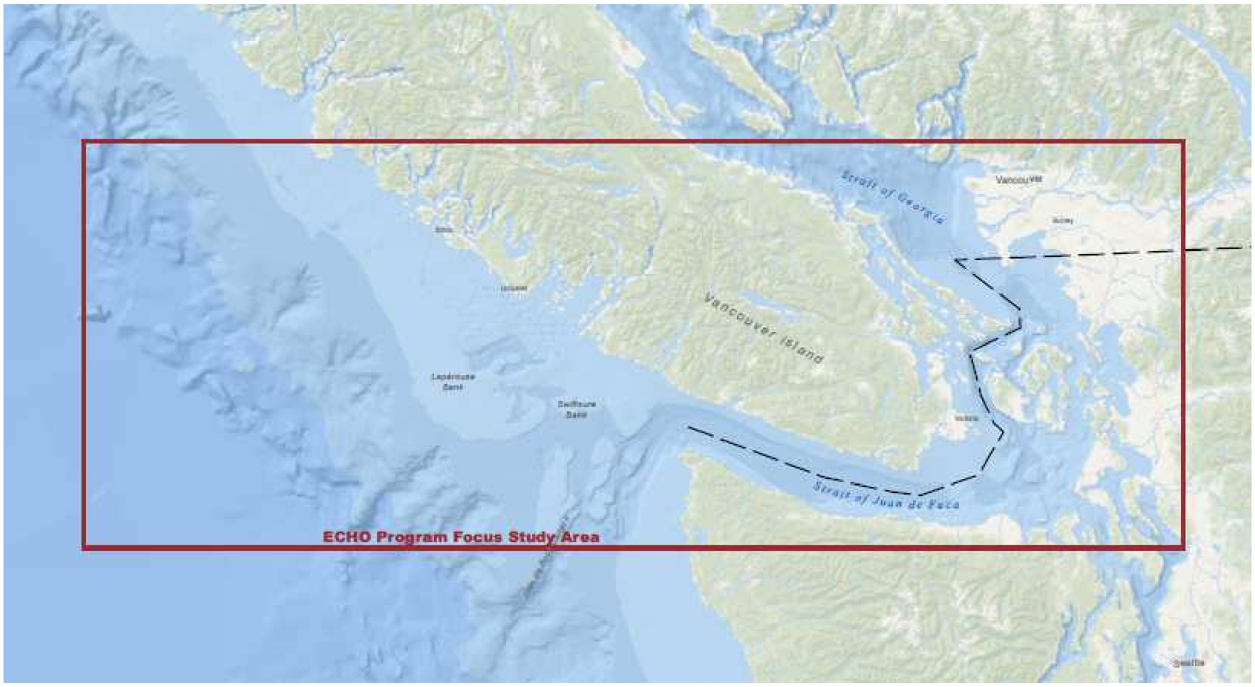
Canadian (blue) and American (green) critical habitat for Southern resident killer whales and commercial shipping lanes overlap.

Program description

The Enhancing Cetacean Habitat and Observation (ECHO) program is a Vancouver Fraser Port Authority-led collaborative initiative aimed at better understanding and managing the impact of cumulative shipping activities on at-risk whales throughout the southern coast of British Columbia. The ECHO program has benefited from early input and advice from scientists, maritime industries, conservation and environmental groups, First Nations individuals and government agencies, to help focus program efforts, and set goals and objectives.

A series of individual short-term projects, scientific studies and educational initiatives are being advanced by the ECHO program. These projects will fill knowledge gaps around vessel-related cumulative regional threats and will inform the development of mitigation solutions and management options. The long-term goal of the program is to quantifiably reduce threats from commercial vessel-related activities to at-risk whales.

Although the geographic scope of Vancouver Fraser Port Authority's jurisdiction is limited, it is recognized that to adequately address the cumulative threats posed by commercial vessel activities, a larger, regional-scale collaborative approach is required. The figure below shows the general area of focus for the ECHO program, although some projects may just include sub-portions of this area and some may extend beyond these boundaries. Within this area of focus, the ECHO program is currently investigating issues relating to acoustic and physical disturbance, and environmental contaminants in the Salish Sea, as well as exploring the risk of vessel strikes posed to larger whale species known to frequent the waters off the western coast of Vancouver Island and the approach to the Strait of Juan de Fuca.



Geographic scope of the ECHO Program.

Program structure

The ECHO program aims to engage and involve key regional interests to maximize program success and help ensure that mitigation and management measures developed through the program are informed by social, cultural, economic and environmental sustainability interests.

The ECHO program is structured such that a program management team, reporting to the Vancouver Fraser Port Authority's Director, Environmental Programs, is guided by the advice and input of an advisory working group, a federal government advisory committee and associated technical committees. The guidance provided by these volunteer advisors greatly assists the program management team in deciding which scientific studies, educational initiatives and other projects should be advanced to best meet program objectives.

Advisory Working Group

ECHO Advisory Working Group meeting on September 29, 2015

The ECHO advisory working group consists of 23 individuals, bringing together a broad spectrum of relevant backgrounds, perspectives and interests from both Canada and the United States, who share the common goal of reducing threats to at-risk whales. The role of the advisory working group is to provide the ECHO program management team with timely input, advice and recommendations during the development and execution of the program. The advisory working group includes representatives from:

- B.C. Ferries
- Chamber of Shipping of B.C.
- Cruise Lines International Association (North West & Canada)
- First Nations
- Fisheries and Oceans Canada
- Hemmera
- National Oceanic and Atmospheric Administration
- Pacific Pilotage Authority
- Vancouver Fraser Port Authority
- Transport Canada
- Vancouver Aquarium
- Washington State Ferries
- WWF-Canada

Federal Government Advisory Committee

The federal government advisory committee offers strategic advice, recommendations and guidance to the ECHO program management team on the overall program direction, objectives and goals. This committee is currently comprised of seven individuals and includes representatives from Environment Canada, Fisheries and Oceans Canada, Vancouver Fraser Port Authority and Transport Canada. This advisory committee provides the opportunity for the ECHO program management team to collaborate and communicate with those federal agencies who have direct regulatory authority or decision-making responsibility pertinent to the goals of the program.

Acoustic Technical Committee

Acoustic technical committee members include leading marine mammal scientist Dr. Lance Barrett-Lennard of the Vancouver Aquarium.

Acoustic disturbance has been identified by Fisheries and Oceans Canada as a key threat to the recovery of the endangered southern resident killer whales, and commercial vessel traffic is identified in the Fisheries and Oceans Canada Recovery Strategy as a key contributor. Recognizing this, and given the complex technical nature of the subject area, the ECHO program management team has convened an acoustic technical committee. The role of the committee is to provide technical and scientific advice in the development and execution of ECHO research, mitigation and management projects and is composed of marine mammal biologists, acousticians, naval architects and others with specific technical knowledge around the sources and impacts of underwater noise. The 16-member acoustic technical committee includes representatives from:

- Fisheries and Oceans Canada
- JASCO Applied Sciences
- National Oceanic and Atmospheric Administration
- Oceans Networks Canada
- Robert Allan Naval Architects
- Sea Mammal Research Unit (SMRU) Consulting Canada
- Transport Canada
- University of British Columbia
- University of St. Andrews
- Vancouver Aquarium
- Washington State Ferries

Other program or project collaborators

The ECHO program is a collaborative undertaking which recognizes and highlights the value of sharing resources and information to meet common project or program goals. Along with the guidance and advice of the advisory working group, federal government advisory committee and acoustic technical committee members listed above, some of these members are also collaborating with the ECHO program on specific projects. Furthermore, the ECHO program has been fortunate to engage with additional parties to support the interests of the program and collaborate on specific aspects, such as data sharing initiatives and research projects. These additional collaborators include:

- Achieve QUieter Oceans (AQUO)
- B.C. Coast Pilots
- Green Marine
- Prince Rupert Port Authority
- Saturna Island Marine Research and Education Society
- University of Victoria Marine Environmental Observation Prediction and Response Network (MEOPAR)
- The Whale Museum


Photo Credit: Beamreach

The Salish Sea is a dynamic trade gateway, one of the world's most biologically rich inland seas and a unified bi-national ecosystem.

Funding contributions

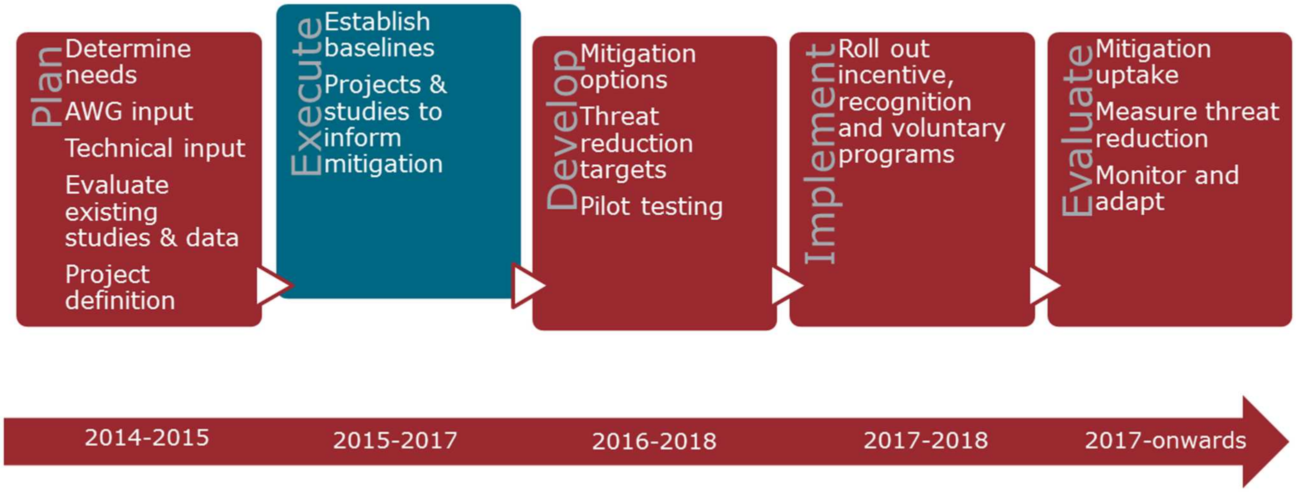
Vancouver Fraser Port Authority has initiated and provided the seed funding for the ECHO program, however, the program has been very fortunate to also receive contributions from other industry and government stakeholders. Contributions have been received or committed either by way of direct financial support or in-kind contribution of equipment, resources and staffing on either the Program level or for specific projects. These partners in funding include:

- Kinder Morgan Canada (direct)
- Transport Canada (direct)
- Fraser River Pile & Dredge (in-direct)
- Fisheries and Oceans Canada (in-kind)
- JASCO Applied Sciences (in-kind)
- Ocean Networks Canada (in-kind)

Program status

Road map

The ECHO program launched in November 2014 with the inaugural ECHO advisory working group meeting. The road map and timeline presented below outline the different stages required to achieve the long-term threat reduction goals of the ECHO program.



The ECHO program is currently in the execute stage. Following the input and advice of the advisory working group and committees, a work plan was developed which aims to fill knowledge gaps and advance science to address key information requirements identified by the advisory working group. The work plan also aligns closely with the recovery actions outlined in DFO's *Draft Action Plan for the Northern and Southern Resident Killer Whales in Canada*, as well as DFO's *Partial Action Plan for Blue, Fin, Sei and North Pacific Right Whales in Pacific Canadian Waters*. The ECHO program has initiated or become affiliated with projects or initiatives which aim to establish baseline environmental conditions or fill data gaps regarding the threat categories of acoustic disturbance, physical disturbance and environmental contaminants. Over the next few years, the program will continue to advance these projects and will receive, collate and analyze the results to inform the development, pilot testing and implementation of potential mitigation options.

Engagement and consultation

Informing and engaging stakeholders, as well as raising the profile of the ECHO program not only in Canada, but internationally, is key to the success of this collaborative program. Since the ECHO program launch in November 2014, it has hosted:

- Four Advisory Working Group meetings
- Three Federal Government Advisory Committee meetings
- Three Acoustic Technical Committee meetings

Members of the advisory working group at the ECHO program launch, November 2014.

In addition to these key meetings, which helped guide and shape the program work plan, the ECHO program has delivered more than 40 presentations, reaching over 1,000 individuals. Presentations have been delivered to a variety of audiences ranging from conservation and environmental groups to industry stakeholders, including a lunch and learn with the Chamber of Shipping B.C., to academic symposia, through to an international green shipping conference.

Media and communications

The ECHO program's communications goal is to build trust and confidence in the program through credible, science-based information delivered in a timely manner. To achieve this goal, the ECHO program maintains regular and open communication with our advisors and collaborators. We have also created an ECHO webpage on Vancouver Fraser Port Authority's website and issued two newsletters to provide program information to interested parties.

The ECHO hydrophone listening station deployment was one of Port of Vancouver's most shared social media stories of the year.

In 2015, the ECHO program has also been highlighted and referenced in a number of media and industry publications, including the following stories:

- Vancouver Sun Opinion Editorial: Safeguarding our marine wildlife
  - Story received 641 likes and 110 shares on Facebook
- Hydrophone Listening Station deployed September 14, 2015
  - Covered in the Vancouver Sun, Surrey Now, CityNews, The Vancouver Observer, The Province, The Maritime Executive and many more.
  - Story received 238 likes and 80 shares on Facebook
- Green Marine Magazine – November Issue
- Maclean's Magazine – November 22, 2015

ECHO projects and initiatives

Project selection

In identifying which projects to support and advance, the ECHO program looks to address those threats identified in DFO's published recovery strategies and action plans. The program also ensures that each scientific study or educational initiative supports the objective of informing the development of mitigation measures to meet threat reduction goals.

In the planning stage of the ECHO program, addressing the threat of acoustic disturbance from vessels was identified by the advisory working group as an initial top priority for the program. Through consultation with the advisory working group and acoustic technical committee, an acoustic work plan was developed and a number of projects have since been initiated which aim to fill specific data gaps and enhance the program's understanding of regional cumulative vessel noise impacts, and how best to reduce them.

The ECHO program is focused on addressing threats identified in DFO's published Recovery Strategies and Action Plans

Physical disturbance, environmental contaminants and the availability of prey have also been identified as threats to the recovery of at-risk whales in the region. Although the initial focus for project selection in 2015 has been on the threat category of acoustic disturbance, projects pertaining to physical disturbance and environmental contaminants have also been initiated.

To address the physical disturbance threat category, the ECHO program is collaborating with Fisheries and Oceans Canada, the Vancouver Aquarium and others to advance a number of projects to better understand and reduce the potential for whale strike risk along B.C.'s coast. Addressing the threat category of environmental contaminants, the program is supporting the Vancouver Aquarium's Pollution Tracker project which aims to establish a baseline of contaminant levels in shellfish and sediment on the B.C. coast.

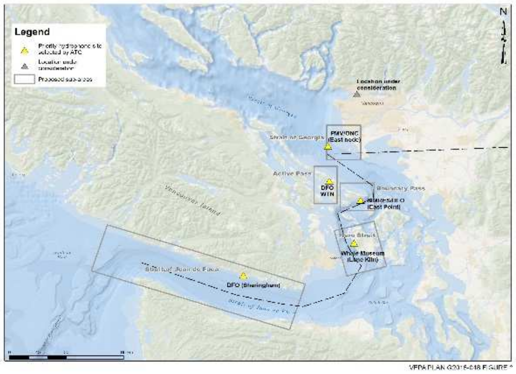
Project status

In accordance with the work and project plans developed through the planning stage of the program, and based on the selection methodology described above, the ECHO program has initiated or provided support for 13 projects in 2015. These projects currently align with 20 of the 73 action items outlined in DFO's *Action Plan for the Northern and Southern Resident Killer Whales in Canada* and align with 10 of the 27 action items outlined in DFO's *Partial Action Plan for Blue, Fin, Sei and North Pacific Right Whales in Pacific Canadian Waters*.

Provided below are brief descriptions of the projects currently underway, broken down by general threat category:

Acoustic disturbance/underwater noise

Regional ambient noise project



The ECHO program acoustic ambient noise monitoring sub-areas.

The ECHO program has initiated a project to consistently measure and analyze ambient underwater acoustic levels at representative locations throughout the region, to provide a better understanding of baseline underwater noise levels in the Salish Sea, and to allow trends to be evaluated into the future. The acoustic technical committee has identified five acoustic sub-areas as representative locations for measuring ambient underwater noise using existing hydrophone infrastructure: Strait of Georgia, Active Pass, Boundary Pass, Haro Strait, and the Strait of Juan de Fuca. Working partners include: Fisheries and Oceans Canada, Sea Mammal Research Unit Consulting Canada, the Whale Museum, Ocean Networks Canada and Saturna Island Marine Research and Education Society.

Regional ocean noise contributors

Using a previously developed computer model of underwater noise from commercial shipping in the Salish Sea region, the ECHO program is working with JASCO Applied Sciences to add new layers to this model to include other 'non-commercial' vessel types such as, recreational boat traffic, fishing vessels and whale watching vessels. The outputs of this revised modelling exercise will be a more complete understanding of how all vessel categories operating in the region (tugs, ferries, containers, whale watching, recreational boats, etc.) contribute to overall underwater noise levels throughout the region.

Exploring underwater noise mitigation options

Vessel noise reduction options

A desk-top study is underway to identify technologies and maintenance measures which are known to reduce the underwater noise outputs from vessels. These identified technologies and measures will be used to inform vessel-quieting criteria for Vancouver Fraser Port Authority's EcoAction[1] Program, a means by which vessel

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[1] Vancouver Fraser Port Authority's use of the name EcoAction refers to a program specifically intended to promote improved environmental performance within the shipping industry and is not related to the EcoAction Community Funding Program administered by Environment Canada.

owners/operators may receive incentives or reduced harbor dues when they meet the criteria.

Underwater listening station

The ECHO program has partnered with Ocean Networks Canada, JASCO Applied Sciences and Transport Canada to install an underwater listening station in the inbound shipping lane of the Strait of Georgia, just west of Roberts Bank. The station contains two, multi-hydrophone arrays which allow for accurate measurement of vessel source levels, marine mammal detections and recording of ambient noise. This state-of-the art listening station provides valuable information on vessel source levels to support future mitigation, and acts as a station for the regional ambient noise project. The station can also enable assessment of the potential noise benefits of applying certain technologies and maintenance measures, such as hull cleaning or alternate fuel/engine types.

Underwater noise education initiative

Working with a marine mammal scientist from Vancouver Aquarium, the ECHO program has developed presentation materials on the effects of vessel underwater noise on marine life, which have been presented to the Chamber of Shipping of B.C. members and other industry stakeholders. In conjunction, a one-page infographic pamphlet to educate mariners on underwater noise is also under development.

ECHO program Lunch & Learn for Chamber of Shipping of B.C. members, October 2015.

Behavioural response of southern resident killer whales to whale watching vessel noise

As part of previous studies on the effects of commercial vessel noise on southern resident killer whales, a detailed model was developed which estimates the number of killer whale behavioural responses to noise stimuli from large commercial vessels. The ECHO program is working with SMRU Canada to develop a new layer in this model which explores behavioral responses from whale watching vessel noise. Applying the sound signature, vessel density, speed and other variables for whale watching vessels in the model will allow behavioural responses estimates resulting from whale watching vessel noise to be compared to estimates resulting from commercial vessel noise.

Effect of ship noise on vocal behaviour of humpback whales

Working with SMRU Canada and Rob Williams, a marine mammal conservation biologist and Pew research fellow, existing acoustic data sets from hydrophones along the B.C. coast will be analyzed to compare humpback whale calling rates in the presence and absence of vessel noise. This analysis will determine if there is evidence of an acoustic effect on humpback whales from vessel noise, as shown by an increase or decrease in call rate as ships pass. An understanding of this potential effect on the *Species at Risk Act* listed humpback whale population will be used in conjunction with the other information gained from ECHO program studies, to inform potential acoustic mitigation and management considerations.

Physical Disturbance/Strike Risk

Large whale vessel strike risk assessment

The ECHO program has been supporting Fisheries and Oceans Canada in its assessment of the risk of a vessel striking a large whale off the west coast of Vancouver Island, as ships make their approach to the mouth of the Strait of Juan de Fuca. Through aerial surveys to determine whale distribution and tracking of vessel distribution and speed via Automated Identification System (AIS), Fisheries and Oceans Canada has modelled the probability of a vessel encountering a whale and will identify areas where encounter probabilities are higher and lower. Results are to be published in the spring of 2016 and will be used to inform future mitigation and management considerations.

Tagging of fin whales

The ECHO program will be supplying Fisheries and Oceans with a number of electronic/GPS suction tags for deployment on fin whales off the West Coast of Vancouver Island. Little is currently understood about the distribution of these at-risk whales on B.C.'s south coast. Electronic tagging will provide valuable data on seasonal movement and habitat use to better inform the strike risk model and the development of potential measures to protect this species.

Fin whale in B.C. waters.

Mariner's guide to whales on B.C.'s coast

The ECHO program, Vancouver Aquarium, and the Prince Rupert Port Authority are working together to publish a mariner's guide to whales on Canada's west coast. This guide will provide information on how to identify the most common whale species, where whales are frequently sighted, and the areas where the probability of a vessel encountering a whale is high. To ensure that the content and format of the guide is appropriate for end users, early and ongoing input is being sought from key west coast collaborators including B.C. Coast Pilots, B.C. Ferries, Pacific Pilotage Authority and Chamber of Shipping of B.C. To learn from their experiences, early input was also sought from collaborators on the east coast (Réseau d'observation des mammifères marins – ROMM and Shipping Federation of Canada), who developed a similar product in 2014. The guide will be available to west coast mariners in hard copy and electronically by spring 2016.

Whale sighting notification system

A scope of work is being developed for a whale sighting notification system whereby whale presence, detected either through Vancouver Aquarium's Whale Report app and/or through in-water hydrophones, could be relayed to commercial vessel pilots and captains in real-time. This notification system could minimize potential vessel strike risks. To date, project collaborations have involved the ECHO program, Prince Rupert Port Authority, Vancouver Aquarium, Ocean Networks Canada, Canadian Coast Guard, and Fisheries and Oceans Canada.

Environmental Contaminants

Tissue samples from mussels will help assess current contaminant baseline.

Vancouver Aquarium Pollution Tracker

The ECHO program is supporting 10 sampling locations in and around Vancouver Fraser Port Authority jurisdiction and southern resident killer whale critical habitat, as part of the Vancouver Aquarium’s Pollution Tracker project. This project aims to establish a baseline of environmental conditions in B.C.’s coastal waters through the sampling of sediment and shellfish. These sampling media represent the health of the habitat and food web for at-risk whale species in the region. This information will help determine the current contaminant loadings, identify priority contaminants and sources, and provide a baseline for assessing trends into the future.

Management of contaminants during underwater hull cleaning

In the spring of 2016, the ECHO program will assist Transport Canada with pilot testing of an underwater hull cleaning technology currently under development. A clean hull is reported to improve fuel efficiency and reduce underwater noise, however in-water hull cleaning is not permitted in many ports due to the potential release of chemical and biological contaminants. Validation of new technology which eliminates the release of contaminants into the receiving environment may allow for regular in-water cleaning at Vancouver Fraser Port Authority and other ports in the future.

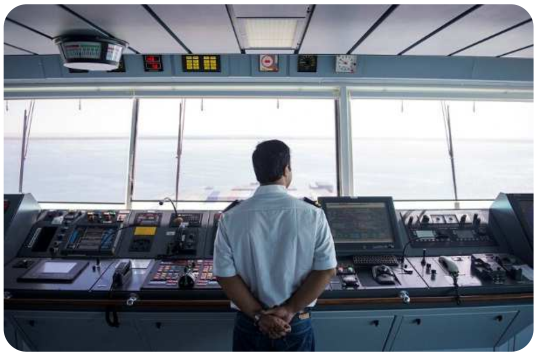
Planned activities for 2016

Looking ahead to 2016, the ECHO program will continue in the execute stage of the program by progressing current projects, as well as identifying new studies to advance knowledge and inform potential mitigations for the three threat categories. The program will also advance into the develop phase, through evaluation of the environmental, economic and cultural benefits and implications of potential mitigation options. Essentials of the ECHO program work plan for 2016 are summarized below:

The ECHO program plans to create noise-quieting EcoAction criteria by 2017.

Projects

- Record and report monthly averages of ambient noise conditions for 2016 at up to five locations in the Salish Sea region.
- Continue refinement of the underwater noise model to identify relative contribution of different vessels to underwater noise in the region and work with significant noise contributors on ways to reduce their inputs.
- Develop criteria around vessel quieting technologies and maintenance measures for inclusion in Vancouver Fraser Port Authority's EcoAction Program in 2017.
- Receive and analyze scientific data from the underwater listening station to understand noise levels of different vessels, inform potential vessel quieting options and work with vessel owners/operators to provide information on those mitigation options.
- Explore opportunities for using underwater listening station infrastructure to investigate the relationship between vessel noise signatures and different vessel maintenance, retrofits, new design practices (e.g., test vessel signatures before and after hull cleaning/propeller repair/engine retrofit/replacement with LNG vessel).
- Evaluate multiple study results and develop and rank list of potential mitigation and management solutions for reducing vessel related threats to whales in this region.
- Evaluate the environmental, economic, and cultural benefits and implications of select short-listed mitigation options.
- Finalize and distribute the *Mariner's Guide to Whales on Canada's West Coast* and the infographic for mariners on underwater noise impacts to whales.



Working with mariners to reduce the impacts of commercial shipping related activities on whales.

- Advance the development of a real-time whale-sighting notification system, in collaboration with multiple west coast partners.
- Explore the potential for the ECHO program to host training workshops for vessel operators on the identification and avoidance of whales, and on ways to reduce vessel noise.

Communications

- Continue engagement with stakeholders in Canada and increase efforts to engage more counterpart stakeholders in the United States.
- Chair session '*Managing the threats to marine mammals from commercial vessel activity*' and present the ECHO program at the 2016 Salish Sea Ecosystem Conference.
- Attend and present the ECHO program at Green Marine's 2016 GreenTech conference.
- Attend and present the ECHO program at the international 2016 Effects of Noise on Marine Life Conference.
- Publish two PortTV episodes highlighting ECHO projects.
- Publish and distribute two ECHO program newsletters.
- Continue to seek opportunities for ECHO program-related stakeholder engagement, media releases, presentations and conferences.

Photo Credit: Green Marine

The ECHO program plans to present at national and international conferences in 2016.

Program governance

- Continue to seek funding contributions to the ECHO program.
- Continue to identify potential long-term governance options for the program.
- Host three advisory working group meetings, two federal government advisory committee meetings, and two or three acoustic technical committee meetings. Establish other technical committees, as required.

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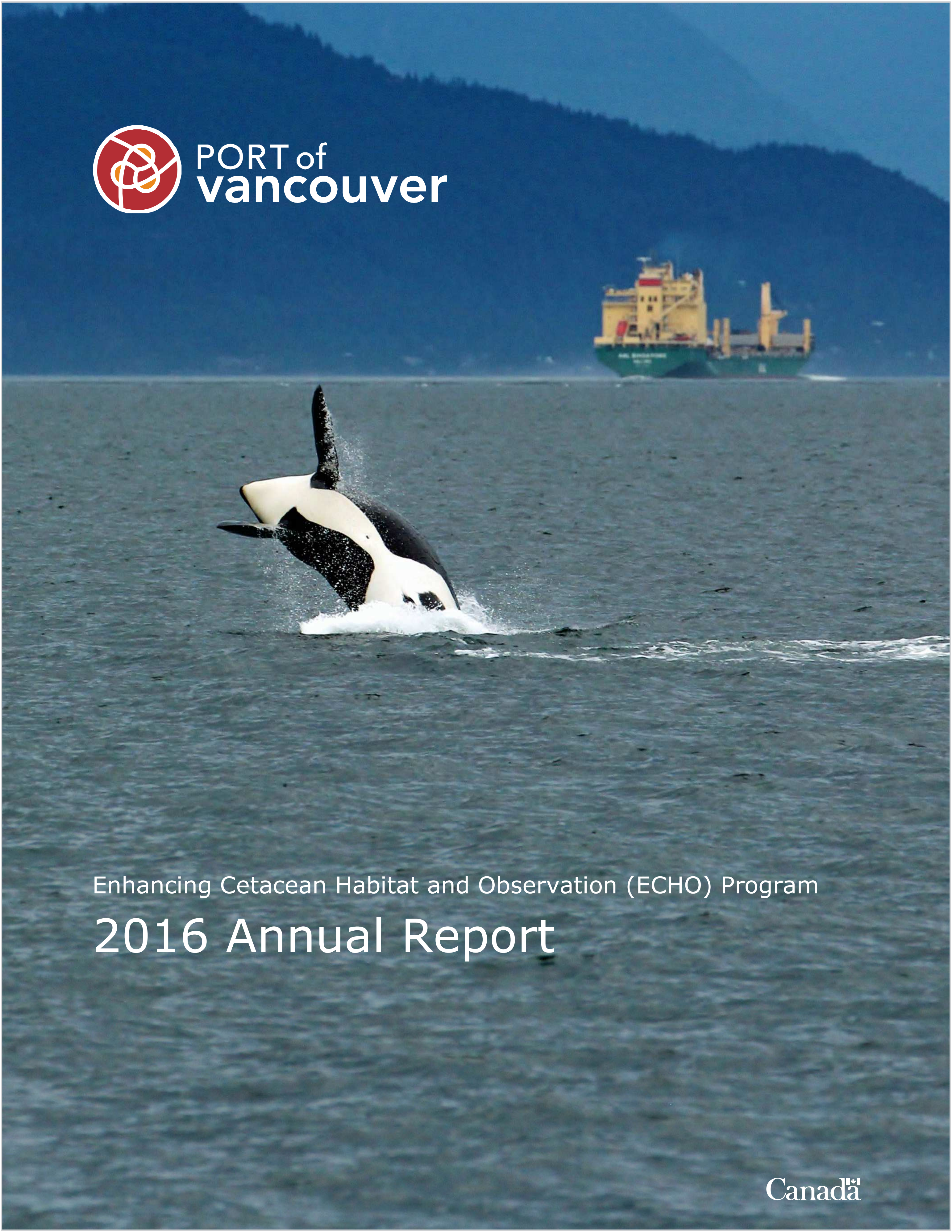

PORT of vancouver

Enhancing Cetacean Habitat and Observation (ECHO) Program

2016 Annual Report

Canada

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ECHO program

British Columbia, Canada is a dynamic and growing international trade gateway. It also has a productive coastal ecosystem that sustains populations of whales, porpoises and dolphins (cetaceans). Fisheries and Oceans Canada has published *Species at Risk Act* recovery strategies and action plans for a number of endangered and threatened whale species in the region. Some of the key threats to whales include: acoustic disturbance (e.g. underwater noise from vessels), physical disturbance (e.g. vessel collisions), environmental contaminants, and the availability of prey.

Much of the commercial vessel activity within the southern coast of British Columbia transits critical habitat for endangered southern resident killer whales, as well as areas known to be of importance to other at-risk whales. The Vancouver Fraser Port Authority is committed to conducting operations in a responsible and sustainable manner. Our mission is to enable Canada's trade objectives, ensuring safety, environmental protection and consideration for local communities. We have a vision to be the world's most sustainable port and we define sustainability as delivering economic prosperity through trade, maintaining a healthy environment and enabling thriving communities. For these reasons, the Enhancing Cetacean Habitat and Observation (ECHO) program was developed in 2014.

The Enhancing Cetacean Habitat and Observation (ECHO) program is a Vancouver Fraser Port Authority-led collaborative initiative aimed at better understanding and managing the cumulative impacts of shipping activities on at-risk whales throughout the southern coast of British Columbia. Although the geographic scope of the Vancouver Fraser Port Authority's jurisdiction is limited, it is recognized that to adequately address the cumulative threats posed by commercial vessel activities, a larger, regional-scale collaborative approach is required. To this end, the ECHO program is advancing projects within the Salish Sea, as well as the waters off the western coast of Vancouver Island and the entrance to the Strait of Juan de Fuca.

Endangered southern resident killer whales in the Salish Sea, BC.

The ECHO program has benefited from early input and advice from scientists, maritime industries, conservation and environmental groups, First Nations individuals and government agencies, to help focus program efforts, and set goals and objectives. The long-term goal of the program is to quantifiably reduce threats from commercial vessel-related activities to at-risk whales.

Program structure

The ECHO program aims to engage and involve key regional interested parties to maximize program success and help ensure that mitigation and management measures developed through the program are informed by social, cultural, economic and environmental sustainability interests.

The ECHO program, led by the Vancouver Fraser Port Authority, is guided by the advice and input of an advisory working group, a federal government advisory committee and associated technical committees. The guidance provided by these volunteer advisors greatly assists the program management team in deciding which scientific studies, educational initiatives and other projects should be advanced to best meet program objectives.

Advisory Working Group

The ECHO advisory working group brings together a broad spectrum of relevant backgrounds, perspectives and interests from both Canada and the United States, who share the common goal of reducing threats to at-risk whales. The role of the advisory working group is to provide the ECHO program management team with timely input, advice and recommendations during the development and execution of the program. The group includes representatives from the following organizations:

- BC Coast Pilots*
- BC Ferries
- Chamber of Shipping of BC
- Cruise Lines International Association (North West & Canada)
- First Nations individuals
- Fisheries and Oceans Canada
- Hemmera Envirochem Inc.
- National Oceanic and Atmospheric Administration (NOAA)
- Pacific Pilotage Authority
- Shipping Federation of Canada*
- Transport Canada
- Vancouver Fraser Port Authority
- Vancouver Aquarium
- Washington State Ferries
- WWF-Canada

**Members new to the advisory working group in 2016*

Federal Government Advisory Committee

The federal government advisory committee offers strategic advice, recommendations and guidance to the ECHO program management team on the overall program direction, objectives and goals. This committee includes representatives from Environment Canada, Fisheries and Oceans Canada, Vancouver Fraser Port Authority and Transport Canada. The committee provides the opportunity for the ECHO program management team to collaborate and communicate with those federal agencies who have direct regulatory authority or decision-making responsibility pertinent to the goals of the program.

Acoustic Technical Committee

Acoustic disturbance has been identified by Fisheries and Oceans Canada as a key threat to the recovery of the endangered southern resident killer whales. Recognizing this, and given the complex technical nature of the subject area, the ECHO program management team has convened an acoustic technical committee. The role of the committee is to provide technical and scientific advice in the development and execution of ECHO research, mitigation and management projects and is composed of marine mammal biologists, acousticians, naval architects and others with specific technical knowledge around the sources and impacts of underwater noise. The acoustic technical committee includes representatives from:

- Fisheries and Oceans Canada
- JASCO Applied Sciences
- NOAA
- Oceans Networks Canada
- Robert Allan Naval Architects
- Sea Mammal Research Unit (SMRU) Consulting Canada
- Transport Canada
- University of British Columbia
- University of St. Andrews
- Vancouver Aquarium
- Washington State Ferries

Vessel Operators Committee

In 2016, the ECHO program convened the first meeting of the vessel operators committee. This committee was established to help provide the ECHO team with advice, support and guidance pertaining to potential mitigation options that may directly impact the shipping industry. In preparation for a proposed vessel slow down research trial (discussed in more detail later in this report), the committee was convened in December, 2016. The vessel operators committee includes industry representatives from:

- BC Coast Pilots
- BC Ferries
- Chamber of Shipping of BC
- Cruise Lines International Association – North West & Canada
- Hapag-Lloyd (Canada) Inc.
- Holland America Group
- Pacific Pilotage Authority
- Shipping Federation of Canada
- Transport Canada
- Vancouver Fraser Port Authority
- Washington State Ferries

Other program or project collaborators

The ECHO program is a collaborative undertaking which recognizes and highlights the value of sharing resources and information to meet common project or program goals. Along with the guidance and advice of the advisory working group, federal government advisory committee and technical committee members listed above, some of these members are also collaborating with the ECHO program on specific projects. Furthermore, the ECHO program has been fortunate to engage with additional parties to support the interests of the program and collaborate on specific aspects, such as data sharing initiatives and research projects. These additional collaborators include:

- Achieve QUieter Oceans (AQUO)
- BC Coast Pilots
- Green Marine
- Prince Rupert Port Authority
- Saturna Island Marine Research and Education Society
- University of Victoria Marine Environmental Observation Prediction and Response Network (MEOPAR)
- Scripps Institute of Oceanography
- Nanaimo Port Authority
- Port of Seattle
- Port of Tacoma
- The Whale Museum

Contributors

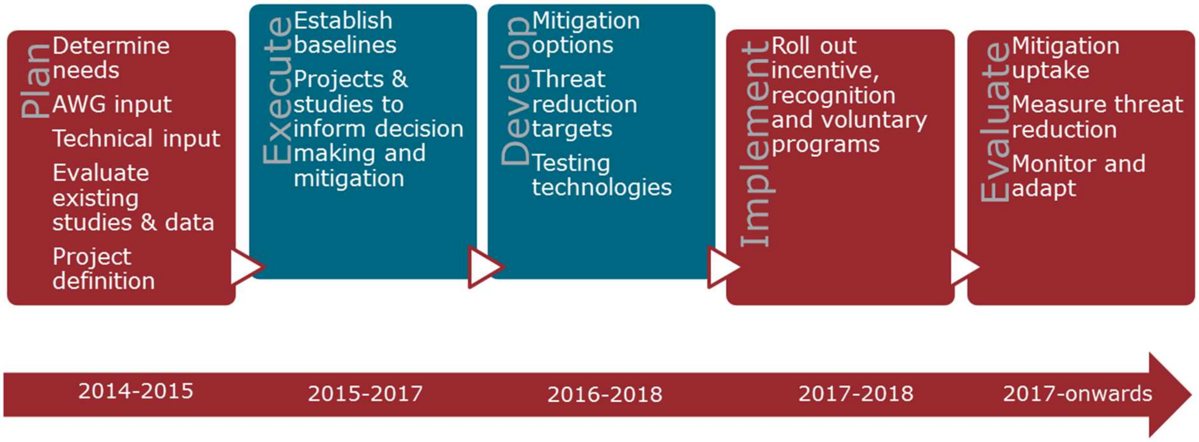
The Vancouver Fraser Port Authority has initiated and provided the seed funding for the ECHO program, however, the program has been very fortunate to also receive contributions from other industry and government stakeholders. Contributions have been received, or committed, either by way of direct financial support or in-kind contribution of equipment, resources and staffing on either the program level or for specific projects. These partners in funding include:

- Fraser River Pile & Dredge
- Trans Mountain
- Transport Canada
- Fisheries and Oceans Canada
- JASCO Applied Sciences
- Ocean Networks Canada

Program status

Road map

The ECHO program launched in November 2014 with the inaugural ECHO Advisory Working Group meeting. The program either initiates or supports short-term projects, scientific studies and educational initiatives to fill knowledge gaps and inform the development of threat reduction solutions and management options. As the program advances, multiple projects are being executed with the intention of developing voluntary mitigation options which will be implemented from 2017 onwards.



Engagement and consultation

Informing and engaging stakeholders, as well as raising the profile of the ECHO program not only in Canada, but internationally, is key to the success of this collaborative program. In 2016, the ECHO program met with the advisory working group three times, convened meetings of the federal government advisory committee and the acoustic technical committee, and launched the vessel operators committee in December, 2016.

Fisheries & Oceans Canada's Species at Risk Recovery Planner, Sheila Thornton, speaking at industry lunch & learn, December 2016

Education

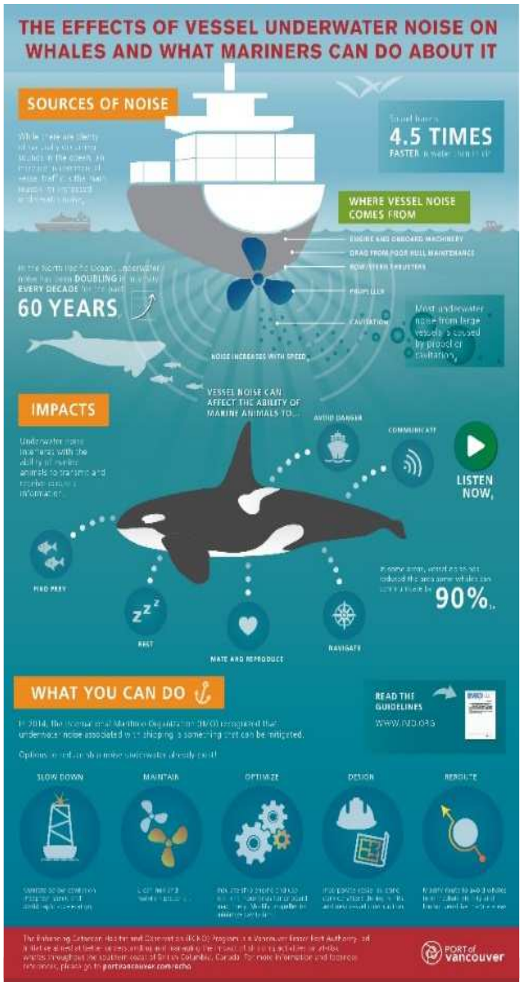
The ECHO program goals are to deliver credible, science-based information in a timely manner and to build trust and confidence in the program through collaboration. We also believe there is a need to educate and enhance awareness on the impacts of shipping on marine mammals. To achieve these goals, the ECHO program maintains regular communication with our advisors and collaborators, issues public newsletters, posts information to our website and creates educational materials to help raise awareness about the program.

The ECHO program delivered 41 presentations, reaching over 1,650 individuals in 2016. Presentations have been delivered to a variety of audiences ranging from regional and international industry stakeholders, environmental groups, acoustic scientists and naval architects. Presentation highlights include; an industry lunch and learn co-hosted with the Chamber of Shipping of BC, three international aquatic noise and environmental conferences, session chair and presentation at the Salish Sea Conference, and hosting a public screening of the award-winning documentary *Sonic Sea* at the Vancouver Aquarium.

In 2016, the ECHO program created an underwater noise infographic designed to introduce the issue of underwater noise to mariners and provide suggestions on what can be done to reduce noise. This infographic has been published in both official languages, shared widely with mariners, and recognized and distributed by the International Maritime Organization through its educational website. Additionally, *People of the Port* videos were created, highlighting two of our project partners: Dr. Peter Ross of the Vancouver Aquarium, speaking about the PollutionTracker program, and Dr. Kate Moran of Ocean Networks Canada discussing their collaboration on the ECHO underwater listening station. Combined, the videos have almost 10,000 views to date.

The ECHO program has also been highlighted and referenced in a number of media and industry publications, including the following stories:

- ECHO program support of *PollutionTracker* project, April 21, 2016
    - Vancouver Sun
    - Vancouver Aquarium Aquablog
- ECHO underwater listening station redeployed, October 7, 2016
    - Vancouver Sun
    - Port Technology
- Proposed underwater noise incentives, November 2016
    - The MotorShip
    - NauticExpo E-magazine
- General program stories
    - GreenPorts Congress review, October 14, 2016
    - Port Technology, December 12, 2016



Underwater noise infographic

ECHO projects and initiatives

Since inception, the ECHO program has initiated or provided support to 17 projects in three vessel-related threat categories that are identified in Fisheries and Oceans Canada's Species at Risk action plans: acoustic disturbance, physical disturbance and environmental contaminants. Availability of prey is identified as another key threat category for at-risk whales. While this threat category is not a focus area for the ECHO program, this threat is being addressed by the port authority through a separate Habitat Enhancement Program. The ECHO program's advisory working group helped identify underwater noise as a priority focus area based on impacts to species-at-risk, in particular the southern resident killer whales.

A few of the ECHO program projects advanced in 2016 are highlighted here:

Acoustic disturbance/underwater noise

Regional ambient noise project - ONGOING

In consultation with the Acoustic Technical Committee, the ECHO program identified five priority sites at which to collect and analyze underwater ambient noise levels in the Salish Sea. In 2016, three of the five sites were collecting data which will be used to help establish current noise conditions. Partners on this project include: Fisheries and Oceans Canada, Sea Mammal Research Unit (SMRU) Consulting Canada, the Whale Museum, Ocean Networks Canada and Saturna Island Marine Research and Education Society.

Five hydrophone sites were selected as representative sites to monitor ambient noise levels in the region.

Regional ocean noise contributors – COMPLETE

The final report for this project, entitled *Regional Ocean Noise Contributors Analysis* was completed in 2016. The work was conducted by JASCO Applied Sciences Ltd., using a regional acoustic model combined with real traffic data to evaluate how much underwater noise different vessel sectors contribute to the soundscape. The study found that the commercial vessel sector (commercial deep-sea vessels, ferries, tugs, etc.) is the main contributor to underwater noise in the region, with different commercial sectors contributing in different geographical sub-regions. The study will help the ECHO program focus voluntary management efforts and inform the development of vessel noise reduction solutions that are appropriate for the vessel sectors and sub-regions.

The report has been posted to portvancouver.com/echo.

In 2016, the regional ocean noise contributor's project was completed.

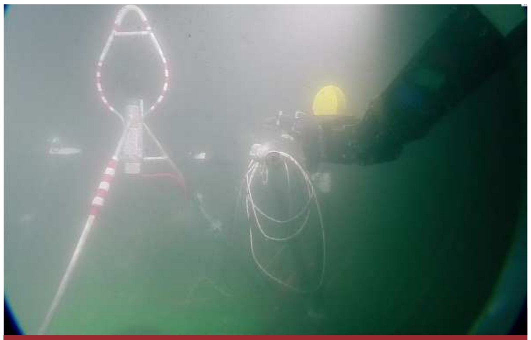
Vessel noise reduction options - COMPLETE

What makes ships quieter? This key question was explored in the *Vessel Quieting Design, Technology and Maintenance Options for Potential Inclusion in EcoAction Program* report completed by Hemmera Envirochem Inc. This desk-top study identified three quiet ship classifications and three propeller technologies shown to reduce underwater noise in support of new criteria for the port authority's EcoAction program. The new EcoAction underwater noise criteria came into effect as of January 1, 2017.

The report has been posted to portvancouver.com/echo.

Underwater listening station – ONGOING

In partnership with Ocean Networks Canada, JASCO Applied Sciences and Transport Canada, the ECHO program installed an underwater listening station in the inbound shipping lane of the Strait of Georgia. The multi-hydrophone array, which allows for accurate measurement of vessel source levels, marine mammal detections and recording of ambient noise, was first deployed in September 2015. In October 2016, after a successful first year of data collection, the array was redeployed for an additional year. Over 1,000 vessel source level measurements were made in the first year of operation. Following each successful vessel pass of the ULS, JASCO PortListen software generates a two-page noise report which can be shared with vessel owners and operators.



Remote controlled robots maintain the underwater listening station in the murky waters 170m below the surface.

The information obtained through the underwater listening station is establishing one of the largest databases of vessel source levels in the world, providing valuable insight on vessel-generated noise, and how it can be reduced.

Physical Disturbance/Strike Risk

Large whale vessel strike risk assessment – ONGOING

Since 2015, the ECHO program has been supporting Fisheries and Oceans Canada in a project to evaluate the distribution and habitat of large whales, and the potential for ship strike. In early 2016, Fisheries and Oceans Canada published a preliminary report which detailed the use of whale distribution data obtained through aerial surveys, in a modelling exercise to assess the risk of lethal ship strikes to humpback and fin whales off the west coast of Vancouver Island. The ECHO program continues to support the Fisheries and Oceans-led project through funding of aerial surveys and satellite tagging. In the 2016 field season, nine temporary satellite tags were deployed on fin whales, six of which successfully transmitted data. Five additional aerial transect surveys were also completed. This work was conducted to collect fine scale habitat use and behaviour data for fin whales and humpback whales. Additional tags will be deployed in the 2017 field season.

Photo Credit: DFO

Aerial surveys to estimate large whale distribution areas.

Environmental Contaminants

Vancouver Aquarium Pollution Tracker - ONGOING

The Vancouver Aquarium successfully sampled ten ECHO program-funded locations in and around the Vancouver Fraser Port Authority's jurisdiction, and southern resident killer whale critical habitat, as part of the Vancouver Aquarium's Pollution Tracker project. This project aims to establish a baseline of environmental conditions in British Columbia's coastal waters through the sampling of sediment and shellfish. These sampling media represent the health of the habitat and food web for at-risk whale species in the region. Samples of sediment and mussels will be analyzed for an extensive suite of chemicals to help determine current contaminant loadings, identify priority contaminants and sources, and provide a baseline for assessing trends into the future. The ECHO program-funded sites are part of a coast-wide project, for which the Vancouver Aquarium will publish a report in 2018.

ECHO program – project list

A complete list of the projects completed, underway or being evaluated by the ECHO program include:

1. Regional ambient acoustic monitoring
2. Regional ocean noise contributors
3. Vessel noise reduction options
4. The underwater listening station
5. Underwater noise education initiative
6. Summary paper on underwater noise impacts to whales
7. Estimating the effects of noise from commercial vessels and whale watch boats on southern resident killer whales
8. Effect of ship noise on vocal behaviour of humpback whales in BC
9. Underwater listening station sea trials
10. Voluntary vessel slowdown trial
11. Feasibility study of underwater listening station locations in the Salish Sea
12. Large whale vessel strike risk assessment
13. Fisheries and Oceans Canada whale tagging and additional aerial transect surveys
14. Mariner's Guide to Whales of Western Canada
15. Whale sightings notification system
16. Vancouver Aquarium PollutionTracker Project
17. Management of contaminants during underwater hull cleaning

Looking ahead to 2017

In its third year, the ECHO program will continue to make progress on current projects and will be initiating new studies to advance research and inform potential mitigation solutions within the three threat categories.

Highlights of the 2017 ECHO program work plan are summarized below:

EcoAction program

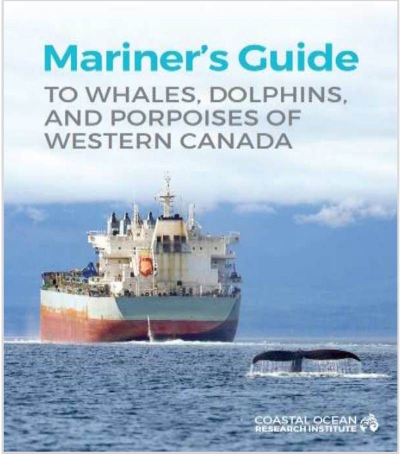
Effective January 1, 2017, the port authority's EcoAction program[1] includes new incentive criteria to provide harbour due rate discounts for quieter ships. This makes Canada the first country in the world with a marine noise reduction incentive.

Regional ambient noise project

In 2017, the ECHO program will continue to monitor and analyze ambient noise conditions through existing infrastructure in the Strait of Georgia, Boundary Pass and Haro Strait. Working with regional partners, additional sites may be brought on line in 2017, with consideration to locations in Active Pass, the Strait of Juan de Fuca and Burrard Inlet.

Mariner's guide to whales on B.C.'s coast

Working together with the Vancouver Aquarium and the Prince Rupert Port Authority, the *Mariner's Guide to Whales, Dolphins and Porpoises of Western Canada* was developed. This guide provides information on how to identify the most common whale species, where whales are frequently sighted, and the areas where the probability of a vessel encountering a whale is high. The guide is available online, and hard copy guides will be printed and distributed to mariners along the west coast. Other project collaborators include BC Coast Pilots, BC Ferries, Fisheries and Oceans Canada, Pacific Pilotage Authority and Chamber of Shipping of BC.



The Mariner's Guide has be distributed to vessel operators along the BC coast.

Underwater listening station

The final report for the first year (September 2015 – October 2016) of data collected from the underwater listening station will be released in 2017, and available at portvancouver.com/echo.

The ECHO program team will use the data obtained through the underwater listening station to better understand how vessel operating conditions such as speed and rotations per minute, as well as vessel characteristics like hull form, engine type, propeller size and shape may affect underwater noise. Working with local stakeholders, operational trials may be conducted to help develop best practices for vessel noise reduction in the region.

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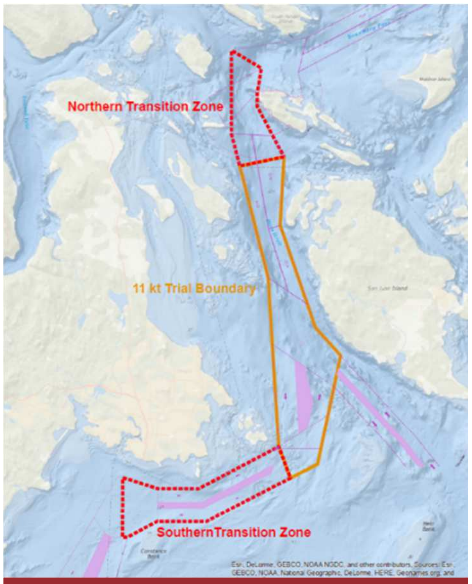
[1] *The Vancouver Fraser Port Authority's use of the name "EcoAction" refers to a program specifically intended to promote improved environmental performance within the shipping industry and is not related to the EcoAction Community Funding Program administered by Environment Canada.*

Voluntary vessel slowdown trial



A vessel slowdown trial through Haro Strait is planned for summer 2017.

In order to better understand the relationship between reduced vessel speed and underwater noise, the ECHO program has planned a voluntary trial to slow down commercial vessels.

The trial asks all vessels transiting Haro Strait to reduce their speed to 11 knots through the water for a distance of approximately 16 nautical miles between Discovery Island at the southern end, and Henry Island at the northern end. Average vessel speeds through this area currently range from 18 knots for containers to 13 knots for bulkers.

During the trial period, hydrophones will be used to monitor both vessel source levels at slower speeds, as well as total underwater noise. Computer modelling will then be used to simulate the resultant benefits to killer whale behaviour. The ECHO program team, in conjunction with industry experts, will also evaluate the potential benefits and implications to the shipping industry as a result of slowing vessels down.

In addition to advancing the projects listed above, we will continue our education and engagement activities, presenting at national and international conferences, convening regular meetings of our advisory and technical committees and promoting educational initiatives. The program team will work closely with our advisors, collaborators and government to find science-based solutions.

Conclusion

In 2016, the population of southern resident killer whales dropped to 78 individuals. The loss of each whale reminds us of the urgency and importance of a regional collaborative approach to better understand and address the threats affecting this iconic species, and other at-risk whales, in the Salish Sea.

The research is telling us that solutions exist to help minimize the impact of shipping on marine life. The ECHO program strives for a science-based approach to environmentally-responsible and sustainable shipping while safeguarding and promoting the protection of local wildlife. We are especially appreciative of the efforts of our advisors, collaborators and contributors who continue to make this goal a priority.

Thank you to our collaborators

Advisory Working Group
BC Coast Pilots
BC Ferries
Chamber of Shipping of BC
Cruise Lines International Association (North West & Canada)
Fisheries and Oceans Canada
First Nations individuals
Hemmera Envirochem Inc.
National Oceanic and Atmospheric Administration (NOAA)
Pacific Pilotage Authority
Shipping Federation of Canada
Transport Canada
Vancouver Aquarium
Vancouver Fraser Port Authority
Washington State Ferries
WWF-Canada

Federal Government Advisory Committee
Environment Canada
Fisheries and Oceans Canada
Transport Canada
Vancouver Fraser Port Authority

Project Collaborators
All-Sea Enterprises
BC Coast Pilots
BC Ferries
Chamber of Shipping of BC
NOAA
Prince Rupert Port Authority
Seaspan
Vancouver Aquarium

Funding Contributors
Fraser River Pile and Dredge
Trans Mountain Pipeline
Transport Canada
Vancouver Fraser Port Authority

Independent facilitation
Fraser Basin Council

Acoustic Technical Committee
Fisheries and Oceans Canada
JASCO Applied Sciences
NOAA
Oceans Networks Canada
Robert Allan Naval Architects
SMRU Consulting
Transport Canada
University of British Columbia
University of St. Andrews
Vancouver Aquarium
Washington State Ferries

Vessel Operators Committee
BC Coast Pilots
BC Ferries
Chamber of Shipping of BC
Cruise Lines International Association (North West & Canada)
Hapag-Lloyd (Canada) Inc.
Holland America Group
Pacific Pilotage Authority
Shipping Federation of Canada
Transport Canada
Vancouver Fraser Port Authority
Washington State Ferries

Other Engagement
Achieve Quieter Oceans (AQUO)
Green Marine
Marine Environmental Observation Prediction and Response Network (MEOPAR)
Nanaimo Port Authority
Ports of Seattle and Tacoma
Scripps Institution of Oceanography

Significant In-kind Contributors
Fisheries and Oceans Canada
JASCO Applied Sciences
Oceans Networks Canada
Vancouver Aquarium

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Cover photo: Joan Lopez

APPENDIX IR4-10-B
ECOACTION PROGRAM DESCRIPTION

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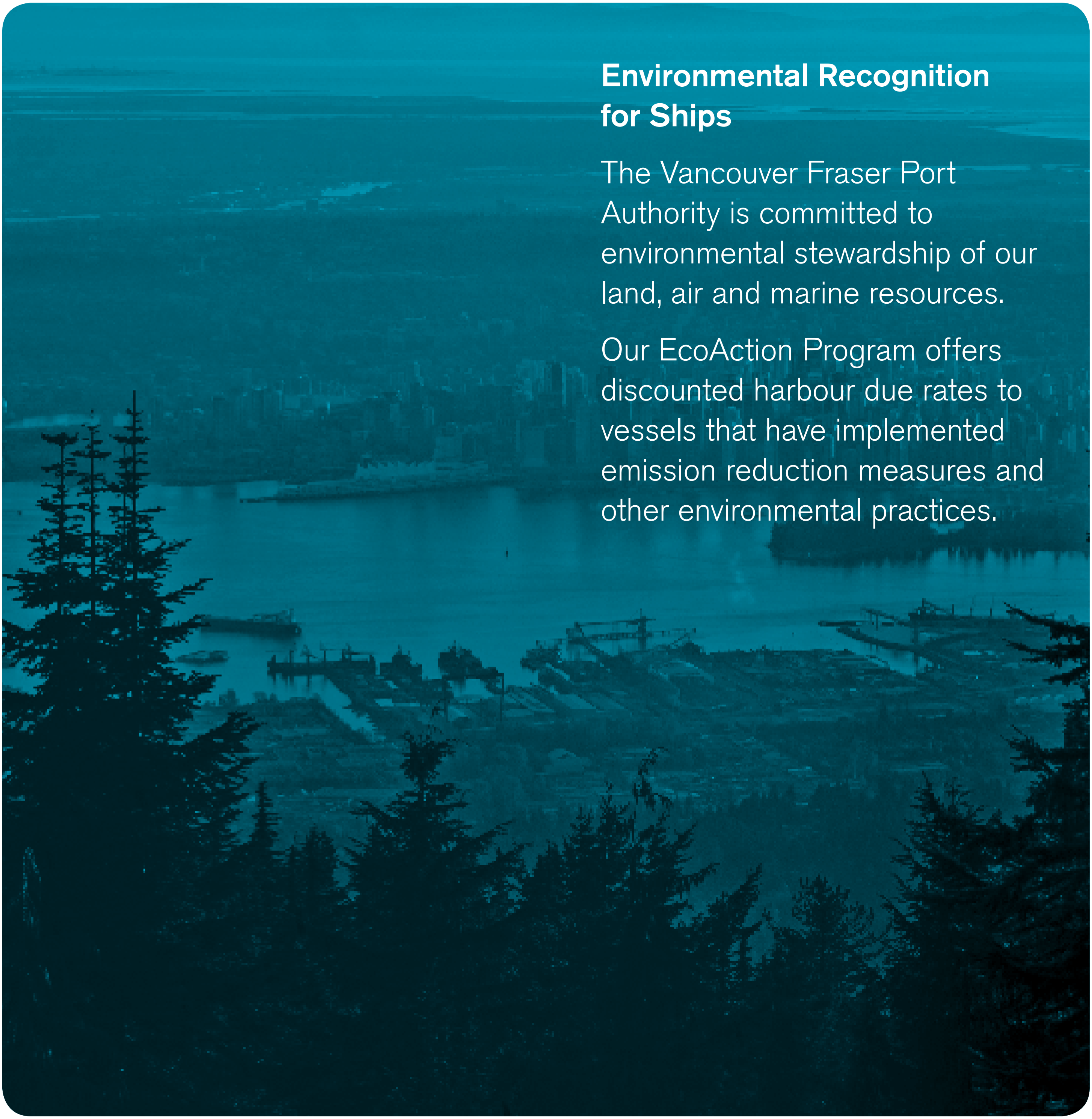
PORT of vancouver

ECOACTION

Receive Discounted Harbour Due Rates by Participating in our EcoAction Program



Environmental Recognition for Ships

The Vancouver Fraser Port Authority is committed to environmental stewardship of our land, air and marine resources.

Our EcoAction Program offers discounted harbour due rates to vessels that have implemented emission reduction measures and other environmental practices.

EcoAction Award Levels

NEW

for 2017

Underwater noise reduction criteria

Underwater noise created from shipping activities can impact whales' ability to navigate, communicate, and find prey. With a number of at-risk whale species frequenting our waters, reducing underwater noise from vessels is a priority for the Vancouver Fraser Port Authority.

We are proud to be the first port in the world to recognize vessels who are doing their part to reduce underwater noise.

Eligible options for reduced rates:

- Ship classification society quiet vessel notations
  - Bureau Veritas Underwater Radiated Noise (URN)
  - DNV-GL Silent-Environmental (E)
  - RINA DOLPHIN
- Cavitation/wake flow reduction technologies
  - Becker Mewis duct
  - Propeller Boss Cap Fins (PBCF)
  - Schneekluth duct

EcoAction Program

The EcoAction Program recognizes a variety of fuel, technology and environmental management options that are eligible to receive discounted harbour due rates. Vessels may qualify for one of three levels GOLD, SILVER or BRONZE.

The EcoAction Program recognizes positive environmental practices while vessels operate within the Vancouver Fraser Port Authority's jurisdiction. These include emission reduction measures that exceed the current North American Emission Control Area (NA-ECA) requirements adopted under the International Maritime Organization, and technologies or class notations that factor into reduction of vessel-generated underwater noise.

Blue Circle Award

The Blue Circle Award recognizes marine carriers with the greatest fleet-wide participation in the EcoAction Program. Marine carriers must have a minimum of five billable calls at reduced, EcoAction rates, and, greater than 50% of billable calls by all vessels in their fleet calling to the Port of Vancouver at reduced, EcoAction rates.

How to qualify?

Satisfy ONE environmental measure

EcoAction Award Levels

🟡 G Gold   ⚪ S Silver   🟤 B Bronze

Performance Based

🟢 P Port authority will determine award level based on actual performance of environmental measure.

Cleaner Fuels

Natural Gas
- 🟢 Performance Based

Biodiesel Blend
- 🟢 Performance Based

Ship Environmental Programs

POPULAR CHOICES

Environmental Ship Index
- 🟡 Score ≥ 40
- ⚪ Score 31 < 40
- 🟤 Score 20 < 31

RightShip
- 🟡 EVDI of A and Environment 3 or higher
- ⚪ EVDI of B and Environment 3 or higher
- 🟤 EVDI of C and Environment 3 or higher

Clean Shipping Index
- 🟡 Vessel Score of Green
- ⚪ Vessel Score of Yellow
- 🟤 Vessel Score of Red

Green Marine
- 🟡 Level 5 GHG and Level 2 Others
- ⚪ Level 4 GHG and Level 2 Others
- 🟤 Level 3 GHG and Level 2 Others

POPULAR CHOICES

Energy Efficiency Design Index
- 🟡 15% better than required
- ⚪ 10% better than required
- 🟤 5% better than required

Green Award
- 🟤 Award Certificate

Vessel and Engine Technologies

POPULAR CHOICES

Shore Power
- 🟡 Ship Side infrastructure

Vapour Control/Recovery
- 🟤 Certified for Tankers

Seawater Scrubber
- 🟢 Performance Based

Direct Water Injection
- 🟢 Performance Based

Combustion Air Humidification
- 🟢 Performance Based

Fuel/Water Emulsion
- 🟢 Performance Based

Selective Catalytic Reduction
- 🟢 Performance Based

Exhaust Gas Recirculation
- 🟢 Performance Based

Reduce underwater noise
- 🟤 Becker Mewis duct NEW
- 🟤 Propeller Boss Cap Fins (PBCF) NEW
- 🟤 Schneekluth duct NEW

Ship Classification Societies

Lloyd's Register (LR)
- 🟤 EP Designation

American Bureau of Shipping (ABS)
- 🟤 ES Designation

Bureau Veritas (BV)
- 🟡 Underwater Radiated Noise (URN) Notation NEW
- 🟤 CLEANSHIP Designation

Nippon Kaija Kyokai (Class NK)
- 🟤 EA Designation

Registro Italiano Navale (RINA)
- 🟡 DOLPHIN Notation NEW
- 🟤 GREEN STAR Designation

Det Norske Veritas-Germanischer Lloyd (DNV-GL)
- 🟡 SILENT Environmental (E) Notation NEW
- 🟤 CLEAN or EP Designations

The Application Process

Gather Information

Applicants must provide the following information when submitting an application:

- ○ Vessel Name
- ○ Vessel IMO identification
- ○ Estimated time of arrival (ETA), for single call applications only
- ○ Environmental measure

Apply online

portvancouver.com/ecoaction

For a Single Call application

1. Submit an application through our website, visit portvancouver.com/ecoaction
2. Port authority verifies the specific environmental measure and will either approve or deny the application.
3. Port authority issues an invoice at the verified rate.

For an Annual Declaration

1. Submit an application through our website, visit portvancouver.com/ecoaction
2. Port authority accepts the declaration subject to review and specifies the default discounted harbour due rate.
3. On the vessel's next visit, the port authority verifies compliance and either approves the default discount rate, adjusts the discount rate on a one-time-only basis or denies the reduction measure and applies the basic harbour due rate.
4. Port authority issues an invoice at the verified rate.

EcoAction Program Guidelines

1. Vancouver Fraser Port Authority harbour due rates, effective January 1, 2017, per gross registered tonne (GRT) in Canadian funds, are as follows:
    - ● GOLD $0.050/GRT
    - ● SILVER $0.061/GRT
    - ● BRONZE $0.072/GRT
    - ● BASIC $0.094/GRT
2. An application must be submitted for every vessel call for which a discounted rate is sought, either through the single call process or the annual declaration process.
3. At the time of verification, the port authority will determine the discount award level for the vessel based on available information.
4. Applications will be APPROVED or DENIED at the time of verification at the sole discretion of the port authority and additional information may be requested.
5. Harbour dues are payable no more than five times for the same vessel in any calendar year.
6. No changes to a submitted application will be allowed during the estimated time of arrival (ETA) window for a single call application or to an accepted annual declaration.
7. Appeals can be filed with the port authority to review a prior decision for both single call applications and annual declaration applications.

The Vancouver Fraser Port Authority's use of the name EcoAction refers to a program specifically intended to promote improved environmental performance within the shipping industry and is not related to the EcoAction Community Funding Program administered by Environment Canada.

Find more information in our fee document at portvancouver.com/fees

Vancouver Fraser Port Authority

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Canada

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APPENDIX IR4-10-C
SUPPORTING TABLE

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Table IR4-10-C1 Initiatives that Have Been Undertaken, and are Currently Being Undertaken as Part of the ECHO Program

Study Name	Study Objective	Study Findings	Timeline
Regional Ambient Acoustic Monitoring	- A coordinated network of hydrophones at priority representative locations through the region will allow temporal trends in acoustic conditions to be established and evaluated over time, providing context for, and evaluation of, the implementation and uptake of future noise mitigation and management measures. Additional regional ambient noise measurements will further allow the existing regional acoustic model to be better calibrated.	- Strait of Georgia: Data collection is ongoing and automated ambient noise reports for each lunar month are being generated - Haro Strait: Data collection is ongoing and ambient noise reports for each lunar month are being generated - Boundary Passage: Data collection is on-going. 2016 Report was received in Q1-2017 - Juan de Fuca Strait: Sheringham location was not collecting data in 2016. Currently exploring options for a potential hydrophone installation in 2017 - Active Pass: Whale Tracking Network hydrophones were not collecting continuous data appropriate for ambient noise analysis in 2016. Options for this area in 2017 are being investigated	Q2-Q4 -2017: Continued investigation of data opportunities for two locations Q1-Q4 -2017: Collection and analysis of ambient noise data for year 2 Q2-2017: Reporting on year 1 baseline ambient noise conditions for key sub-areas in the region
Regional Ocean Noise Contributors Analysis	- A complete regional ocean noise budget will further our understanding of how different vessel sectors (commercial shipping, recreational, whale watching, and fishing) are contributing to baseline acoustic conditions. Further differentiation by individual vessel types (e.g., tugs, bulk carriers, container ships, cruise ships, ferries, whale watching) will assist in identifying how and where different vessel types contribute to the ocean noise budget. Evaluation of this information will help target management efforts by vessel sector, vessel type, and location within the region.	- See Appendix IR4-05-A of IR4-05 - The commercial vessel sector (e.g., commercial deep-sea vessels, ferries, tugs, etc.) is the main contributor of underwater noise in region - Commercial deep-sea vessels make a relatively large contribution to underwater noise, mostly along international shipping lanes - Smaller crafts (e.g., recreational, fishing, and whale-watch vessels) make an important contribution in sub-regions such as Haro Strait and the San Juan Islands, especially in summer	Final report posted to ECHO website January 2017

Study Name	Study Objective	Study Findings	Timeline
Vessel Noise Reduction Options	• Explore potential underwater noise reduction options and the economic and environmental implications of different noise reduction management options. • Evaluation of the cost, feasibility and effectiveness of potential vessel noise reduction options will allow criteria to be developed for inclusion into the VFPA's EcoAction Program which can incentivise ship owners to reduce their vessel noise outputs.	• Desktop study identified three quiet ship classifications and three propeller technologies shown to reduce underwater noise • Supported new criteria for the VFPA's EcoAction Program	Final report posted to ECHO website January 2017. Informed EcoAction incentives put in place January 1, 2017
Underwater Listening Station (ULS)	• Multi-hydrophone array, which allows for accurate measurement of vessel source levels, marine mammal detections, and recording of existing underwater noise.	• Over 1,000 vessel source level measurements were made in 2015-2016 • Following each successful vessel pass of the station, a noise report (on the noise made by the vessel) can be shared with vessel owners and operators • Increased participation by large ocean-going vessels is being continually observed, resulting in a large dataset that will soon allow for vessel ranking within each category. The project is near achieving the 100 measurements required in each category to provide a ranking of source levels by each vessel class	Ongoing
ULS Trials with Regional Tug and Ferry Operators	• A range of regional tug and ferry operators are participating in vessel source level measurements and will be analysed at different operating speeds and conditions (i.e., fuel type, shaft rate/RPM, operational mode, etc.) and in some instances comparisons will be made between LNG and traditional diesel run vessels from the fleet.	• In progress	Results and analysis Q1-2018

Study Name	Study Objective	Study Findings	Timeline
Feasibility Study of ULS Locations in the Salish Sea	• In partnership with Transport Canada and DFO, the ECHO Program advanced a feasibility study evaluating potential locations within the Salish Sea for underwater listening station(s).	• Completed. In review	In review
Estimating the Effects of Underwater Noise from Commercial and Whale-watching Vessels on SRKW	• Understand the contributions of different vessel types to the overall noise budget. • Provide an increased understanding of what levels of underwater noise could be causing behavioural responses in SRKW. • Understanding the effects of noise from different vessel types on SRKW will help inform and target management efforts.	• Whale watch boat noise increased the estimated time when SRKW may not be able to find prey because of changes in behaviour from 3 hours per day that SRKW were present in the study area to 3.2 hours per day (i.e., from 12.5% to 13.4%) when compared to noise from commercial vessels alone. This noise exposure effect was primarily due to commercial vessel noise (up to 93% of this time) • The potential for noise of reducing prey detection range through masking of echolocation clicks outside this period was negligible for commercial vessels, but for whale watch boats, ranged between 5% and 34%. This is equivalent to whales detecting prey at up to 238 m and 165 m, respectively, rather than 250 m. Whale watch boats and commercial vessels had a cumulative effect (12% to 37% range reduction) • Potential lost foraging time due to click masking resulted in an additional 1.7 to 2.3 hours per day (7% to 9% of each day whales are present). This noise exposure effect was primarily due to whale watch boat noise (up to 93% of this time) • Overall, the time for foraging potentially lost due to behavioural responses and click masking totalled 20% to 23% of each whale day (4.9 to 5.5 hours), with approximately two	Final report posted to ECHO website July 2017.

Study Name	Study Objective	Study Findings	Timeline
		thirds of this time due to noise from large commercial vessels and one third due to noise from whale watch boats • These results are reflective of the difference in noise intensity (loudness) and frequencies of whale watch and commercial vessels and the difference in vessel number, proximity, and behaviour around the whales • Confidence in model results was higher for behavioural responses than for echolocation click masking predictions due to limited data to estimate noise levels received by the whales from whale watch boats	
Effect of Ship Noise on Vocal Behaviour of Humpback Whales in B.C.	• This project will evaluate the impacts of underwater ship noise on the vocal behaviour of humpback whales. • Evaluation of humpback vocalisations in a period immediately before, during, and after transit of a large ship. • Understanding how humpback whales react to vessel underwater noise will help inform and target management efforts.	• Humpback whale call rates declined in the 30-minute period when a ship was transiting (during) compared to call rates in the 30-minute period prior to the ship transit (before) • No significant difference in humpback whale call rate was detected between the 30-minute period after a ship had passed (after) and the 30-minute period when a ship was transiting (during) • Because there was no visual observation or tagging undertaken on the whales during the underwater noise recordings, it was not possible to determine if the lower call rate during the period of ship transit was because the whales changed their behaviour (i.e., actually called at a lower rate, stopped calling or left the area) or because the ship noise masked whale calls	Final report posted to ECHO website July 2017.

Study Name	Study Objective	Study Findings	Timeline
Hull Cleaning Pilot and Vessel Source Level Measurement	• Measure the effect of hull cleaning as a noise reduction technique on vessel source levels. • Identify whether noise reduction measures (such as hull cleaning) are effective, but will also inform which vessel types or particular vessels emit the least and most noise. • The Strait of Georgia ULS, installed in partnership with Ocean Networks Canada (ONC) and JASCO Applied Sciences, and supported by Transport Canada, has been successfully collecting high quality underwater sound data since September 2015.	• Hull cleanings were conducted on two vessels in February 2017. An analysis for underwater noise levels will be undertaken to evaluate if there are notable differences observed before and after hull cleaning for both vessels cleaned • Data shared with ship owners to increase collaboration and education on how their vessel sound signature changes over time and/or compares to other vessels • Help inform potential EcoAction incentive criteria around 'quiet' versus 'noisy' vessel levels	Expected completion of hull cleaning trials Q3-2017. Analysis and reporting Q4-2017 Year 1 vessel source level measurements, ambient noise measurement and marine mammal detections: final report submitted Q4 2016 Operation of the listening station has been extended to October 2017
Seasonal Vessel Slowdown Trial	• Implementing an 11-knot speed limit for commercial vessels in Haro Strait may reduce noise impacts and improve acoustic habitat conditions for SRKW in this high use area of critical habitat. • This hypothesis will be evaluated through both computer modelling and in-water measurement of ambient noise and vessel source levels during a trial slowdown. • An economic assessment will be undertaken before the trial to evaluate the potential impacts of the slow down to vessel operators.	• In progress • See Appendix IR4-10-D for trial description	The trial will be conducted between August 7 and October 6, 2017, requesting all vessels to slow down to 11 knots (speed through water) in Haro Strait. More details on the trial can be found at www.portvancouver.com/slowdowntrial

Study Name	Study Objective	Study Findings	Timeline
Vessel Strikes			
Mariner's Guide	- Guide provides information on how to identify the most common whale species, where whales are frequently sighted, and the areas where the probability of a vessel encountering a whale is high.	- See Appendix IR4-10-E - The purpose of this guide is to help mariners reduce their risk of striking and killing, or seriously injuring a cetacean (whale, dolphin, or porpoise). - It includes descriptions of frequently encountered whales and dolphins, locations along the coast where cetacean densities are highest, and simple measures they can take to greatly reduce their risk of striking a whale, dolphin, or porpoise.	Guide completed in Q4-2016. Hard-copies distributed in Q4-2016 and Q1-2017, digital copy available from the websites of the Vancouver Aquarium and the ECHO Program
Large Whale Vessel Strike Risk Assessment	- An analysis of ship strike risk was completed based on whale sightings and effort data collected during aerial surveys 2012-2015 and compiled shipping intensity data off the west coast of Vancouver Island, Canada, and approaches to major shipping lanes in Juan de Fuca Strait.	- Report published by DFO in 2017 - Humpbacks were most likely to be struck along the shelf edge, the inshore approaches to Juan de Fuca Strait, and within the strait itself - Although uncommon, fin whales were most likely to be struck in the offshore approaches to Juan de Fuca Strait and inside the western portion of the strait	Completed
Whale Tagging and Additional Aerial Transect Surveys	- Large whale vessel strike risk model will be improved with the addition of satellite tag telemetry studies and additional aerial surveys to incorporate fine scale habitat use and behaviour of fin whales and humpback whales. - The results will provide spatial representation of ship strike risk to large baleen whales over the region off southwest Vancouver Island.	- In progress	Tag deployment and aerial transect surveys: Q2-Q4-2016 Remainder of tags deployed Q2-Q3 2017 Tag data analysis: Q2-Q4-2017 Preliminary reporting: Q4-2017 Complete analysis of aerial survey data Q1-2018 Final report Q2-2018

Study Name	Study Objective	Study Findings	Timeline
Whale Sightings Notification System	• This project aims to inform commercial vessels of recent whale sightings throughout the west coast, to reduce the potential for vessel collision. • The project will develop a notification system for communicating out the real-time whale sightings data being gathered through Vancouver Aquarium's recently released WhaleReport App to commercial vessel pilots, and potentially the commercial vessel captains further offshore. • The project will also explore the possibility of transmitting real time whale detection data from hydrophone systems along the coast to the notification system.	• The ECHO program had discussions with Prince Rupert Port Authority, Vancouver Aquarium, Ocean Networks Canada (ONC), the Pacific Pilotage Authority and BC Coast Pilots on the development of a consistent coast wide whale notification system for commercial vessel pilots and captains in 2015 and early 2016 • The project would also require the involvement of DFO's Coast Guard and would likely overlap with the longer term objectives of DFO's Whale Tracking Network project • Following meetings between the VFPA, Prince Rupert Port Authority, ONC, and the Vancouver Aquarium in early 2016, the ECHO team is awaiting feedback from ONC and the Vancouver Aquarium on whether a collaborative project is possible. The project has not advanced further as potential project roles and partnerships have still not been defined	On hold

Study Name	Study Objective	Study Findings	Timeline
Environmental Contaminants			
Vancouver Aquarium PollutionTracker Project	• Sediments and shellfish provide insight into the state of contamination of coastal environments by providing guidance to managers and stakeholders on the nature of priority pollutants, contaminant trends over time, and the identification of geographic hotspots. • The results will serve to assess the health of killer whale critical habitat, as well as habitat within VFPA jurisdiction. • The results will also identify priority contaminants which can accumulate in killer whale food webs. This data will inform baseline conditions, identify potential contaminant sources and inform pollution priorities, and will support the development of best practices or other mitigation measures to reduce contaminant loading to the marine environment.	In progress.	The Vancouver Aquarium has successfully sampled all ECHO-funded locations, including the deployment and sampling of caged mussels completed in Q1-2017. A draft report on the first year of PollutionTracker sampling, and analysis of sediment for VFPA sites has been submitted, and generalised results were presented at the June 6, 2017 advisory working group meeting. The Vancouver Aquarium will publish the coast-wide findings of the two-year project in a report to all stakeholders in Q4-2017 or Q1-2018.

Study Name	Study Objective	Study Findings	Timeline
Management of Contaminants During Underwater Hull Cleaning	• In-water cleaning of vessel hulls has the potential to release both chemical (such as metals and anti-fouling compounds) and biological (invasive species) contaminants to the marine environment. • Measurement of chemical and biological contaminants in the receiving water body adjacent to a vessel hull both before and during hull cleaning, will help determine the effectiveness of the underwater hull cleaning technology at containing the release of contaminants. • The results of these measurements will also indicate whether underwater hull cleaning is safe for the local receiving marine environment.	• Hull cleanings were conducted on two vessels in February 2017 • In-water observations and environmental sampling indicated further adjustments to the WhaleShark technology are required • WhaleShark is currently making refinements and conducting environmental sampling in accordance with methods established by DFO and Transport Canada, prior to further validation	Expected completion of hull cleaning trials Q3-2017. Analysis and reporting Q4-2017

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APPENDIX IR4-10-D

ECHO PROGRAM VOLUNTARY VESSEL SLOWDOWN TRIAL BACKGROUNDER

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ECHO Program voluntary vessel slowdown trial

Haro Strait: August 7th – October 6th, 2017

Overview

As part of its objective to better understand and manage the impact of shipping activities on at-risk whales throughout the southern coast of British Columbia, the Vancouver Fraser Port Authority-led Enhancing Cetacean Habitat and Observation (ECHO) Program is launching a voluntary trial to study the relationship between commercial vessel speed and underwater noise.

About the voluntary vessel slowdown trial

Between August 7th and October 6th, 2017, all piloted commercial vessels transiting Haro Strait are requested to reduce their speed to 11 knots (speed through the water) between Discovery Island at the southern end, and Henry Island at the northern end. Average vessel speeds through this area range from 18 knots for containers to 13 knots for bulkers.

The voluntary trial is being planned and coordinated by the ECHO Program with the assistance of a vessel operators committee representing B.C. Coast Pilots, BC Ferries, the Chamber of Shipping of British Columbia, Cruise Line International Association North West and Canada, the Shipping Federation of Canada, the Pacific Pilotage Authority, Vancouver Fraser Port Authority, Washington State Ferries and Transport Canada.

Haro Strait is an important feeding area for the Southern Resident Killer Whale (SRKW) population, which is listed as endangered under the *Species at Risk Act (SARA)*. While the majority of SRKW sightings in this region occur between May and November, August and September is typically when the whale population peaks in Haro Strait. Research indicates that underwater vessel noise can mask the whales’ echolocation clicks, interfering with their ability to hunt, navigate and communicate with each other.

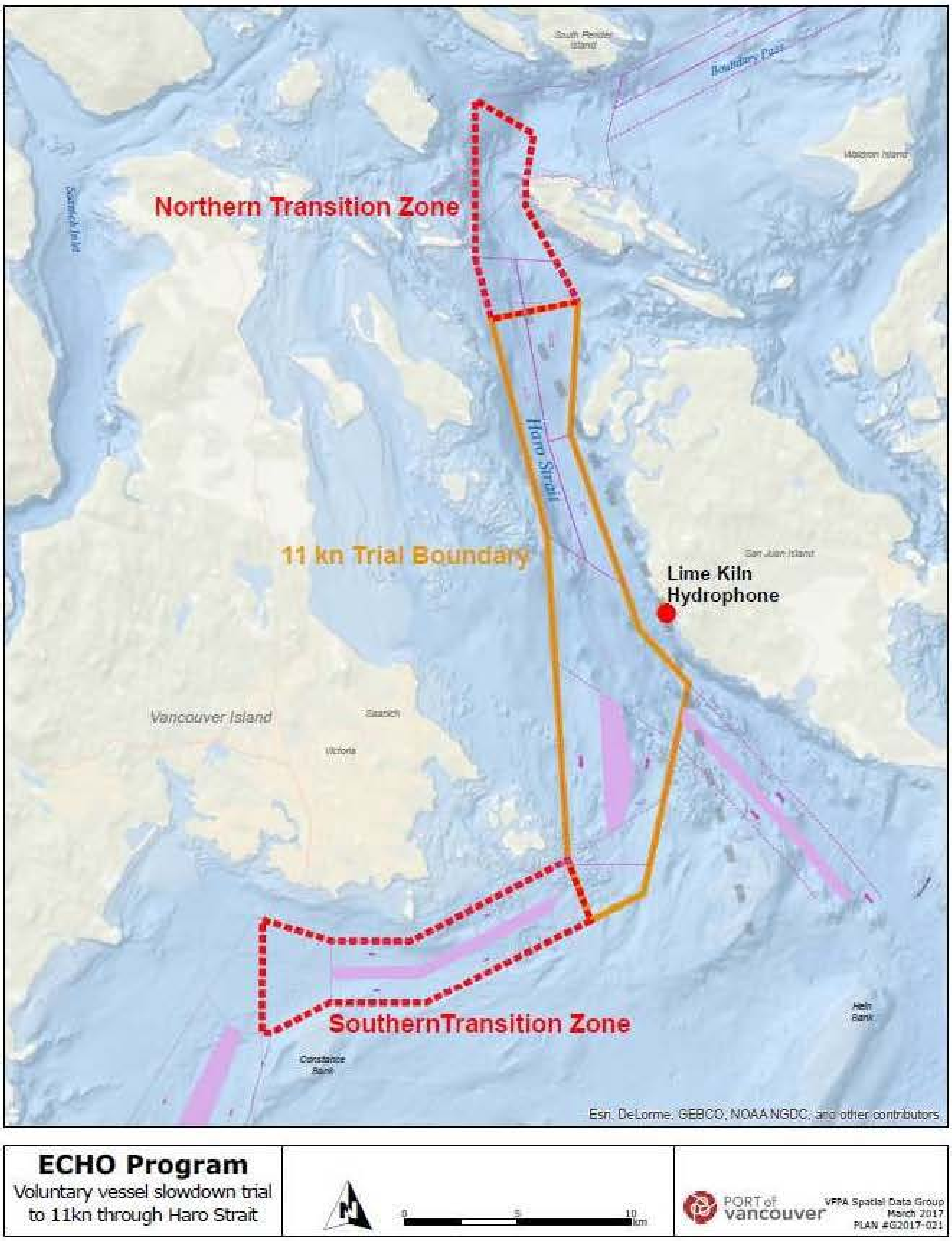
The purpose of the trial is to better understand and measure the level of noise reduction which is achieved through reduced vessel speed. During the trial period, the ECHO program team will use AIS to monitor and measure commercial vessel participation rates, and hydrophones to assess the impact of reducing vessel speed on underwater noise. Potential financial and operational impacts to the shipping industry will also be evaluated.

High vessel participation rates will greatly enhance the strength and value of the information collected, in turn supporting rigorous analysis and sound, scientific conclusions on the effectiveness of the trial. It will also demonstrate the shipping industry’s commitment to proactively explore sustainable options to minimize its environmental impact on endangered whales.

At the conclusion of the trial, a full analysis of the effectiveness of slowing vessels down to reduce acoustic disturbance will be conducted by the ECHO program team. In consultation with our vessel operators committee regarding industry impacts, this analysis will be used to inform decision making and determine next steps.

The slowdown to 11 knots through Haro Strait could introduce delays of between 30 minutes to an hour to the total transit time between Boundary Pass and Brotchie Point, depending on vessel type and tidal currents. Inbound vessels should adjust their planned arrival time at Brotchie Point to minimize potential impacts to their scheduled berth or anchorage arrival times.

Voluntary trial boundary



The trial distance is 16.6nm inbound, 14.9nm outbound.

Context for the voluntary trial

The endangered Southern Resident Killer Whale has a current population of just 78 individuals (February 2017) and the species has shown little sign of recovery since the 1980s.

This species is of great cultural significance to coastal First Nations and is highly valued by the general public. As such, Canadian and US federal regulators have designated SRKW critical habitat across most of the southern Salish Sea, offering the species legal protection to feed, socialize and rest.

Recent studies indicate that underwater noise from existing vessel traffic in the Salish Sea is disruptive to the SRKW population's ability to hunt, navigate and communicate with each other. Projected increases in human population and future development projects with marine components are expected to further increase vessel traffic and related underwater noise.

Many vessel types contribute to underwater noise, including recreational craft, but large commercial vessels are typically the loudest. Even short exposure to these noise levels at close range could cause temporary hearing loss in killer whales.
Although there is variability in noise generation within a given vessel type, speed range and frequency, multiple studies report that a one knot reduction in vessel speed typically results in a >1dB reduction in underwater radiated noise levels.

Because sound levels are reported on a logarithmic scale, a 3 dB reduction can result in a 50 per cent decrease in sound intensity and a 6dB reduction can result in a 75 per cent decrease in sound intensity.

Acoustic disturbance from vessel noise is identified by the federal government as a key threat to the recovery of the southern resident killer whale (SRKW). SRKW critical habitat directly overlaps with international shipping routes, ferry routes and other marine traffic routes in the Salish Sea. Under SARA, the federal government has highlighted the need to develop and implement measures to reduce or eliminate acoustic disturbance, including that generated by vessels.

About the ECHO Program

The Enhancing Cetacean Habitat and Observation (ECHO) Program is a Vancouver Fraser Port Authority-led initiative aimed at better understanding and managing the impact of shipping activities on at-risk whales throughout the southern coast of British Columbia.

Some of the key threats to whales in this region include:
- acoustic disturbance (underwater noise)
- physical disturbance (ship collisions)
- environmental contaminants
- availability of prey

The long-term goal of the ECHO Program is to develop voluntary mitigation measures that will lead to a quantifiable reduction in potential threats to whales as a result of shipping activities.

For more information on the slowdown trial please see www.portvancouver.com/slowdowntrial or contact VFPA's Operations Centre at 604.665.9086.

For more information on the ECHO program please see www.portvancouver.com/echo or email echo@portvancouver.com

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APPENDIX IR4-10-E

MARINER'S GUIDE TO WHALES, DOLPHINS, AND PORPOISES OF WESTERN CANADA

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Mariner’s Guide

TO WHALES, DOLPHINS, AND PORPOISES OF WESTERN CANADA

COASTAL OCEAN
RESEARCH INSTITUTE

Credits
This document was prepared by the Coastal Ocean Research Institute at the Vancouver Aquarium Marine Science Centre

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With assistance from Beatrice Proudfoot unless otherwise noted, between January 2016 and July 2016.

Survey data for this project were contributed by Fisheries and Oceans Canada (1955-2015) and Stantec for Pacific Northwest LNG Ltd. (2014-2016). Opportunistically collected data were obtained from the B.C. Cetacean Sightings Network (1931-2015). Over 93,000 sightings records were used in the analysis for this Guide. Maps were created using ArcGIS [GIS software]. Version 10.4.1 Redlands, CA: Environmental Systems Research Institute, Inc., 2015.

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Early assistance was provided by Caroline Gravel and the Shipping Federation of Canada, sharing knowledge gained from the production of "Mariner's Guide to Whales in the Northwest Atlantic"

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Prefaces

The island-studded coast of British Columbia features pristine water, dramatic shorelines, deep fjords, mist-shrouded mountains, and forests aplenty. Indigenous people have lived on this shoreline for millennia, feeding on a rich bounty of fish and shellfish and developing cultural traditions that continue to nourish them. The coast continues to support British Columbians in modern times — it serves as a highway for commerce, has some of the most productive fisheries in the world, and offers unparallelled recreational and ecotourism activities. It is no wonder, then, that British Columbians treasure their coast and are tireless in their efforts to conserve its natural values.

More than 20 species of marine mammals — from sea otters to mighty blue whales — call the B.C. coast home. Many of these species are listed as threatened or endangered, and active efforts are helping their populations recover. For some species, such as the humpback whale, these efforts are successful and recovery is well underway. For others recovery is slow, and for others still, such as the North Pacific right whale, population numbers remain perilously low.

One of the most significant human-caused threats whales face is injury or death from vessel collisions. One might expect the whales to hear the ships approach and take evasive actions to avoid them, and indeed this does occur sometimes. However, whales often have difficulty estimating the speed and bearing of ships and/or recognizing the risk they present, and collisions are tragically frequent.

> “”
> One of the most significant human-caused threats whales face is injury or death from vessel collisions.

The purpose of this guide is to help mariners reduce their risk of striking and killing, or seriously injuring a cetacean (whale, dolphin or porpoise). It includes descriptions of frequently encountered whales and dolphins, locations along the coast where cetacean densities are highest, and simple measures they can take to greatly reduce their risk of striking a whale, dolphin or porpoise.

I have yet to meet a mariner who doesn’t feel terrible if his or her ship hits a cetacean, and who, all things being equal, wouldn’t avoid such an event if possible. So I know the motivation to reduce strikes is there — the key is knowing how to do it. To that end, I hope that bridge crew on vessels transiting through B.C. coastal waters will use the information in this guide to reduce the risk of hitting a whale on their watch. I also hope it will encourage mariners to record sightings of cetaceans (see page 16) and pass them on so researchers can improve sightings maps over time.

Finally, I’d like to thank those who helped in the preparation of this guide — notably Vancouver Aquarium marine mammal researchers Caitlin Birdsall, Bailey Eagan, and Tess Danelesko; the Ports of Prince Rupert and Vancouver for funding its production; and their environmental program managers Jason Scherr and Orla Robinson for their support, advice, and helpful reviews.

Dr. Lance Barrett-Lennard,
Head Marine Mammal Scientist
Coastal Ocean Research Institute
Vancouver Aquarium Marine Science Centre

British Columbia's waters are full of natural beauty and wildlife. Not only do our waters sustain diverse populations of whales, porpoises and dolphins, but they also offer west coast mariners a place to work and play.

The safety of wildlife populations is essential to a healthy and fully functioning marine environment. A number of at-risk cetacean species frequent these west coast waters and are known to be vulnerable to both vessel collisions and noise disturbance.

> The safety of wildlife populations is essential to a healthy and fully functioning marine environment.

With projected future growth in Canada's trade demands, as well as projected population growth on the west coast, movements of all types of vessels are anticipated to increase. Canadian port authorities are mandated under the *Canada Marine Act*, to facilitate Canada's trade objectives, ensuring goods are moved safely, while protecting the environment and considering local communities. These are some of the reasons why Vancouver Fraser Port Authority and the Port of Prince Rupert have partnered to create this Mariner's Guide.

This guide is intended to increase awareness about the potential impacts of vessel activities on cetaceans in this region, and highlight how mariners can help reduce these impacts. Collaborating with marine mammal experts from the Vancouver Aquarium and scientists from Fisheries and Oceans Canada, we hope this guide will be a valuable tool for all mariners; whether it be commercial vessel captains, coastal pilots, recreational boaters, fishers or whale watchers.

Thank you for reading. Enjoy these shared waters!

Jason Scherr
Manager, Environmental Sustainability
Port of Prince Rupert

Duncan Wilson
Vice President, Corporate Social Responsibility
Vancouver Fraser Port Authority

Contents

Introduction

Marine transportation, or carriage of goods and people by water, has played a significant role in developing Canada's west coast over the centuries. Commercial vessel movements remain an essential part of life on the west coast today, serving both Canadian import and export markets, and British Columbia's many island and coastal communities and economies.

British Columbia's productive coastal ecosystem sustains numerous populations of cetaceans (whales, dolphins, porpoises) and sea turtles. It is also home to Canada's Pacific Gateway, moving people and goods within British Columbia and beyond, to more than 160 world economies.

Not only does reliable marine transportation support B.C.'s and Canada's economies, and move British Columbians safely and efficiently, it remains the most carbon-efficient mode of transportation. It produces fewer air emissions for each ton of goods transported per kilometre, compared to air or road transport. Nevertheless, because of the scale of marine transportation activities regionally and globally, the industry continuously seeks opportunities to improve sustainability and environmental performance and reduce potential environmental impacts.

To this end, the purpose of the *Mariner's Guide to Whales, Dolphins and Porpoises of Western Canada* is to promote a safer coexistence of vessels and cetaceans along the British Columbia coast. The information it provides will help vessel crew members identify key cetacean and sea turtle species, understand the potential threats their vessels pose to these species, and take action to minimize those threats.

Maps highlight areas where greater vigilance is required based on each species' known seasonal distribution and relative abundance.

Finally, the guide encourages mariners to share cetacean and sea turtle sighting information, which will help to conserve vulnerable species in B.C. waters by providing data that inform scientists and managers about their occurrence, distribution and relative abundance. This information is continually used for conservation-based research projects.

In this guide, the term cetacean will be used to describe whales, dolphins and porpoises collectively. Although not a cetacean, later in the guide, we will also include information on leatherback sea turtles, a visitor to our coast also impacted by vessel traffic.

When Vessels Meet Cetaceans

There is an urgent need to protect British Columbia's vulnerable cetacean populations. Impacted by anthropogenic threats, 12 of the 27 populations or species of cetaceans (and sea turtles) found in B.C are listed as "At Risk" by Canada's Species at Risk Act (SARA). At-risk species in B.C. include:

- Endangered: blue, sei, North Pacific right, southern resident killer whale, leatherback sea turtle
- Threatened: fin whale, northern resident killer whale, offshore killer whale and Bigg's (transient) killer whale
- Special Concern: grey, humpback, harbour porpoise[49]

Potential vessel impacts on cetaceans include vessel strikes, disturbance, underwater noise and pollution. The importance of reducing these vessel-associated impacts is highlighted in the SARA Recovery Strategies and Management Plans for all 12 of these listed species'[10-17, 20]. Actions detailed in this guide are essential to address and mitigate these threats and help conserve these populations.

The Species at Risk Act (SARA) is a piece of Canadian federal legislation. SARA was created to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk.

SARA Definitions

Endangered: Species facing imminent extirpation or extinction.

Threatened: Species which are likely to become endangered if nothing is done to reverse the factors leading to their extirpation or extinction.

Special concern: Species which may become threatened or endangered because of a combination of biological characteristics and identified threats.

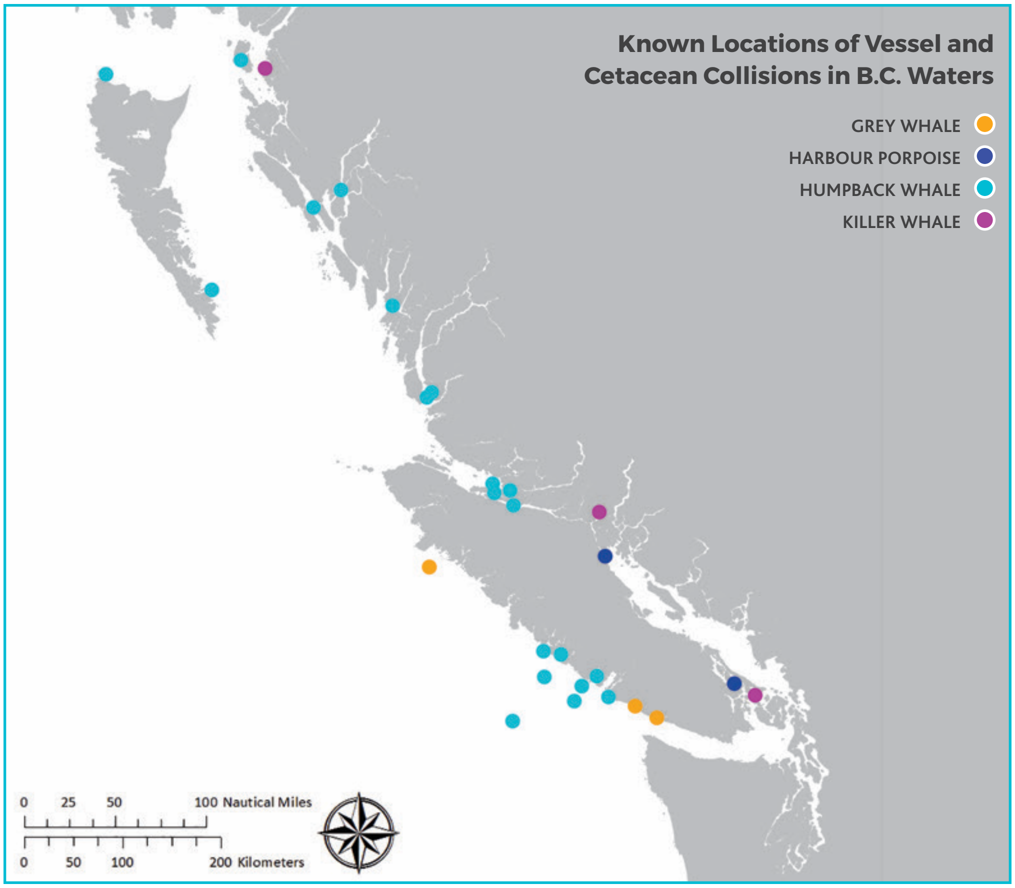
Extirpated: Species that no longer exist in the wild in Canada, but exist elsewhere in the wild[49].

VESSEL STRIKES

The waters of the eastern North Pacific are host to high densities of both cetaceans and marine traffic[39,56]. Cetaceans are vulnerable to being struck and injured or killed by vessels. Based on data collected from many of the world's oceans and examination of floating or beach-cast carcasses, vessel strikes are a recognized cause of mortality for a variety of cetaceans, many of which are found in B.C. waters[26,29].

Thirty cetacean-vessel collisions categorized as "definite" or "probable" were reported to the B.C. Marine Mammal Response Network hotline and investigated by Fisheries and Oceans Canada from 2004-2011 These collisions involved killer whales, humpback whales, grey whales, fin whales and harbour porpoise[48]. The majority of these witnessed and reported strikes involved smaller vessel (less than 15m), however, this number likely underrepresents the frequency of vessel strikes and the involvement of larger vessels. Smaller vessels are more likely to detect, and therefore report, a strike because the impact in more easily felt and visibility of animals off the bow is superior[27, 29]. Many strikes undoubtedly go undetected, especially by large vessels or with small species, or unreported, resulting in an underestimation of this threat in B.C.

Maps featured on page 23 to 51 will give readers a sense of high density areas for various species of cetaceans found off the coast of B.C. and where encounters would most likely occur.



In B.C., PLEASE REPORT any confirmed or suspected cetacean strike, or carcasses observed at sea, to the B.C. Marine Mammal Response Network at 1.800.465.4336. This information is extremely valuable in improving the understanding of this issue and developing mitigation strategies to avoid strikes in the future. See page 23 for more details.

FACTORS THAT INCREASE THE RISK OF COLLISION

Studies have shown that while all vessel types are implicated in vessel-cetacean collisions, those involving large and fast-moving vessels have a more severe impact and a higher chance of killing the cetacean[29].

Vessels over 80 metres long, travelling faster than 14 knots, are the most likely to kill cetaceans in the event of a strike[29]. Studies have demonstrated that travel below 10 knots greatly decreases the likelihood of fatal vessel strikes, and that travel over 17.5 knots greatly increases that risk[26,48].

Mitigating Vessel Strikes

Reducing speed in areas where vessels and cetaceans overlap may decrease the probability of a strike[42,47], as slower speeds increase the likelihood of detecting and avoiding cetaceans and allows more time for the animal to avoid the oncoming vessel. For example, speed restrictions in the eastern U.S. that require vessels greater than 65 metres in length to travel at speeds of 10 knots or less in areas frequented by endangered North Atlantic right whales have decreased strike-related mortality of this species by 80-90%[4].

Decreasing vessel speed at night when visibility is low has also been proposed as a potential mitigation measure[35].

Understanding the distribution of cetaceans helps identify and map high-risk areas for vessel strikes, and a large amount of these valuable data come from sightings reported by mariners on the water. You can help researchers learn more about high density whale-areas by reporting your sightings (see page 16 for information on how to do so).

SOUFFLEURS D'ECUME

VESSEL DISTURBANCE

Cetacean populations are vulnerable to general disturbance by vessels. Large and small vessels may disturb and alter activities essential to cetacean survival, such as foraging (searching for food), surfacing, resting, predator avoidance, communicating, socializing, mating and nurturing calves[32, 54]. Interrupting these activities negatively affects individuals. In small populations (e.g. southern resident killer whales), these impacts on individuals can have population-level effects.

Mitigating Vessel Disturbance

To reduce disturbance, vessels should keep a distance of at least 100 metres, although behavioural responses to vessels may be observed when vessels are 200-250 meters from cetaceans[8, 37].

VESSEL NOISE

In the North Pacific Ocean, underwater noise has doubled in intensity every decade for the past 60 years[22]. Motorized vessels contribute to underwater noise and may reduce the ability of cetaceans to detect prey, communicate, navigate, rest, avoid danger, mate and reproduce.

In high vessel traffic areas, whale communication and echolocation can be almost completely masked by noise[9]. Vessel noise can also increase a whale's stress level, and cause it to move away from or avoid entering an area[8, 46].

Mitigating Vessel Noise

Vessel noise can be decreased by operating below cavitation inception speed and avoiding rapid acceleration, as well as rerouting when in the immediate vicinity of cetaceans and known sensitive marine areas.

Additionally, the IMO guidelines[25] provide information on how to reduce vessel noise through maintaining clean hulls and propellers, insulating vessel engines and making use of resilient mountings for onboard machinery, as well as incorporating vessel quieting methods and materials during re-fits and new vessel construction.

AIR POLLUTION FROM VESSELS

Marine engines burning diesel make sizeable contributions to emissions of sulphur dioxide (SO_2), particulate matter (PM2.5), and nitrogen oxides (NO_X) in B.C.[42b]. Unlike terrestrial mammals, cetaceans do not have sinuses to filter the air they breathe or a sense of smell to help them detect and potentially avoid airborne pollutants such as exhaust gases (e.g. CO_X, SO_X, NO_X). When whales do breathe in airborne pollutants, elevated lung pressure associated with diving causes pollutants to enter the blood more rapidly than in non-diving animals. Additionally, stable atmospheric inversion layers that commonly occur during the summer months trap air pollutants and concentrate them above the water's surface, exposing cetaceans to higher concentrations[28].

Mitigating Air Pollution

All vessel owners and operators can reduce their impact through the use of clean-burning fuels, and emission-reducing technologies. Adherence to emission limits and fuel specifications designated by the International Maritime Organization's MARPOL Annex VI and North American Emissions Control Area for ocean-going vessels are important steps to reducing air pollutant exposure [25b].

MINIMIZE LARGE VESSEL STRIKES AND DISTURBANCES

Acknowledging engineering and navigational limitations, and that safety is paramount, the following strategies are suggested to help reduce the impact of large vessels on cetacean populations. They should be employed when appropriate, feasible and safe to do so.

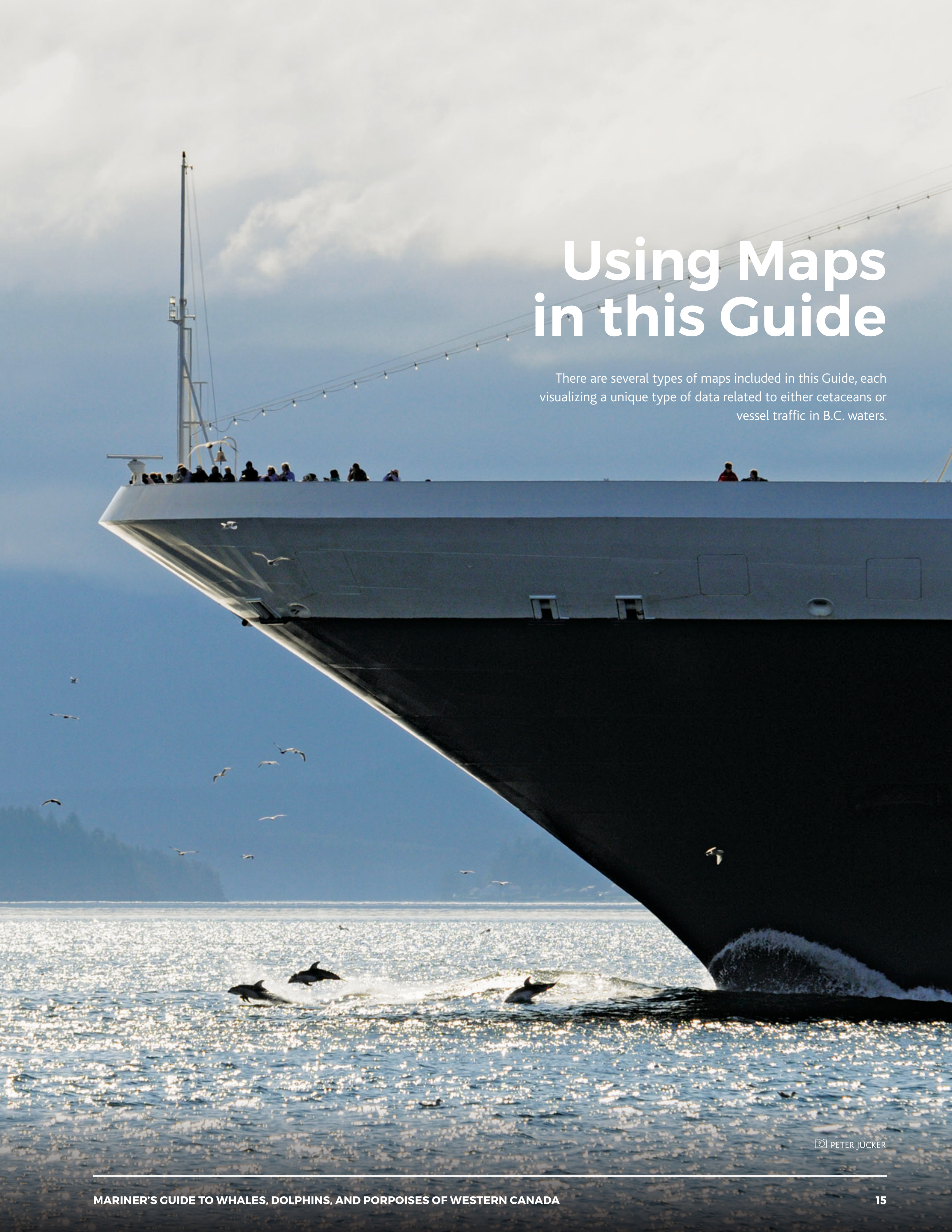
1. **When cetaceans are observed or reported in your path,** or in known high-density areas, **consider reducing speed to 10 knots or less,** if possible and safe. The risk of striking cetaceans greatly increases with vessel speed.

2. **When possible, make gradual course changes away from the cetacean location or direction of travel.** If you sight a large aggregation of cetaceans that makes it impossible to avoid the group entirely, try to pass through the least dense part of the aggregation.

3. **Maintain a sharp lookout for cetaceans in all coastal waters,** paying particular attention when visibility is low. If possible, post extra crew on the bow of the vessel to watch for cetaceans.

4. Should groups of dolphins or porpoises choose to ride the bow wave of your vessel, **avoid sudden speed or course changes.**

5. **Review the International Maritime Organization's guidelines[25] for vessel noise reduction** to find out how activities such as vessel maintenance, propeller design and selection, as well as selection and mounting of engines and machinery can lead to a quieter vessel.



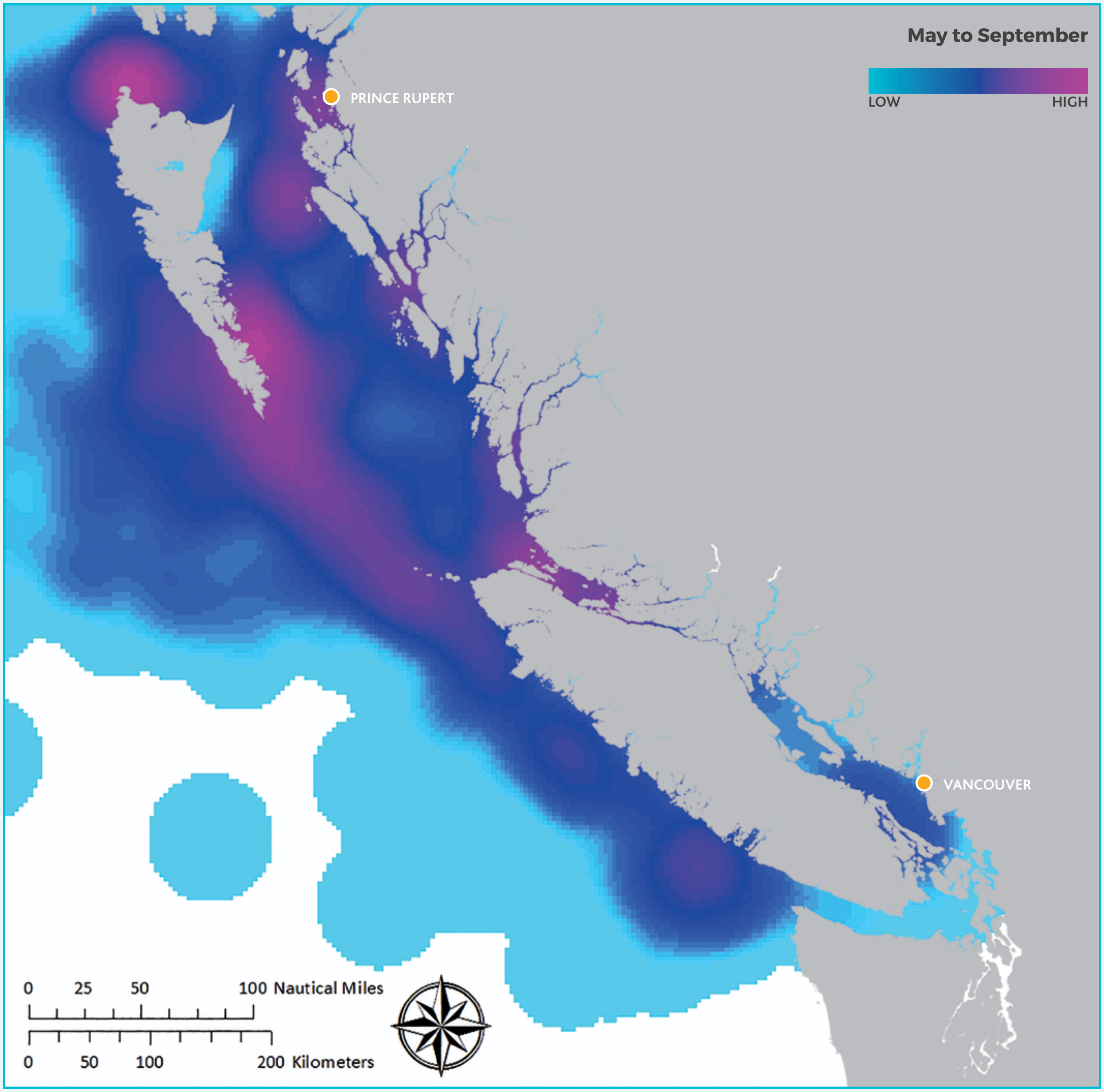
Using Maps in this Guide

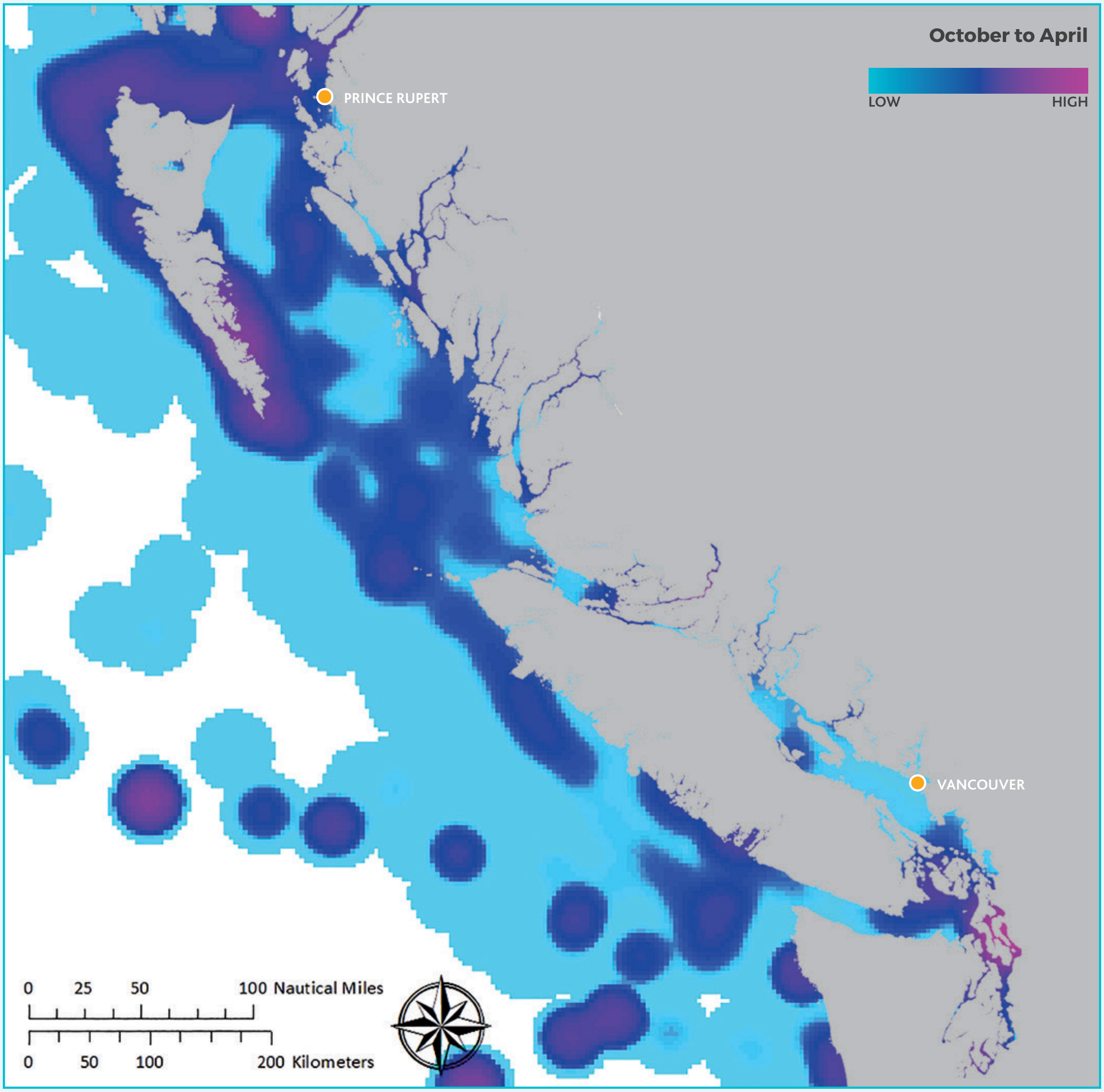
There are several types of maps included in this Guide, each visualizing a unique type of data related to either cetaceans or vessel traffic in B.C. waters.

PETER JUCKER

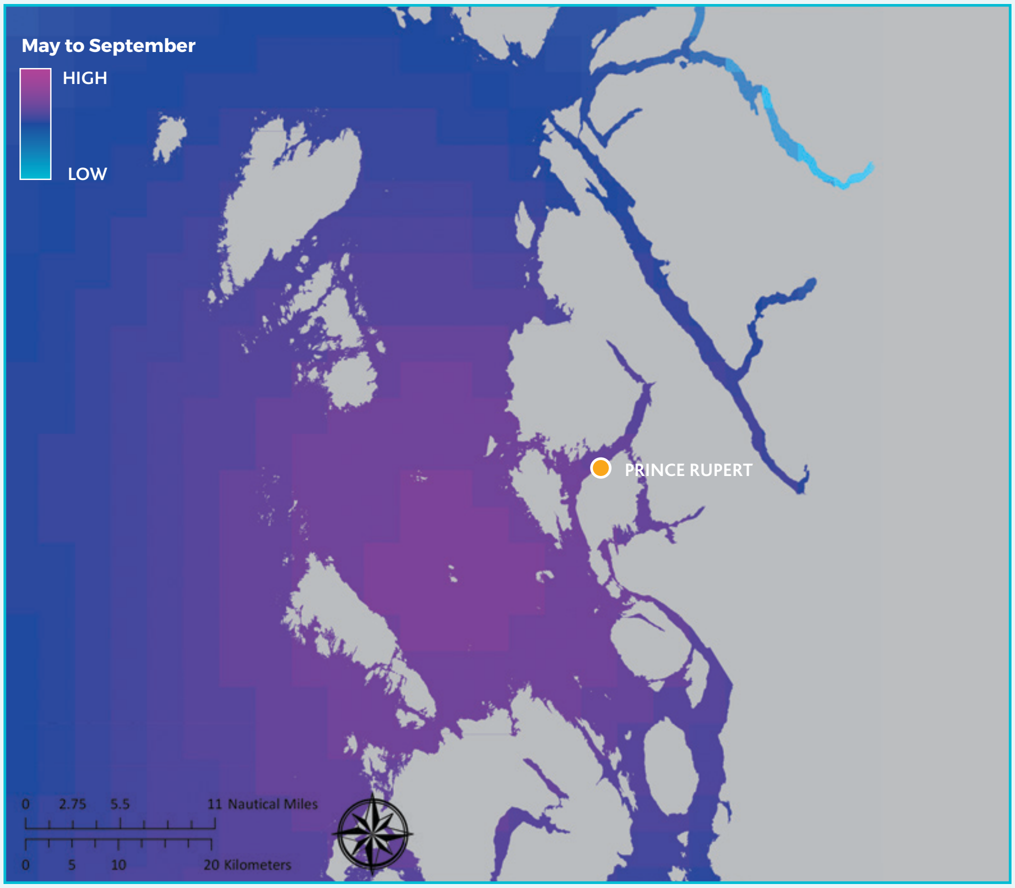
Relative Abundance of Cetaceans in B.C. Waters

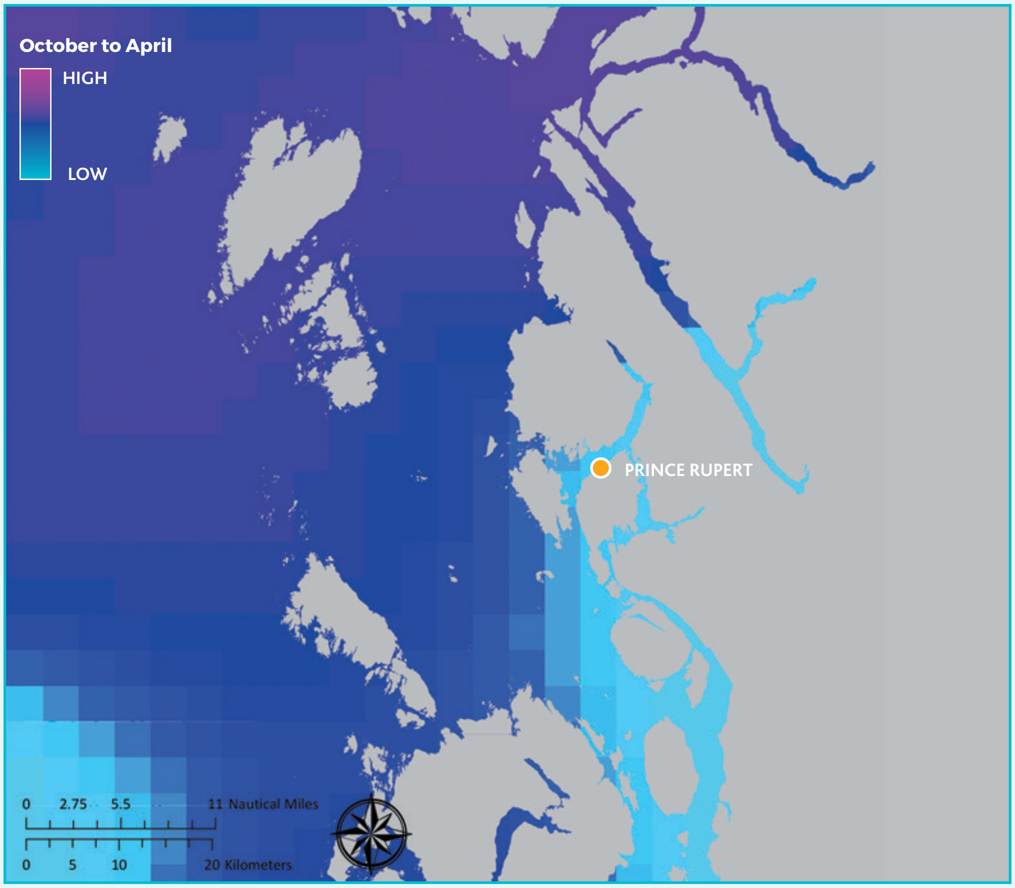
These maps highlight cetacean hotspots. Areas symbolized by the high end of the colour scale denote areas of high abundance, where the chance of a vessel encountering that particular species, or group of species, is highest. Both opportunistically collected data, which were corrected to account for the distribution of observer effort[43], and systematic survey data were used in the creation of these maps. The goal of these maps is to make mariners aware of where they are most likely to encounter cetaceans in B.C. waters. It is important to note that cetaceans are wide-ranging and highly mobile, and while these figures may serve as a guide to highlight areas of higher density, a cetacean encounter can occur anywhere in marine waters at any time. To ensure accurate estimates of relative abundance were displayed on each map, only data that was rated as high species identification confidence was used from the opportunistically collected dataset. Additionally, density values were smoothed to minimize potential anomalies resulting from very high or very low effort values and to prevent adjacent cells from having significantly different values.



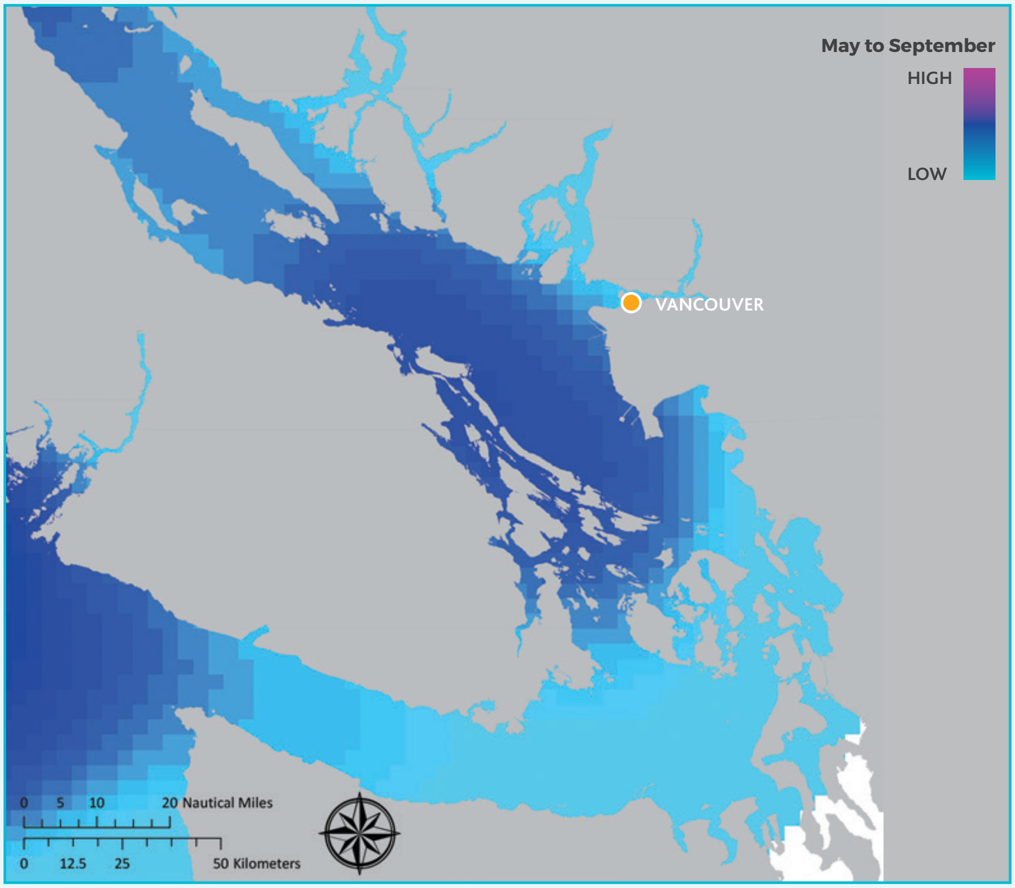

October to April
LOW
HIGH
PRINCE RUPERT
VANCOUVER
0
25
50
100 Nautical Miles
0
50
100
200 Kilometers

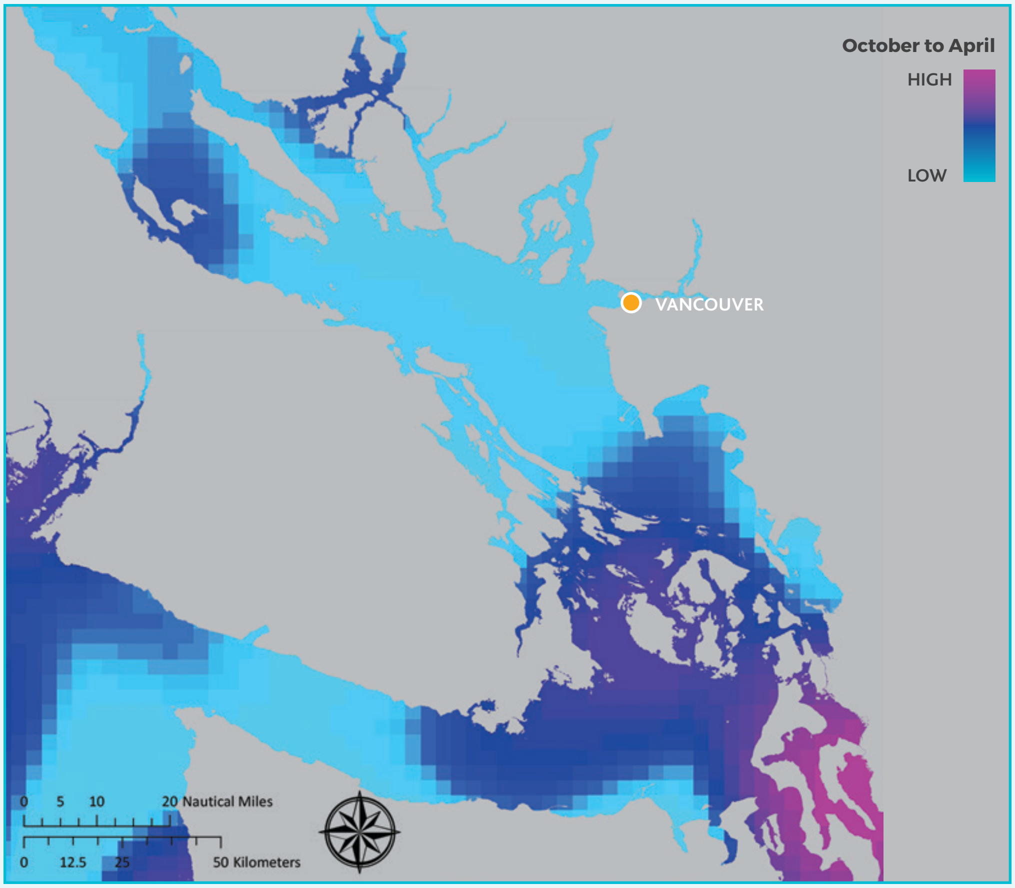
Relative Abundance of Cetaceans Along the Approach to Prince Rupert





Relative Abundance of Cetaceans Along the Approach to Port of Vancouver



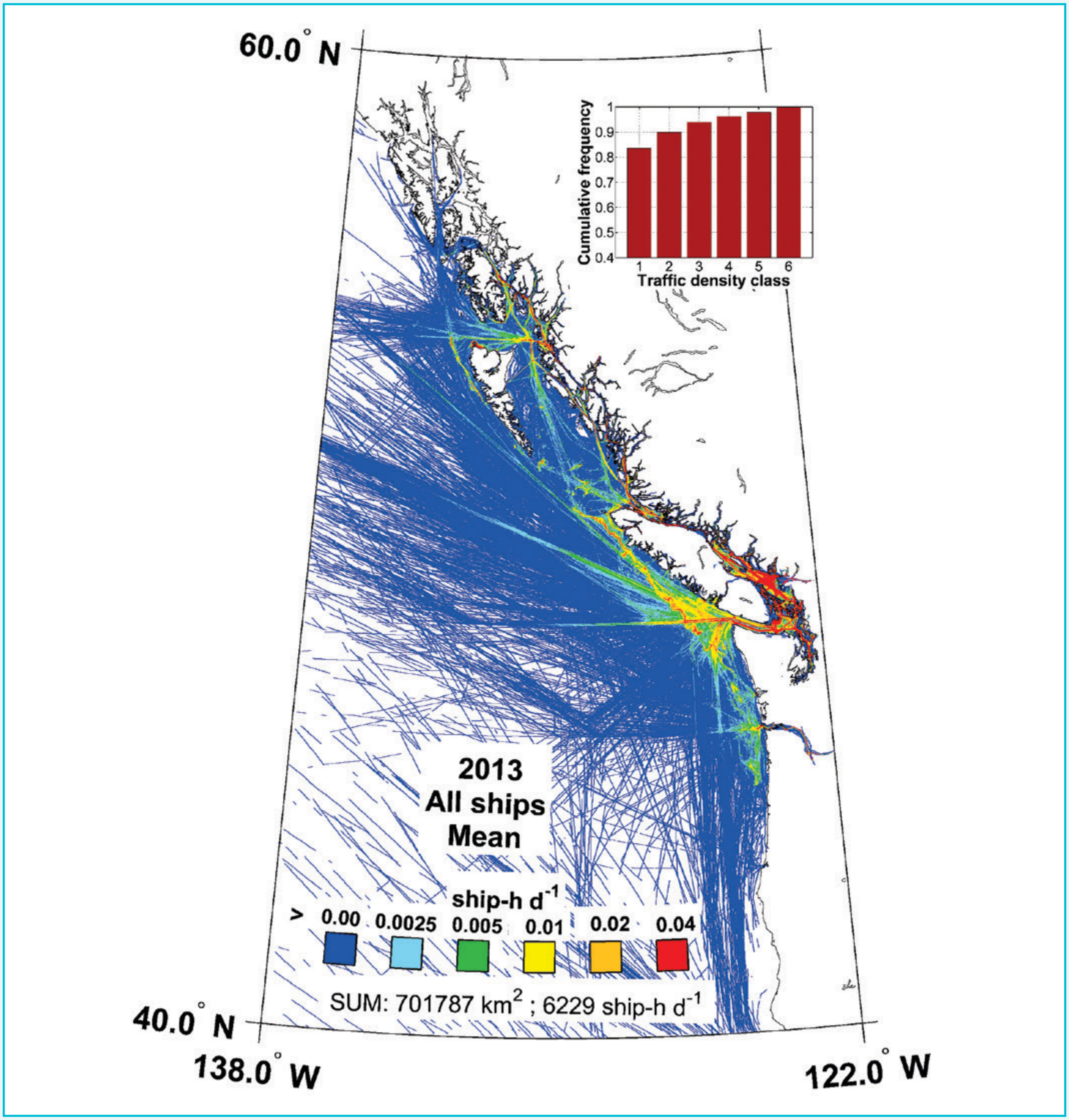


AIS Vessel Traffic Density Off the West Coast of Canada for 2013

Traffic density in time and space is visualized in five distinct categories, with dark blue symbolizing zero to very low density, and red symbolizing high density.

This figure (below) may be helpful to reference when reviewing the maps of cetacean and sea turtle abundance as a means of identifying areas where vessels and cetaceans and sea turtles both occur in high density. The data displays all AIS mean traffic density in 2013.

Additionally, the number of squared kilometres containing traffic is provided below the palette as well as the sum of the daily traffic. The histogram shows traffic density per kilometre squared, with each bar corresponding sequentially to the traffic density intervals of the map palette (ie. > 0 to 0.0025 ship-h per $1km^2$ grid cell is represented by traffic density class 1 and > 0.04 ship-h per $1km^2$ is represented by traffic density class 6).



Simard, Y., Roy, N., Giard, S., and Yayla, M. 2014. Canadian year-round shipping traffic atlas for 2013: Volume 3, West Coast. Can. Tech. Rep. Fish. Aquat. Sci. 3091(Vol.3)E: xviii + 327 pp.

BCFerries
Quadra Queen II

Report Your Cetacean Sightings

Many populations of cetaceans are at risk in B.C. Report your sightings to help provide valuable information. By reporting your sightings, you are helping researchers better understand the distribution and abundance of these species.

What to Report

YOUR NAME AND CONTACT INFORMATION

SPECIES

DATE AND TIME

LOCATION
Latitude/Longitude coordinates if available

NUMBER OF ANIMALS

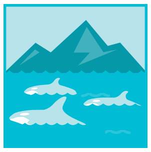
BEHAVIOUR OF ANIMALS

SEA STATE, WIND SPEED, AND VISIBILITY


BREACH


FLUKE


PORPOISE


TRAVEL


TAIL/PECTORAL SLAP


BOWRIDE


SPYHOP


FEED

Report your Sightings

WILDWHALES.ORG

1.866.I.SAW.ONE (1.866.472.9663)

SIGHTINGS@VANAQUA.ORG

WHALEREPORT SMARTPHONE APP
iOS and Android devices

Whales

Killer whale
Common

Humpback whale
Common

Grey whale
Common

Minke whale
Common

Fin whale
Common

Sperm whale
Less Common

Blue whale
Less Common

Sei whale
Less Common

North Pacific right whale
Less Common

Baird's beaked whale

Killer whale
Orcinus orca

Description

Body has a distinctive pattern with black on the back, white on the belly, white-grey "saddlepatch" behind the dorsal fin and white "eyepatch" located just behind the eye. Dorsal fin is short and curved in juvenile and female whales, whereas mature males will have a tall dorsal fin up to 1.8 metres in height. Tail flukes are black on top and white underneath. Maximum length of 8 metres for males and 6 metres for females.

Distribution

Three distinct eco-types can be found in British Columbia: Resident, Bigg's (transient) and offshore killer whales that are widely distributed throughout the coast and can be found in inshore and offshore waters. Year-round resident.

Whale-Vessel Strikes and Marine Mammals in Distress

Fisheries and Oceans Canada is responsible for assisting marine mammals and sea turtles in distress. If your vessel strikes a whale, or if you observe a sick, injured, distressed or entangled marine mammal in B.C. waters, please contact the B.C. Marine Mammal Response Network Incident Reporting Hotline immediately:

1.800.465.4336 or VHF Channel 16

What to Report

YOUR NAME AND CONTACT INFORMATION

SPECIES

DATE AND TIME

LOCATION

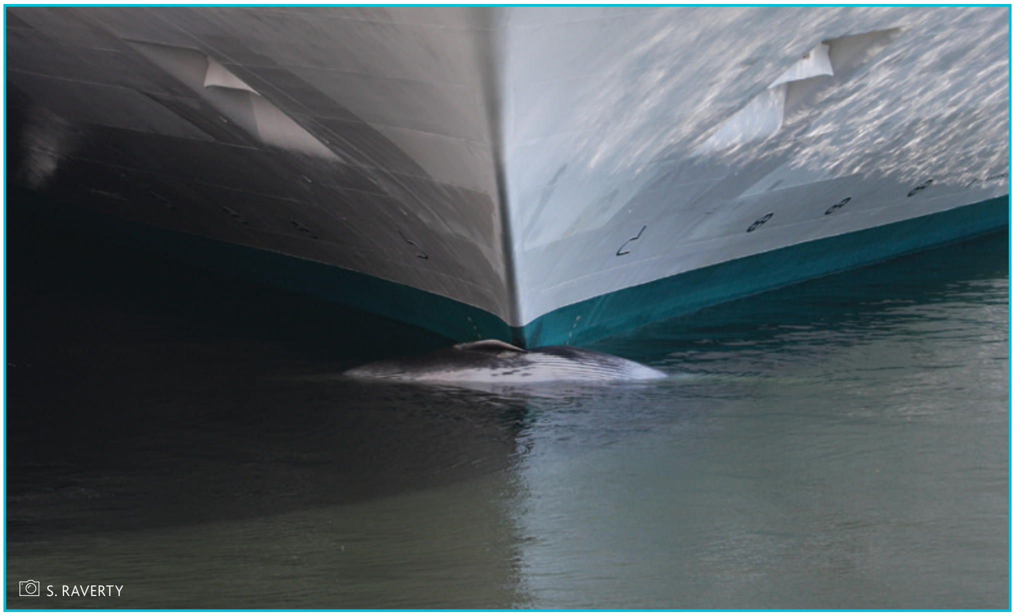
Latitude/Longitude coordinates if available

ANIMAL ALIVE/DEAD

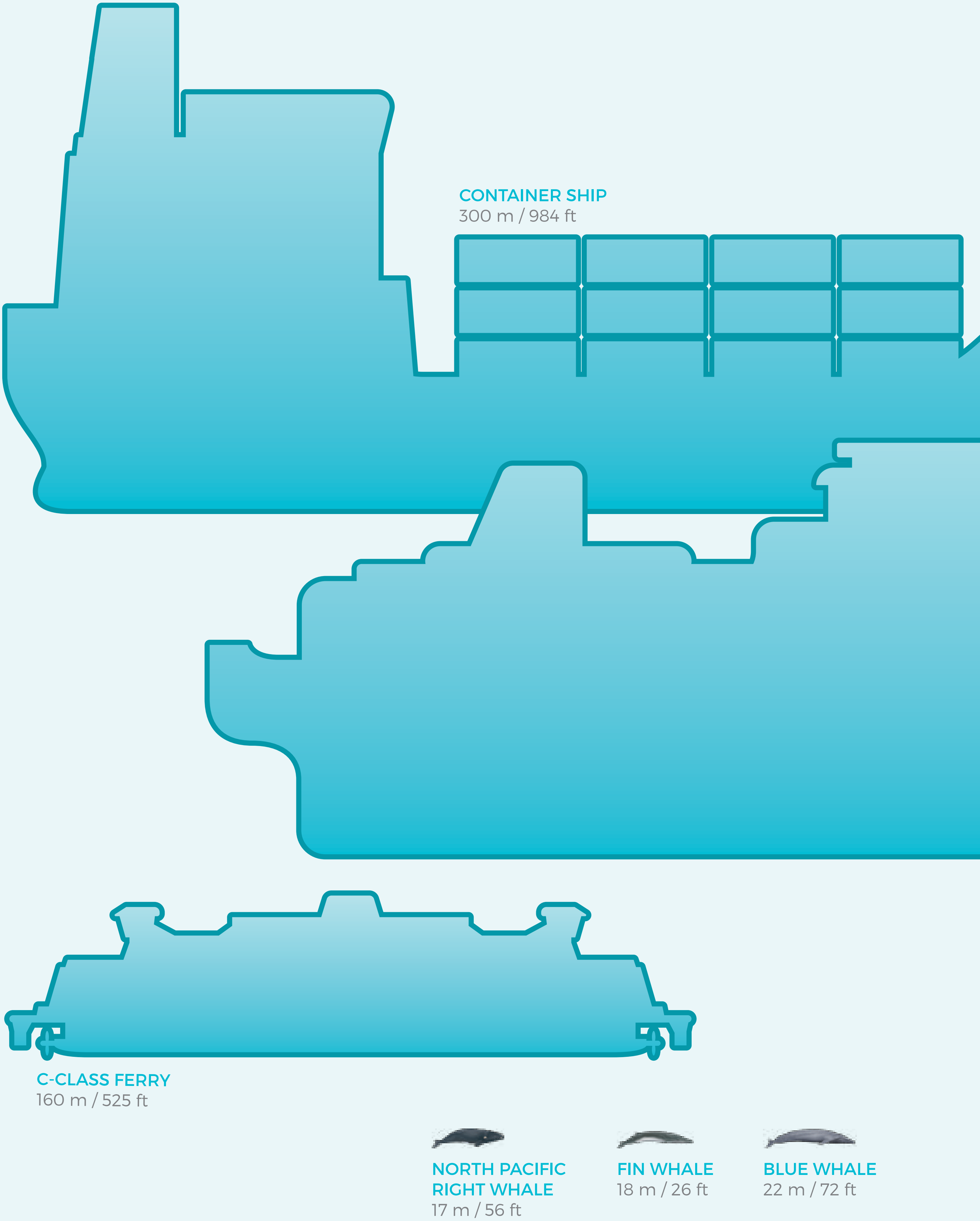
NATURE OF INJURY

PICTURES/VIDEO TAKEN

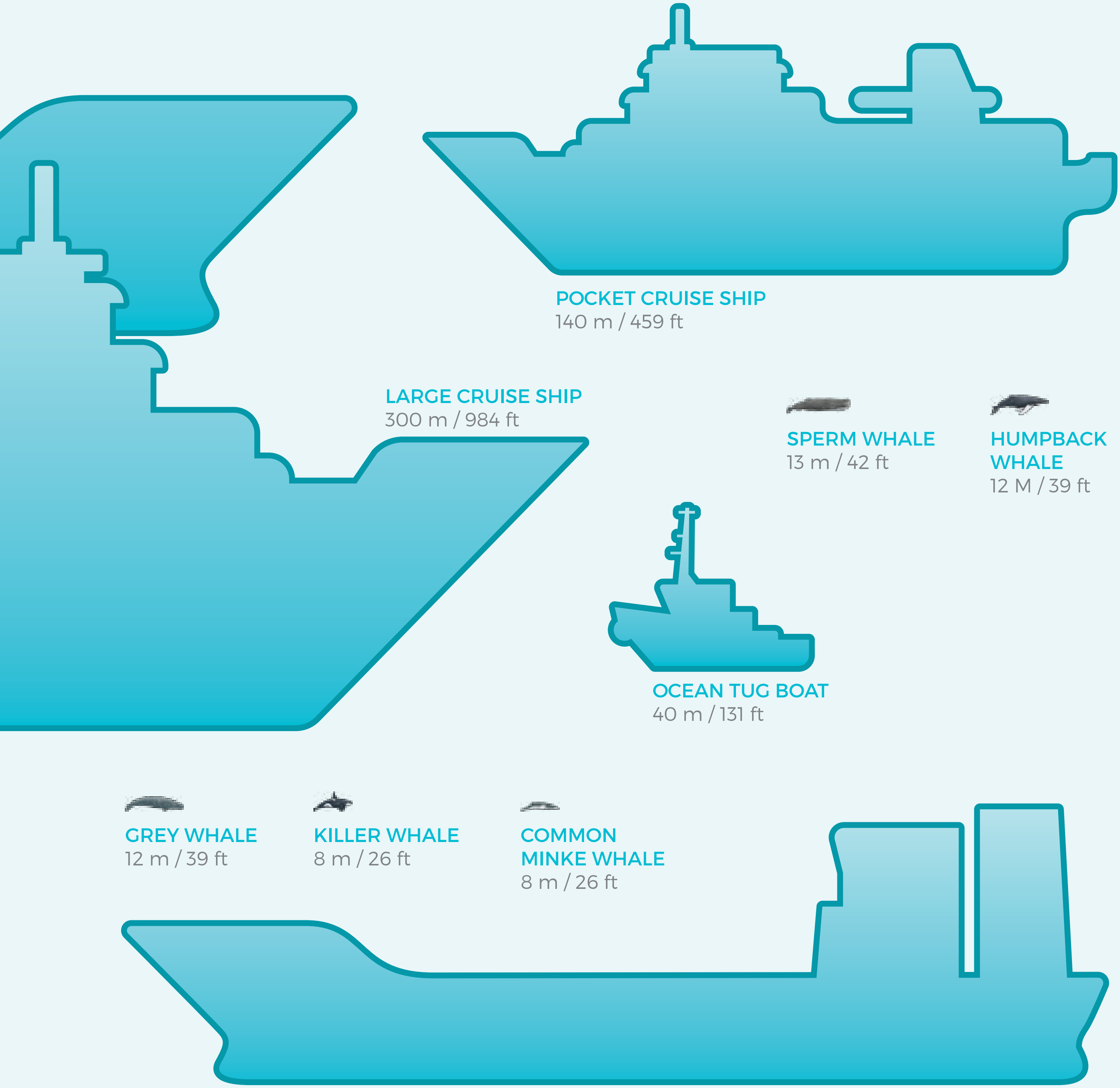
DIRECTION OF ANIMAL'S TRAVEL



S. RAVERTY


CONTAINER SHIP
300 m / 984 ft
C-CLASS FERRY
160 m / 525 ft
NORTH PACIFIC RIGHT WHALE
17 m / 56 ft
FIN WHALE
18 m / 26 ft
BLUE WHALE
22 m / 72 ft

How does your vessel compare to a whale?



POCKET CRUISE SHIP
140 m / 459 ft

LARGE CRUISE SHIP
300 m / 984 ft

SPERM WHALE
13 m / 42 ft

HUMPBACK WHALE
12 M / 39 ft

OCEAN TUG BOAT
40 m / 131 ft

GREY WHALE
12 m / 39 ft

KILLER WHALE
8 m / 26 ft

COMMON MINKE WHALE
8 m / 26 ft

BULK CARRIER
200 m / 656 ft

Cetaceans of British Columbia

Cetaceans (whales, dolphins and porpoises) are divided into the baleen whales (Mysticetes) and toothed whales (Odontocetes). Toothed whales, as the name implies, have teeth which vary in shape and size depending on the species. Toothed whales have highly developed biological sonar known as echolocation. They have only one blow hole opening on the top of their heads. Baleen whales do not have teeth. Instead, their mouths contain baleen which is made up of keratin-based, comb-like plates that filter the water for food. They have a blowhole with two openings on the top of their heads.

In the following section, average adult length measurements come from Ford 2014 and species statuses are displayed with the year of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessment or designation by the Species at Risk Act (SARA).

SARA was created to protect Canada's vulnerable wildlife species and uses COSEWIC as an independent organization tasked with recognizing and assessing at-risk species. COSEWIC assessments are considered the initial step in listing a species as SARA protected, and the federal government will use such assessments to determine if COSEWIC assessed species qualify for protection under SARA. In this guide we have listed COSEWIC statuses in cases where a particular species has been assessed by COSEWIC but not listed under SARA.

Baleen Whales

HUMPBACK WHALE

Megaptera novaeangliae

Average Adult Length: 12 m / 40 ft

SARA Status 2013

Not at Risk	Special Concern	**Threatened**	Endangered	Extirpated
NR	SC	**TH**	EN	EX

Dorsal Fin

Short with a broad base and variable in shape, located 2/3 of the way along the back of the body.

Appearance

Grey to black on top, with varying amounts of white on underside, throat and pectoral fins. Thick body shape. Distinct pectoral fins, nearly 1/3 as long as body, colour can range from all black to all white, leading edges are scalloped. Distinctive knobs present on top of head. Underside of tail can range from all black to mostly white. Bushy-shaped blow.

Behaviour

Usually lifts tail flukes when making a deep dive. Can be active and acrobatic at surface.

Distribution

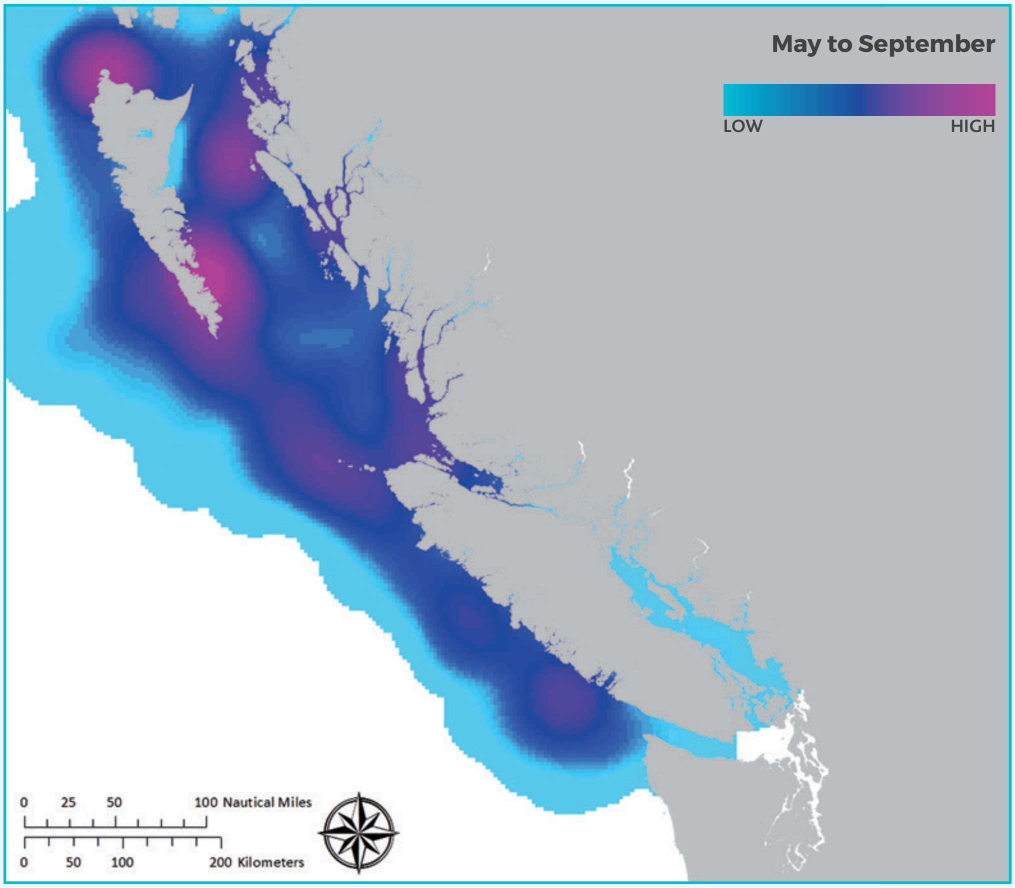
Found in all the world's oceans. North Pacific population is highly migratory and can be found in coastal shelf waters of northern Japan, Russia, Alaska, B.C. and the west coast of the United States during summer months. Breeding grounds are near islands or reefs in Hawaii, Mexico, Central America and Asia during winter months.

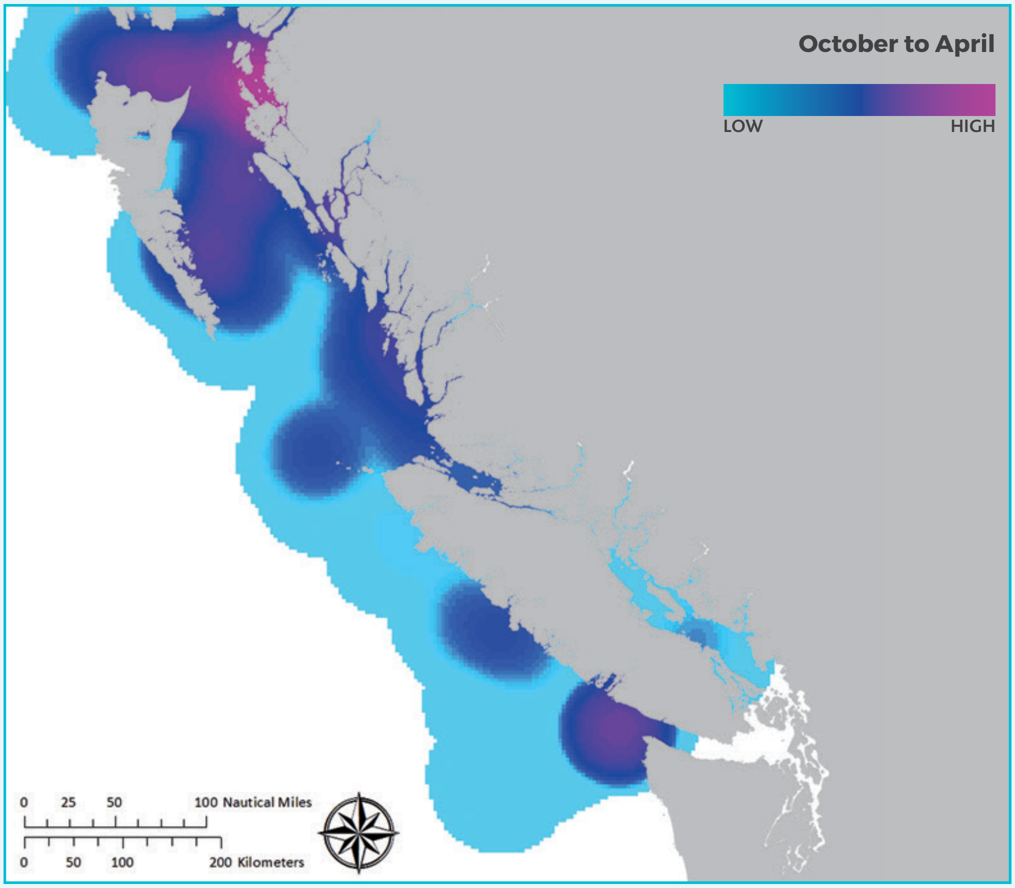
Vulnerability of the Species

Humpback whales experience the second highest strike rate of any whale species worldwide because they are relatively abundant and they often feed at or near the surface[29]. Additionally, vessel noise may disturb humpback whales and cause them to move away from the best feeding areas[16].

Further threats to humpback whales include entanglement, toxic spills and prey reduction[16].

Relative Abundance of Humpback Whales in B.C. Waters





GREY WHALE

Eschrichtius robustus

Average Adult Length: 11-12 m / 36-40 ft

SARA Status 2010

Not at Risk	Special Concern	Threatened	Endangered	Extirpated
NR	SC	TH	EN	EX

Dorsal Fin

No dorsal fin, has knuckle-like bumps on lower back.

Appearance

Mottled grey skin with scarring and varied pigmentation. Body and head are covered with patches of barnacles. Tail fluke has convex trailing edge with a deep notch in the middle. Heart or v-shaped blow.

Behaviour

Occasionally lifts tail flukes when making a deep dive. Often feeds close to shore.

Distribution

Only found in the North Pacific Ocean; eastern and western populations are distinct. The eastern population's migratory range spans from Baja California and the northwestern coast of Mexico's mainland to the Chukchi and Beaufort seas in the Arctic. On their northward migration, they usually pass the coast of B.C. starting in early spring and are found close to shore except when crossing open bodies of water (e.g. Queen Charlotte Sound and Hecate Strait). On the southbound migration in late-fall/early-winter, the whales travel further offshore. A small population remains resident in B.C. throughout the summer months[19].

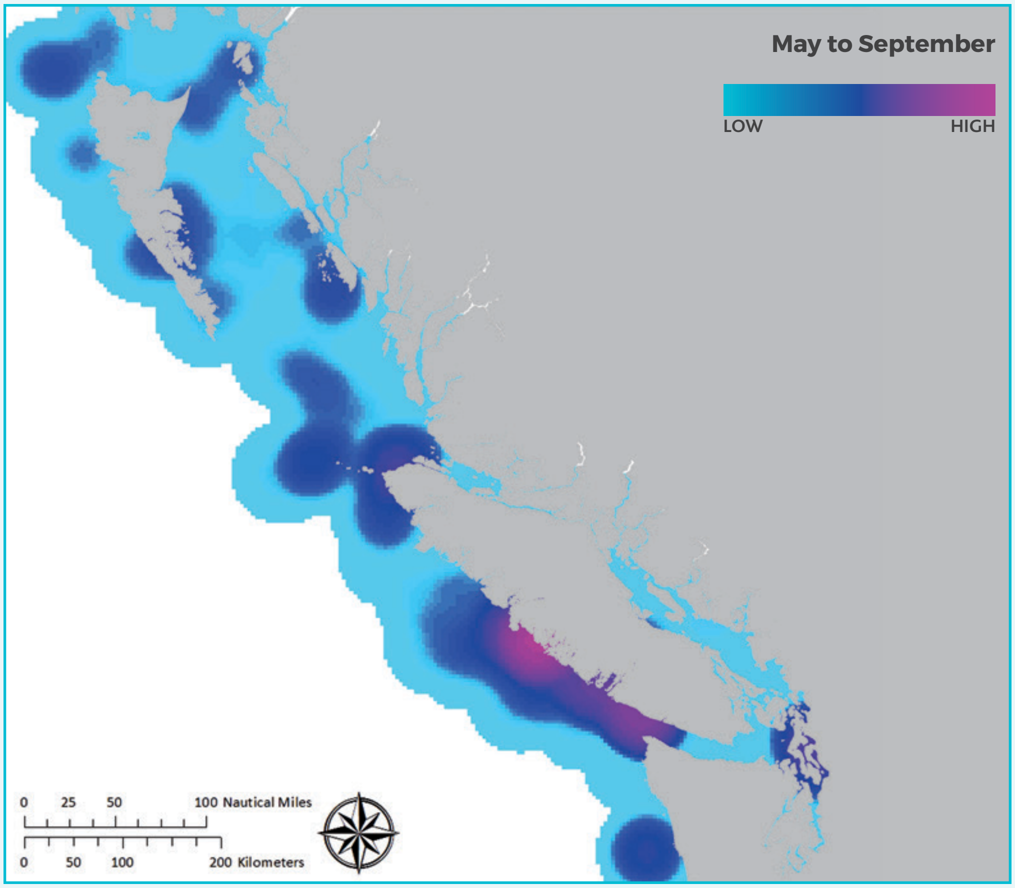
Vulnerability of the Species

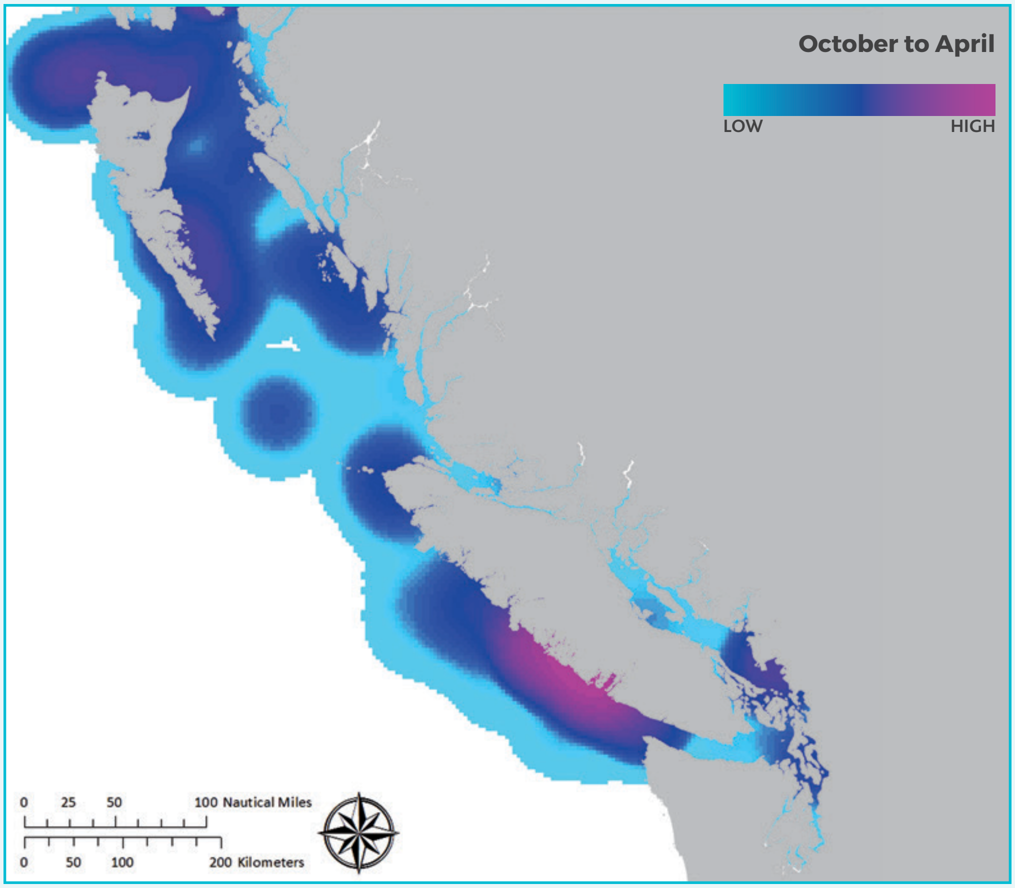
Like most large whale species, grey whales are threatened by vessel strikes[29]. While their tendency to travel close to shore in shallower waters may decrease their likelihood of interacting with large vessel traffic, recent studies have demonstrated that grey whale migration includes Hecate Strait and Dixon Entrance, both active shipping areas[18].

Additionally, vessels may contribute toward acoustic and physical disturbance of grey whales, potentially disrupting feeding behaviours or displacing them from their habitat[13].

Further threats include increased human activity in breeding lagoons, environmental variability, disruption and destruction of feeding habitat, toxic spills, physical disturbance, fossil fuel exploration and extraction, prey reduction, pollution, and entanglement in fishing gear (especially crab traps due to shallow water distribution)[13].

Relative Abundance of Grey Whales in B.C. Waters





FIN WHALE

Balaenoptera physalus

Average Adult Length: 17-18 m / 56-59 ft

SARA Status 2013

Not at Risk NR	Special Concern SC	[✓ Threatened] TH	Endangered EN	Extirpated EX

Dorsal Fin

Prominent and sickle-shaped, located far back on body.

Appearance

Dark grey back, often with lighter grey swirled markings behind the head. Right lower lip is white while left is dark. Streamlined body shape with tapered head. Skin may have a brownish tinge caused by diatoms. Tall, narrow blow.

Behaviour

Usually does not lift tail when diving. Fast swimmer.

Distribution

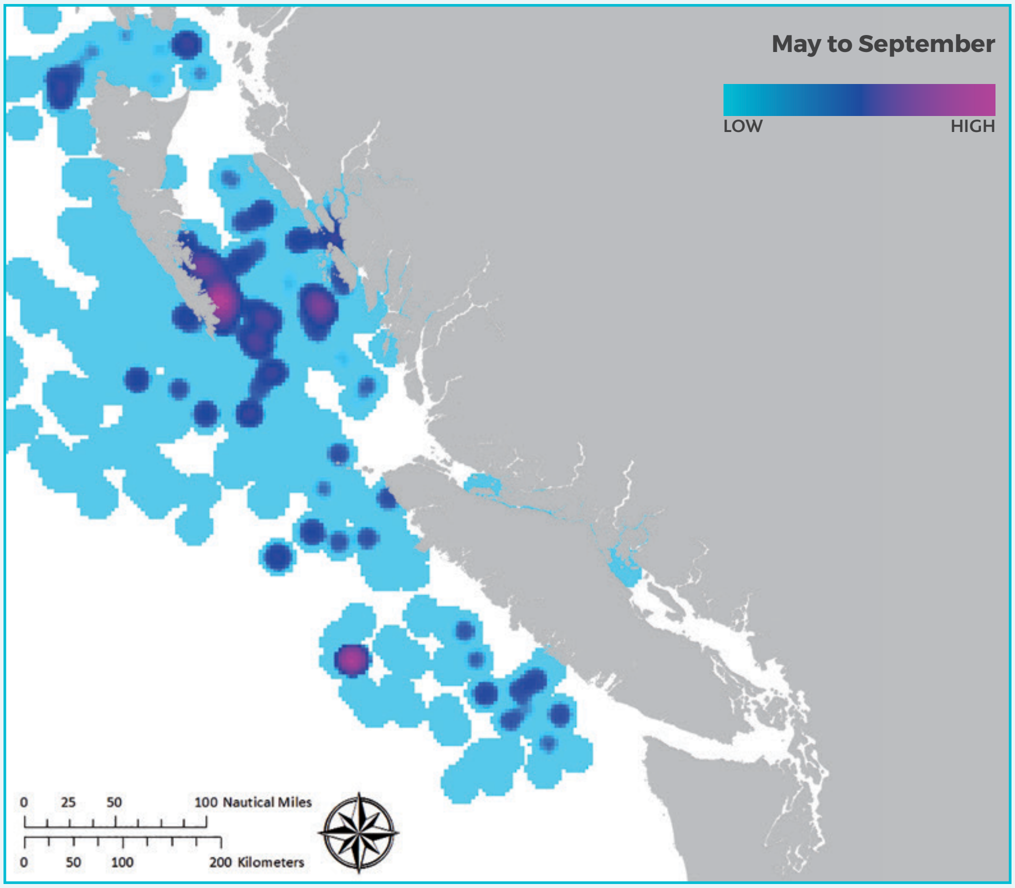
Found in all the world's oceans. The North Pacific population has been reported from the Gulf of California to the Gulf of Alaska (potentially two separate populations). Migrate to high latitudes in the summer for feeding, and to warm waters in the winter for breeding. Found mostly near or off the continental shelf, occasionally in near-shore deep water.

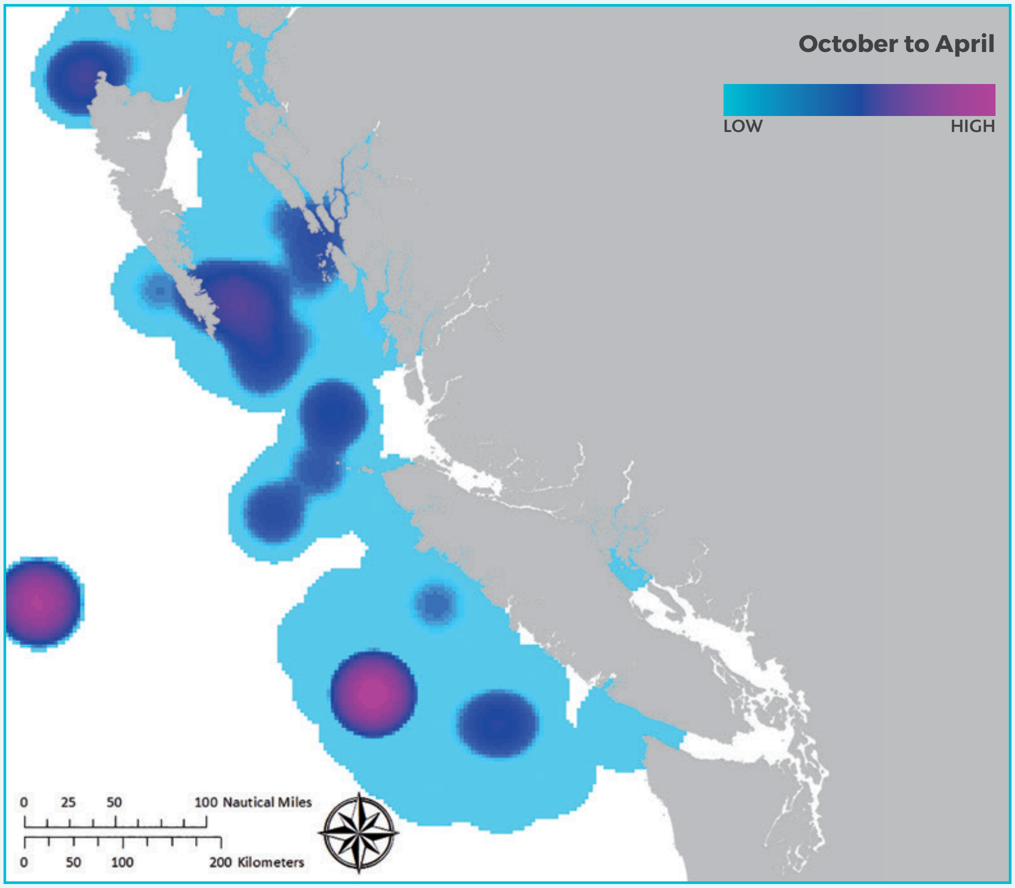
Vulnerability of the Species

Fin whales are the most commonly struck whale species worldwide[29, 26, 6], and vessel strikes are the greatest human-caused threat to fin whales in B.C. As fin whales are distributed along the shelf-break, they are in locations that frequently coincide with shipping lanes[20]. Additionally, vessel noise may cause disturbance and mask the low-frequency calls of fin whales[17].

Further threats to fin whales include entanglement in fishing gear and debris, pollution, and habitat displacement by changes in ocean climate and prey distributions[17].

Relative Abundance of Fin Whales in B.C. Waters





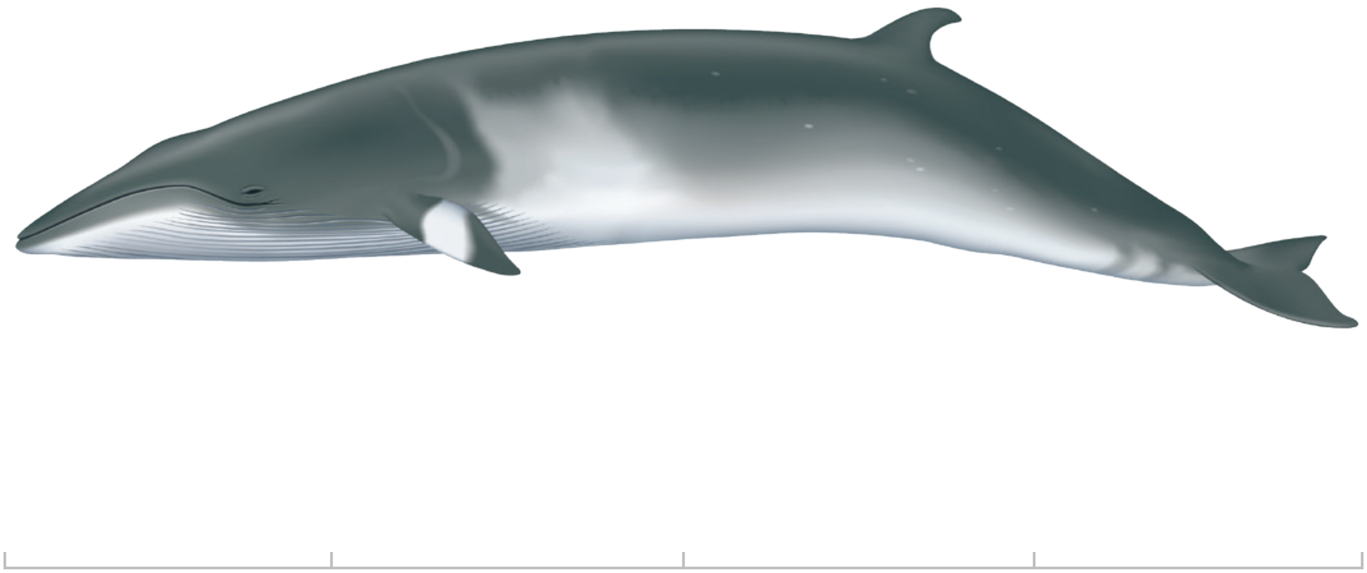

J. TOWERS


J. TOWERS


J. TOWERS

COMMON MINKE WHALE

Balaenoptera acutorostrata



Average Adult Length: 8 m / 26 ft

COSEWIC Status 2006

[✓ Not at Risk]	Special Concern	Threatened	Endangered	Extirpated
NR	SC	TH	EN	EX

Dorsal Fin

Sharply curved dorsal fin, located far back on body.

Appearance

Dark grey back, often with lighter grey swirled markings behind the head. Distinctive white band on top of each pectoral flipper. Pointed head with prominent nose ridge. Body slender and streamlined. Blows rarely visible.

Behaviour

Usually elusive and solitary. Surfaces 1-2 times between dives.

Distribution

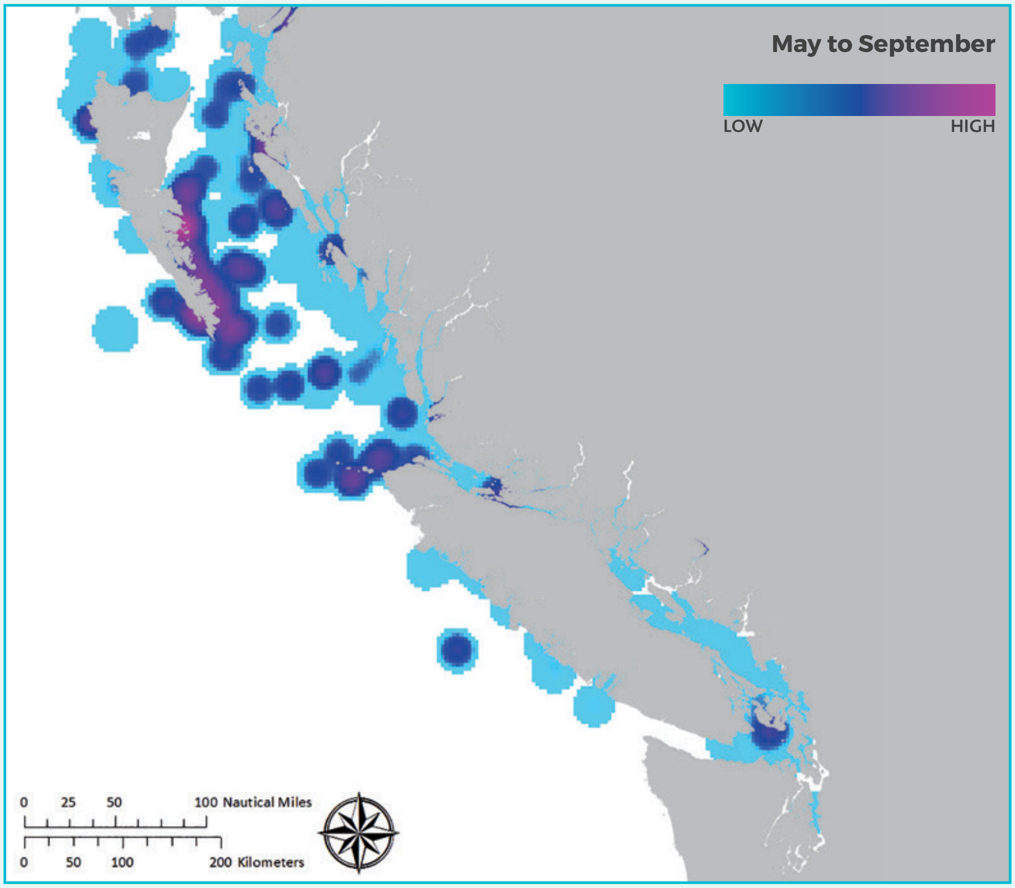
Distributed in both the northern and southern hemispheres, and have been observed year round in B.C., although more commonly seen in summer months. Found in shallow coastal areas and can be found offshore.

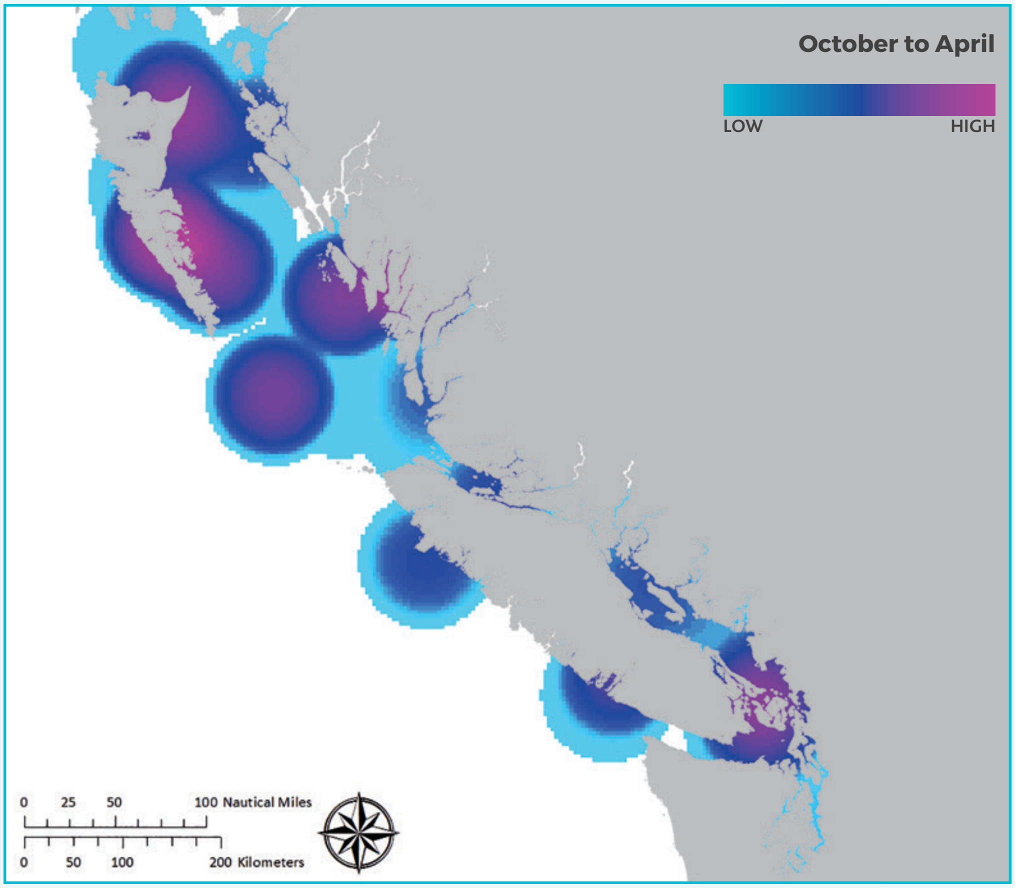
Vulnerability of the Species

Vessels can negatively affect minke whales due to risk of strikes[50], and pose threats associated with pollution and disturbance.

Entanglement in fishing gear is one of the largest human-caused threats to minke whales in B.C.[19].

Relative Abundance of Minke Whales in B.C. Waters

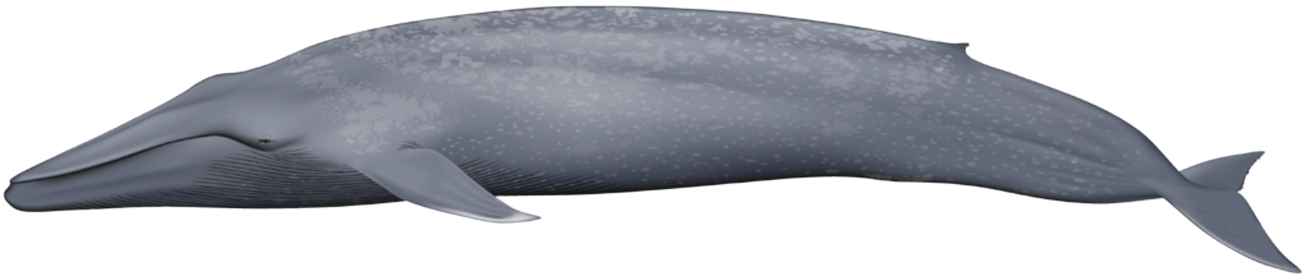




📷 E. STREDULINKSY

BLUE WHALE

Balaenoptera musculus



Average Adult Length: 21-22 m / 69-72 ft

SARA Status 2013

Not at Risk	Special Concern	Threatened	[✓ Endangered]	Extirpated
NR	SC	TH	EN	EX

Dorsal Fin

Variable shape, often rounded at tip. Very small relative to body.

Appearance

Blue grey, mottled colouring. Dorsal fin generally not seen until long after blow appears and head has submerged. Head is broad and flat with a raised "splashguard" in front of blowhole. Column-shaped blow 9 m (30 ft) tall.

Behaviour

Often raises tail when diving.

Distribution

Found in all the world's oceans. The eastern North Pacific population ranges from Central America to the Gulf of Alaska. Seasonal movements are not fully understood, but it is generally accepted that the species migrates south to Baja California (especially the Gulf of California) and west of Costa Rica in the winter, moving north off California, B.C. and the Gulf of Alaska in the spring and summer. Primarily found in offshore waters, occasionally in coastal and shelf waters.

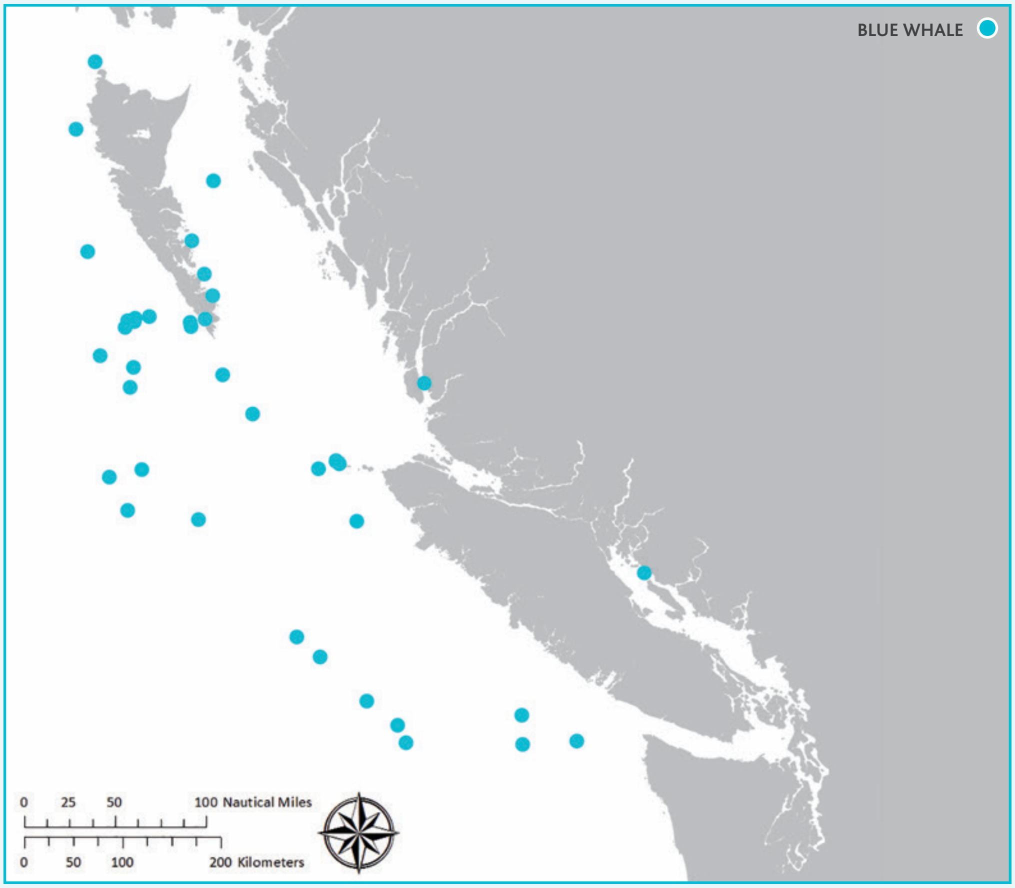
Vulnerability of the Species

Vessel strikes are one of the most significant human-caused threats to blue whales. Blue whales may be particularly vulnerable to strikes due to their tendency to feed at the surface and their slow and shallow dive response to vessels[33]. Blue whales spend more time at or near the surface at night when they are more difficult to see and avoid[2].

Additionally, vessels pose a threat to blue whales due to acoustic disturbance, which may mask their communication calls[17].

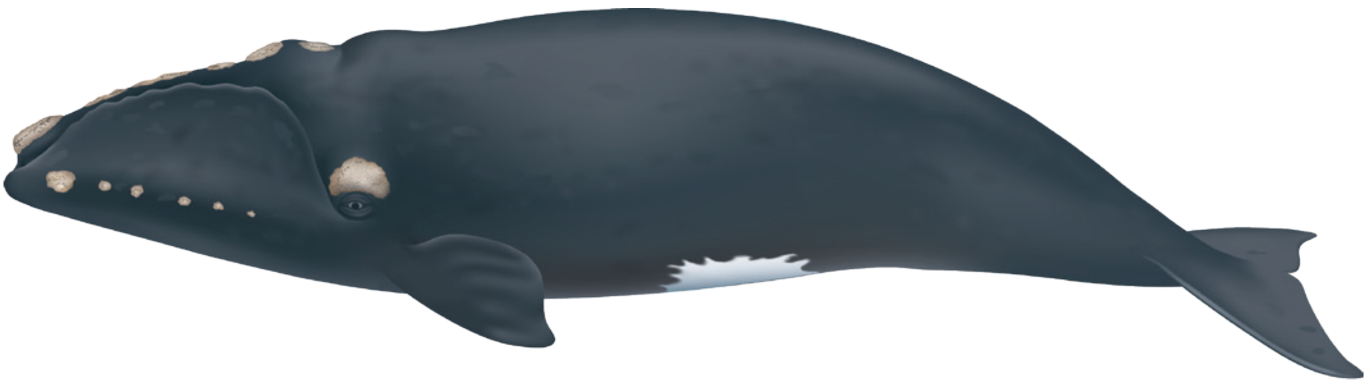
Further threats to blue whales include entanglement in fishing gear and debris, pollution, and habitat displacement caused by changes in ocean climate or food web[17].

Blue Whale Sightings in B.C. Waters



NORTH PACIFIC RIGHT WHALE

Eubalaena japonica



Average Adult Length: 17 m / 56 ft

SARA Status 2011

Not at Risk	Special Concern	Threatened	[✓ Endangered]	Extirpated
NR	SC	TH	EN	EX

Dorsal Fin
No dorsal fin present and no dorsal ridge evident.

Appearance
Dark grey to black body with large, white callosities (small, irregular knobs of calloused skin) on the head. White patches on the side of the belly. Very rotund shape with short pectoral flippers. Mouth line is strongly arched downwards. Tail flukes are very triangular. Wide, V-shaped blow.

Behaviour
May raise tail when diving. Feeds by swimming slowly along the surface with mouth agape.

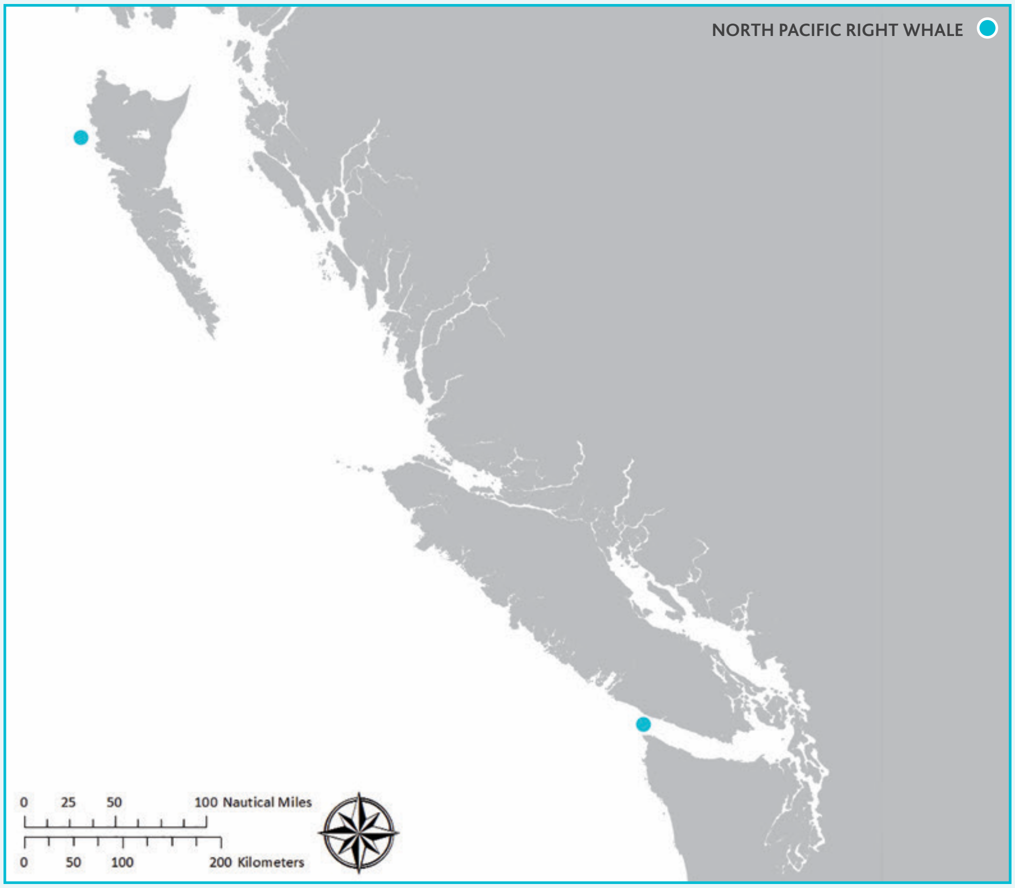
Distribution
Extremely rare. Historically found across the entire North Pacific (eastern and western North Pacific populations considered discrete).

Vulnerability of the Species
Small population size is a critical threat to North Pacific right whales, making their species especially vulnerable to threats such as vessel strikes, as the loss of one individual could have drastic effects on the population's chances of recovery[29]. In the North Atlantic, it has been found that vessel strikes are the most significant human-caused source of injury and mortality for right whales[26]. Right whales show very low responsiveness to vessels[38], have slow swimming speeds, and spend a significant amount of time at the surface resting, feeding, nursing and mating, making them very vulnerable to strikes[29].

Further threats to North Pacific right whales include entanglement in fishing gear, noise and pollution[17, 44].

NOTE: North Pacific right whales are extremely rare. Two sightings in 2013 of two different individual animals were the first confirmed observations of this species in over 60 years. **If you see one, please call 1 866 I SAW ONE immediately.** They are featured in this guide due to their significant vulnerability to vessel collisions and to highlight the importance of reporting this species.

North Pacific Right Whale Sightings in B.C. Waters




J. PILKINGTON

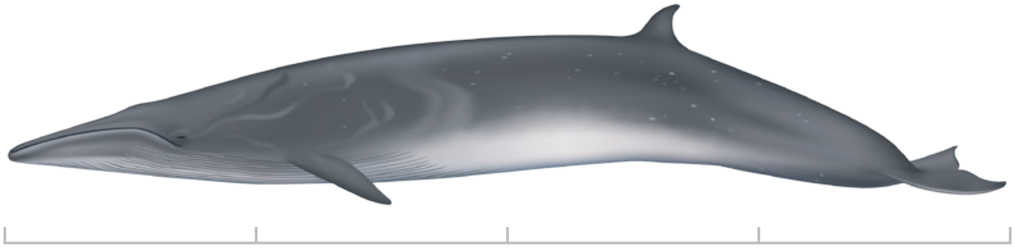

J. PILKINGTON


J. PILKINGTON

LESS COMMON BALEEN WHALES

SEI WHALE

Balaenoptera borealis



Average Adult Length: 13 m / 43 ft

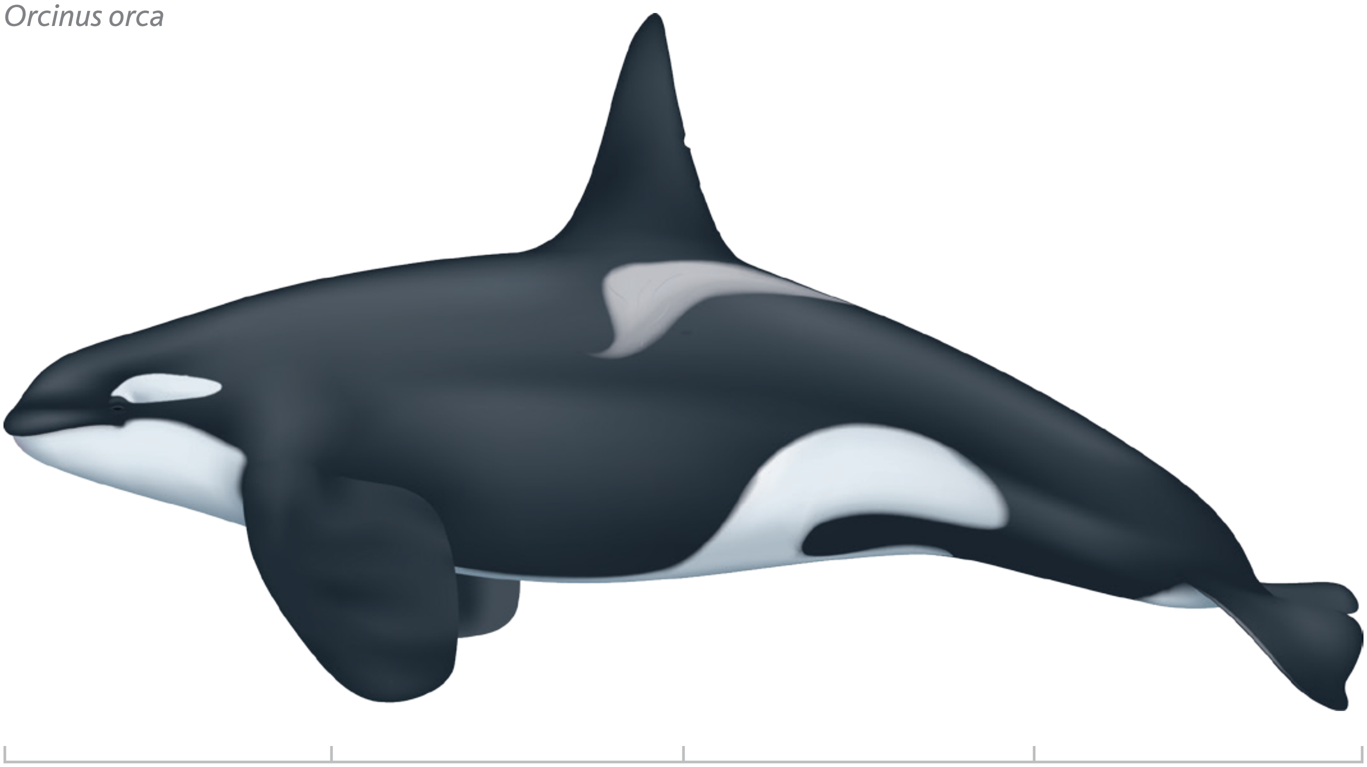
Description

Dark to bluish grey, often with grey to white circular scars. Dorsal fin is strongly curved towards back, generally more erect compared to a fin whale, and positioned less than 2/3 from the front of the body. Lower jaw is dark on both sides of the head.

Toothed Whales

KILLER WHALE / ORCA

Orcinus orca



Average Adult Length: 6-8 m / 20-26 ft

Southern Resident	Northern Resident	Bigg's	Offshores
SARA Status 2011	SARA Status 2011	SARA Status 2007	SARA Status 2009
Endangered	Threatened	Threatened	Threatened
NR	TH	TH	TH

Dorsal Fin

Short and curved in juvenile and female whales, tall in mature males up to 1.8 m in height.

Appearance

Distinctive pattern with black on the back, white on the belly, white-grey "saddlepatch" behind the dorsal fin and white "eyepatch" located just behind the eye. Tail flukes are black on top and white underneath.

Behaviour

Can be very acrobatic and active at the surface.

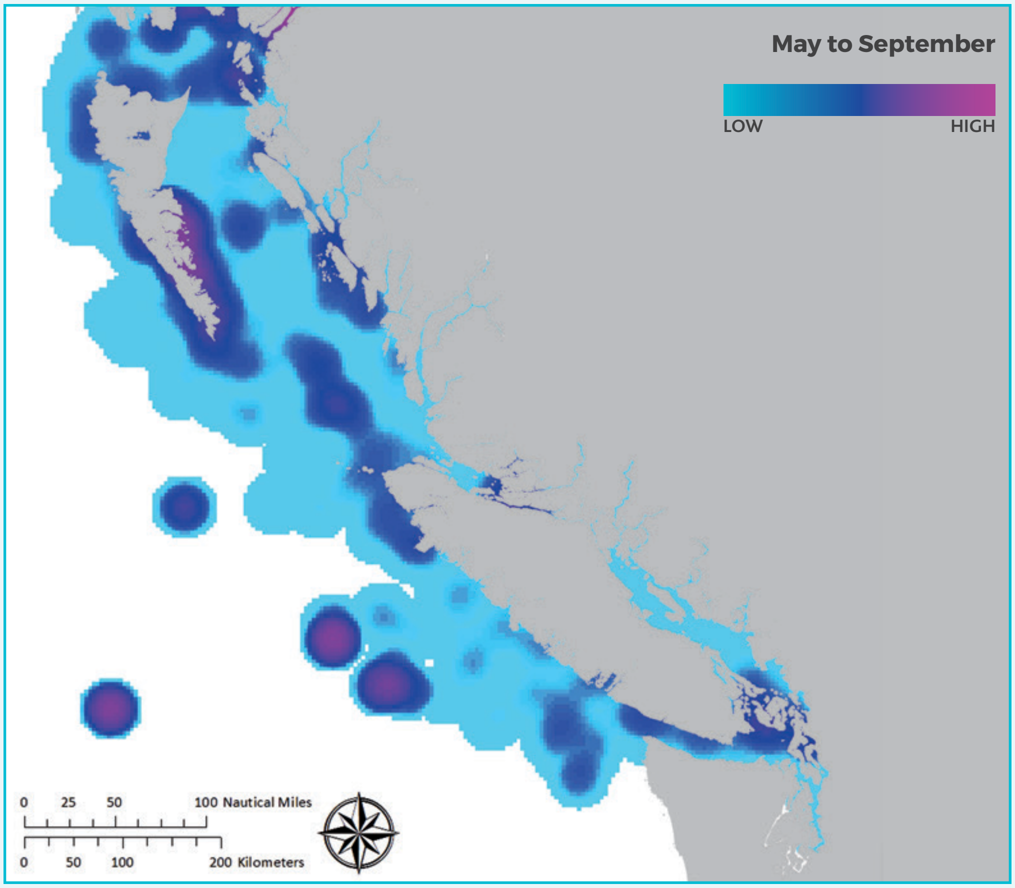
Distribution

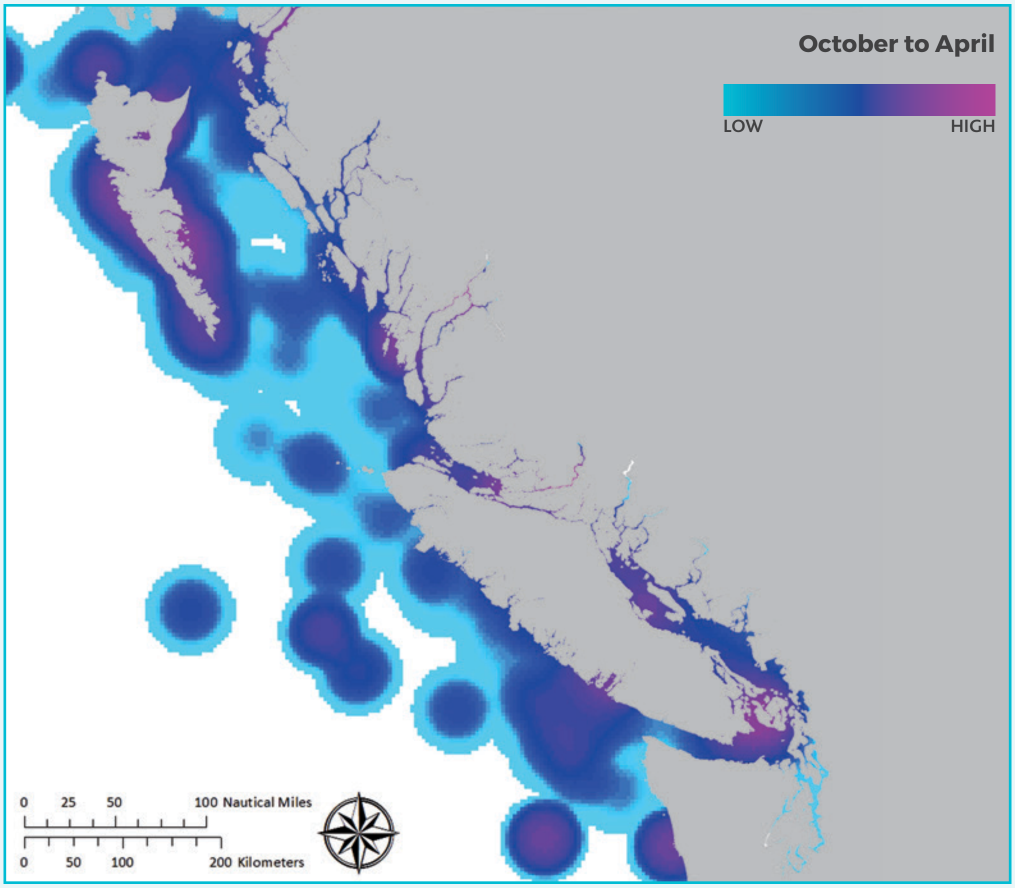
Three types of killer whales exist in B.C.: resident killer whales, Bigg's killer whales and offshore killer whales. Resident killer whales are observed throughout B.C. waters, but are most common south and east of Vancouver Island and in larger channels and passages on the central and north coast. They are usually seen in groups of 10 or more. Bigg's killer whales are more commonly seen in smaller groups, often very close to shore, among islands, and in or near bays and inlets. Offshore killer whales are usually found in groups of 10 to 50 or more and are most commonly seen in continental shelf waters west of Vancouver Island and Haida Gwaii[19]. In B.C., killer whales are subject to intensive whale watching by private and commercial vessels in the summer months, and vessel crews may be alerted to their presence by clusters of small vessels.

Vulnerability of the Species

The greatest impact of vessels on killer whales is noise and physical disturbance, which impairs and masks both their communication and echolocation, and can interrupt important behaviours such as foraging, group cohesion, resting and mating[8, 54]. Vessel strikes are relatively rare, but when they occur they usually cause serious injury or death (Spaven *et al.* 2013). Further human-caused threats to killer whales include injuries associated with depredation (whales taking fish off fishing lines), entanglement in fishing gear, contaminants and pollution, and competition for fish stocks[15, 11, 10].

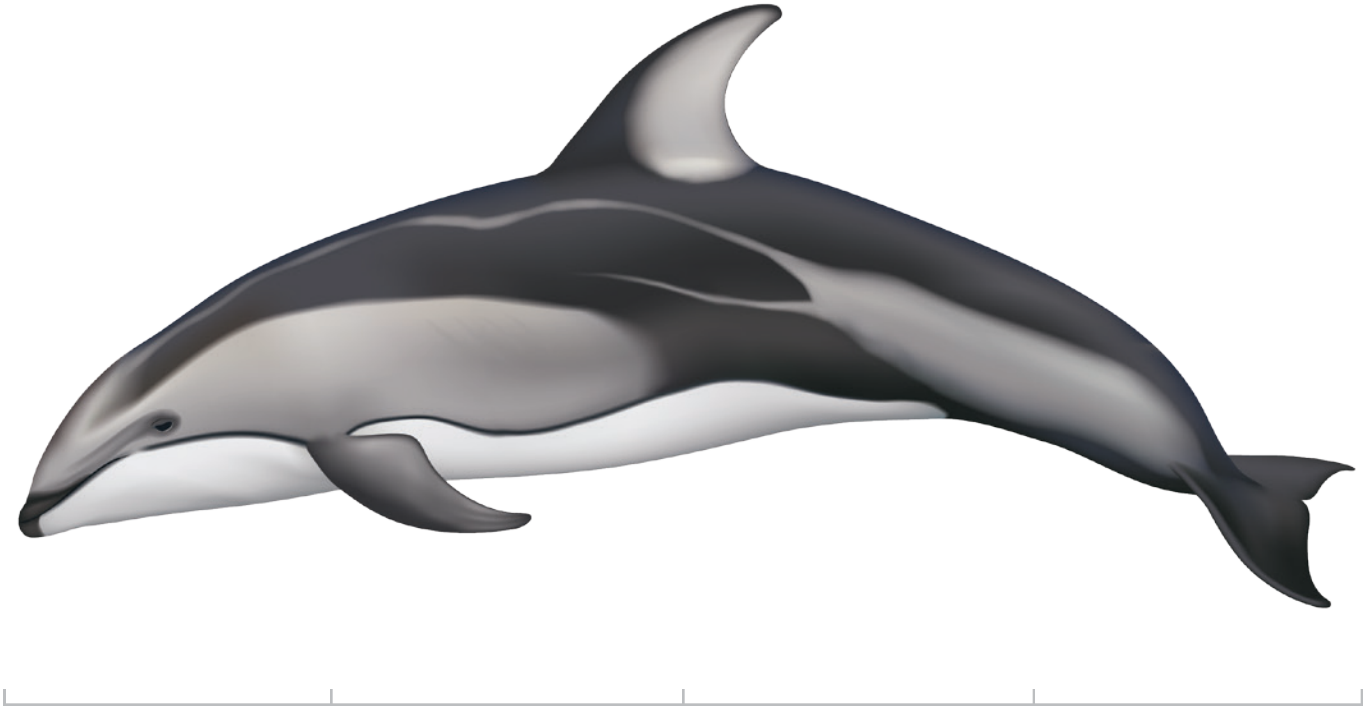
Relative Abundance of Killer Whales in B.C. Waters





PACIFIC WHITE-SIDED DOLPHIN

Lagenorhynchus obliquidens



Average Adult Length: 2.5 m / 8 ft

COSEWIC Status 1990

Not at Risk	Special Concern	Threatened	Endangered	Extirpated
NR	SC	TH	EN	EX

Dorsal Fin

Grey and white bi-coloured, very curved, located in the middle of the back.

Appearance

Back is dark-grey to black, sides are striped light and dark grey, and belly is white. Tip of the beak is black, and visible when out of water.

Behaviour

Often leap completely clear of water. Create a "rooster-tail" of spray when swimming quickly. Often in groups of 50 or more.

Distribution

Only found in the North Pacific. The eastern North Pacific population occurs from southern Gulf of California to the Gulf of Alaska. It is the most abundant cetacean species in B.C., found in most coastal and offshore waters of the province.

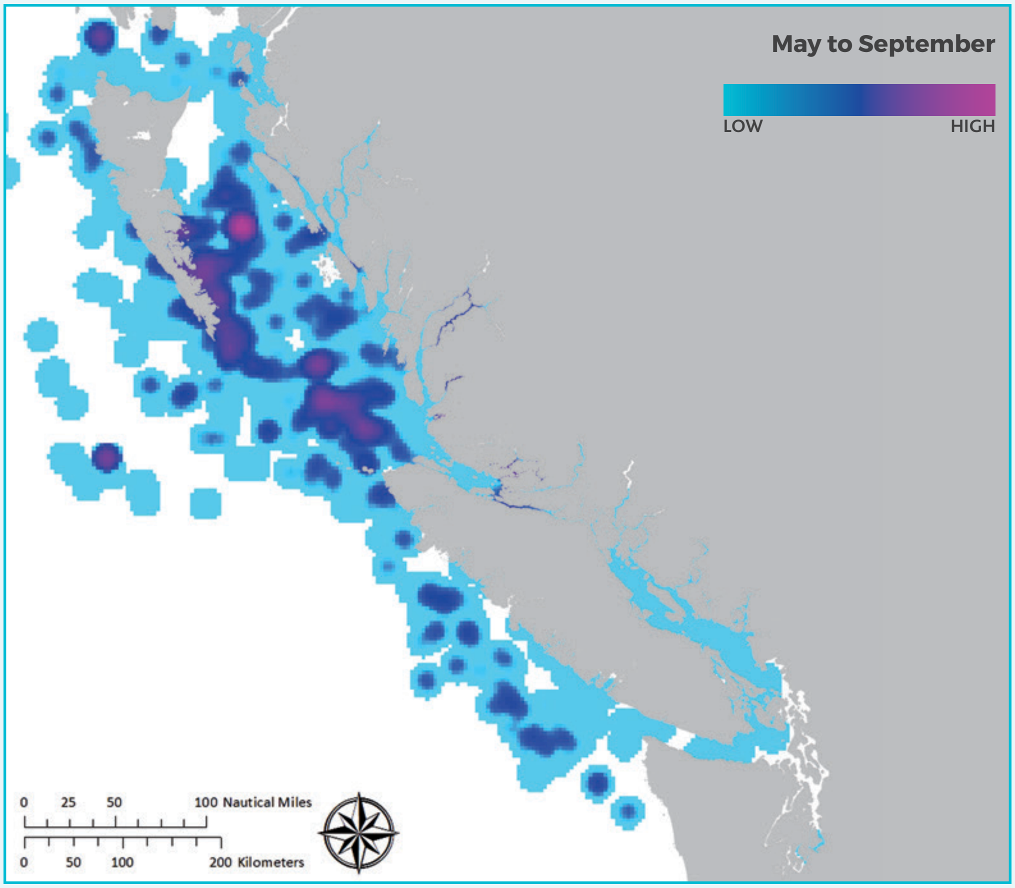
Vulnerability of the Species

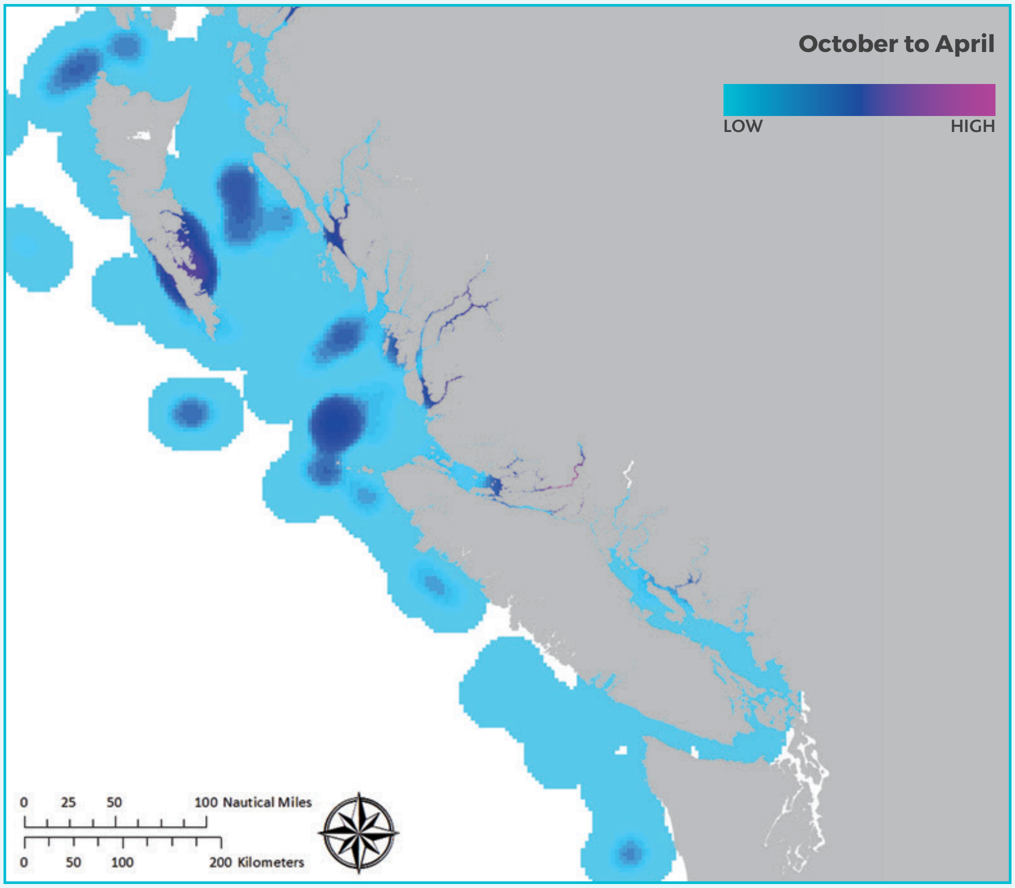
Researchers and ecotourism professionals in British Columbia have observed Pacific white-sided dolphins with injuries or scars consistent with vessel strikes, although the prevalence of strikes to this species is believed to be low[21,23].

Pacific white-sided dolphins have a tendency to approach vessels and bow-ride, which may increase the risk of vessel strikes.

Historically, bycatch from drift gillnet fisheries for salmon and squid caused a significant decline to Pacific white-sided dolphin populations. The moratorium placed on the practice in 1993 greatly decreased mortality due to bycatch[18].

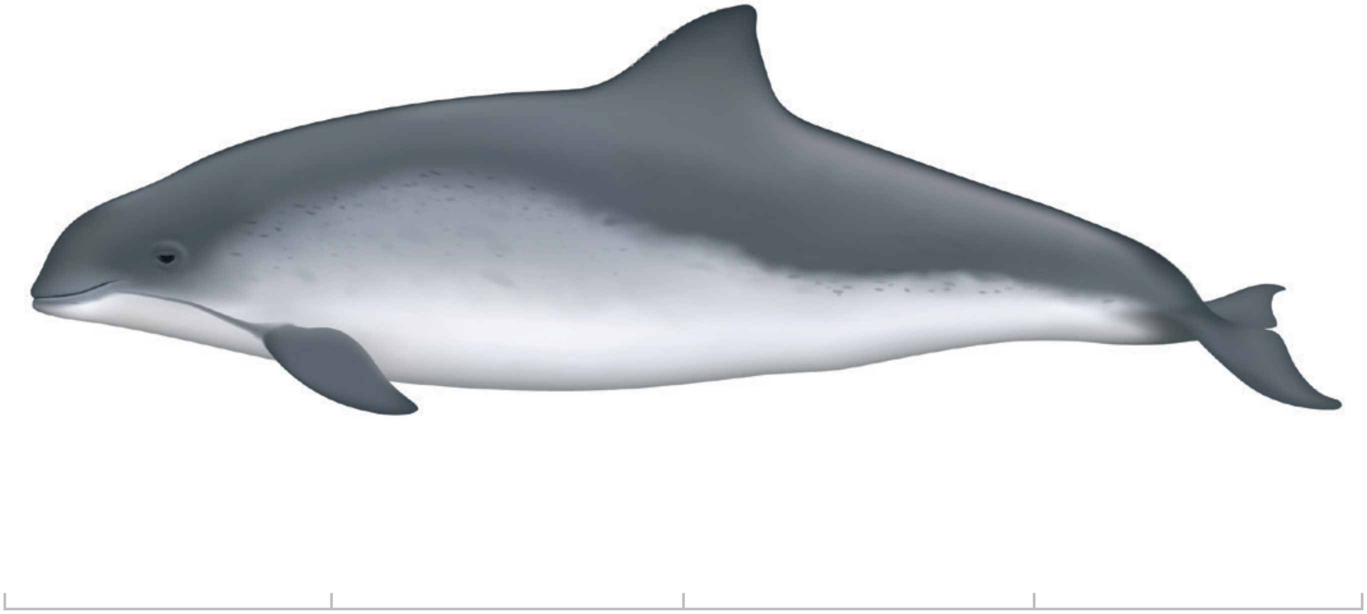
Relative Abundance of Pacific White-Sided Dolphins in B.C. Waters





HARBOUR PORPOISE

Phocoena phocoena



Average Adult Length: 1.5 m / 5 ft

SARA Status

Not at Risk	**Special Concern**	Threatened	Endangered	Extirpated
NR	**SC**	TH	EN	EX

Dorsal Fin

Triangular, blunt, uniformly grey.

Appearance

Uniform colouration, dark grey-brown back with a lighter belly and speckled greyish white area along the sides. Lighter sides or belly not usually seen when surfacing. Chunky body with small pectoral flippers.

Behaviour

Often inconspicuous and travel slowly. Generally spotted alone or in small groups of 2-3. Larger aggregations may occur occasionally.

Distribution

Found in the North Pacific, North Atlantic and the Black Sea. Pacific population ranges from Point Conception California, north through B.C. and Alaska to the southern Beaufort and Chukchi Sea, and west to Japan. Present in B.C. year-round in shallow waters, as well as on the outer coast.

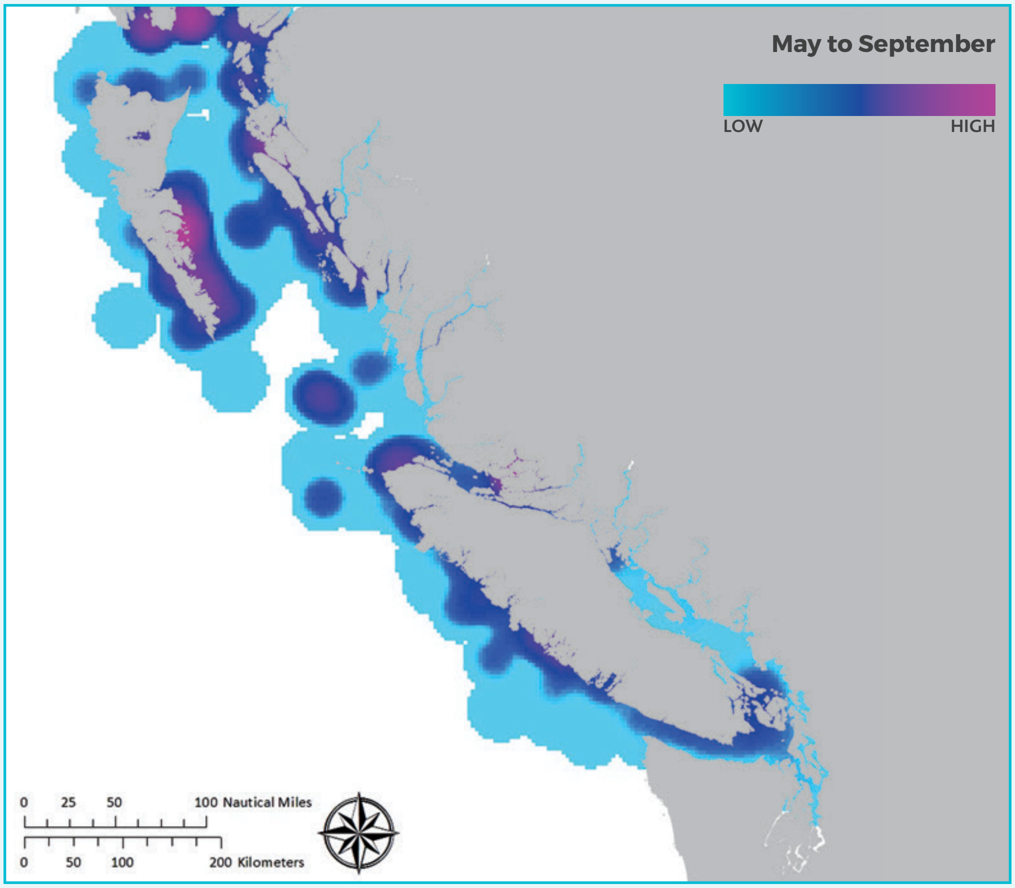
Vulnerability of the Species

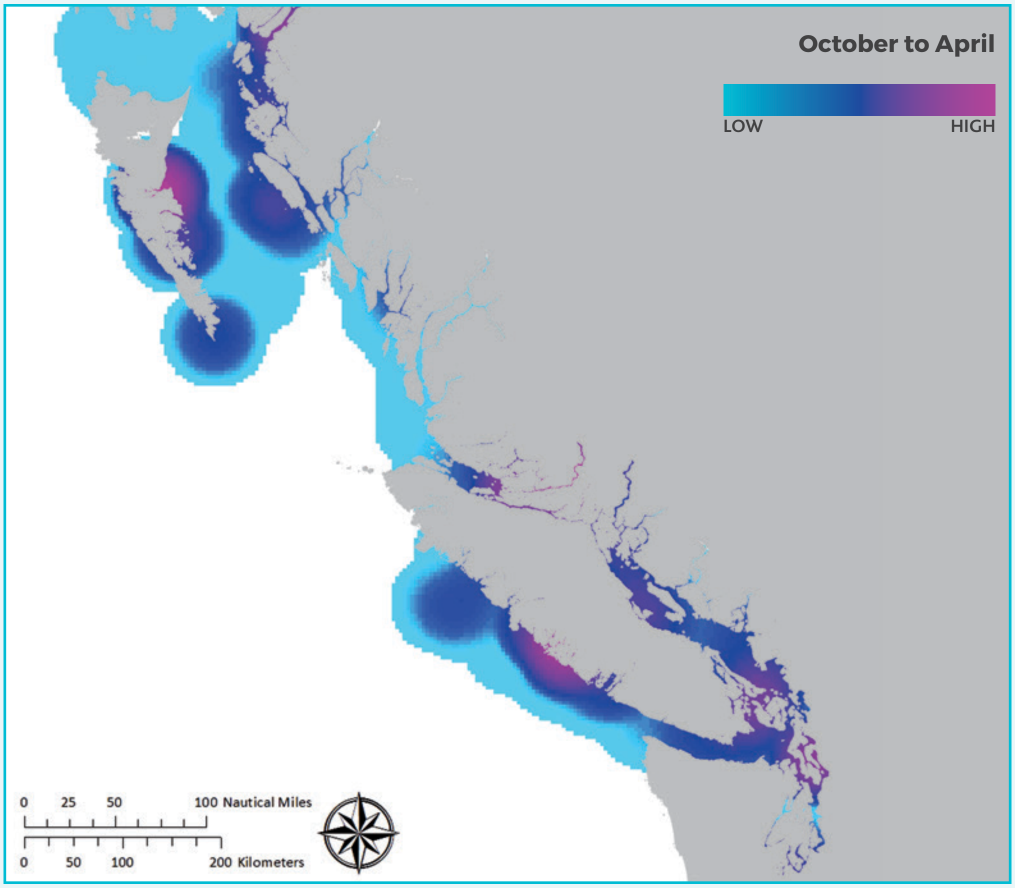
Harbour porpoise habitat in B.C. includes narrow, coastal waterways and areas close to urban centres exposing them to close contact with vessels. As the smallest cetacean in B.C., they are easy to miss, particularly in choppy seas.

Vessels may acoustically disturb harbour porpoise, which may interfere with foraging, navigating or social communication, and cause them to leave or not enter an area[12].

Further threats include entanglement, habitat degradation, toxic spills, contaminants and reduction in prey[12].

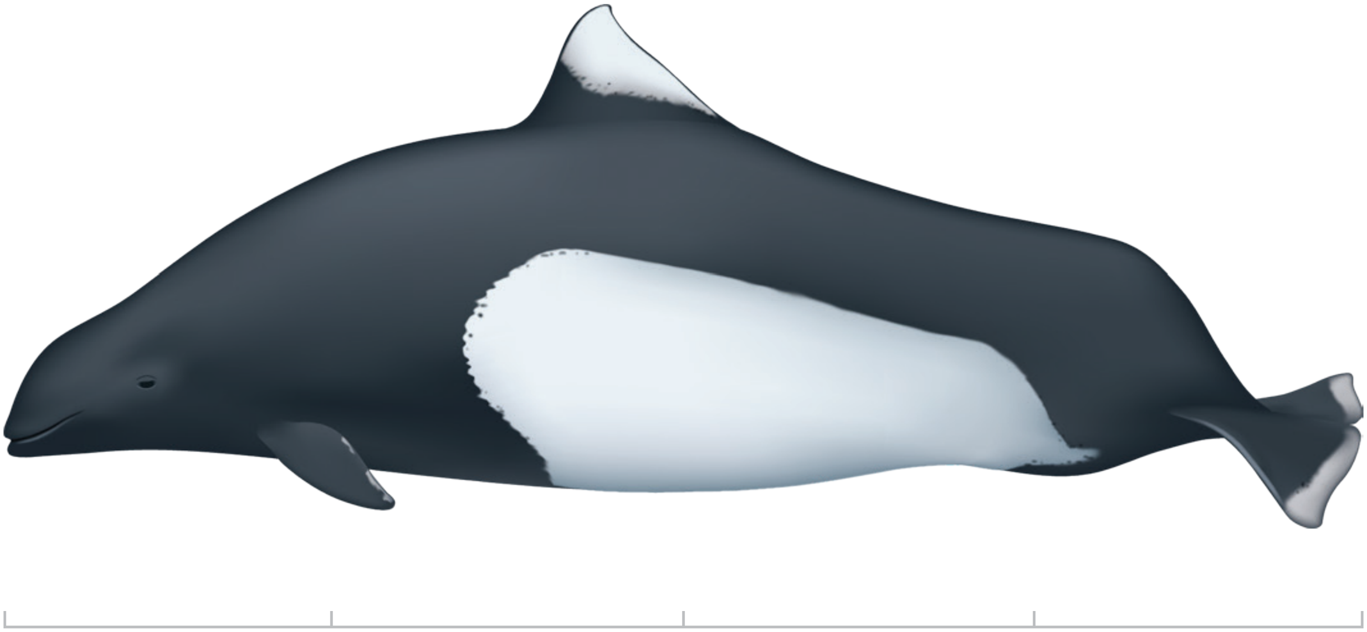
Relative Abundance of Harbour Porpoise in B.C. Waters





DALL'S PORPOISE

Phocoenoides dalli



Average Adult Length: 2 m / 6.5 ft

COSEWIC Status 1989

Not at Risk	Special Concern	Threatened	Endangered	Extirpated
NR	SC	TH	EN	EX

Dorsal Fin

Small, triangular, black with a white tip.

Appearance

Black back with prominent white flanks. Body is chunky with a small head and flippers. Small hump on tailstock before the flukes is evident when surfacing slowly.

Behaviour

Usually travel in groups of 2-10 animals. Create "rooster-tail" of spray when swimming quickly. Often approach vessels to bow-ride.

Distribution

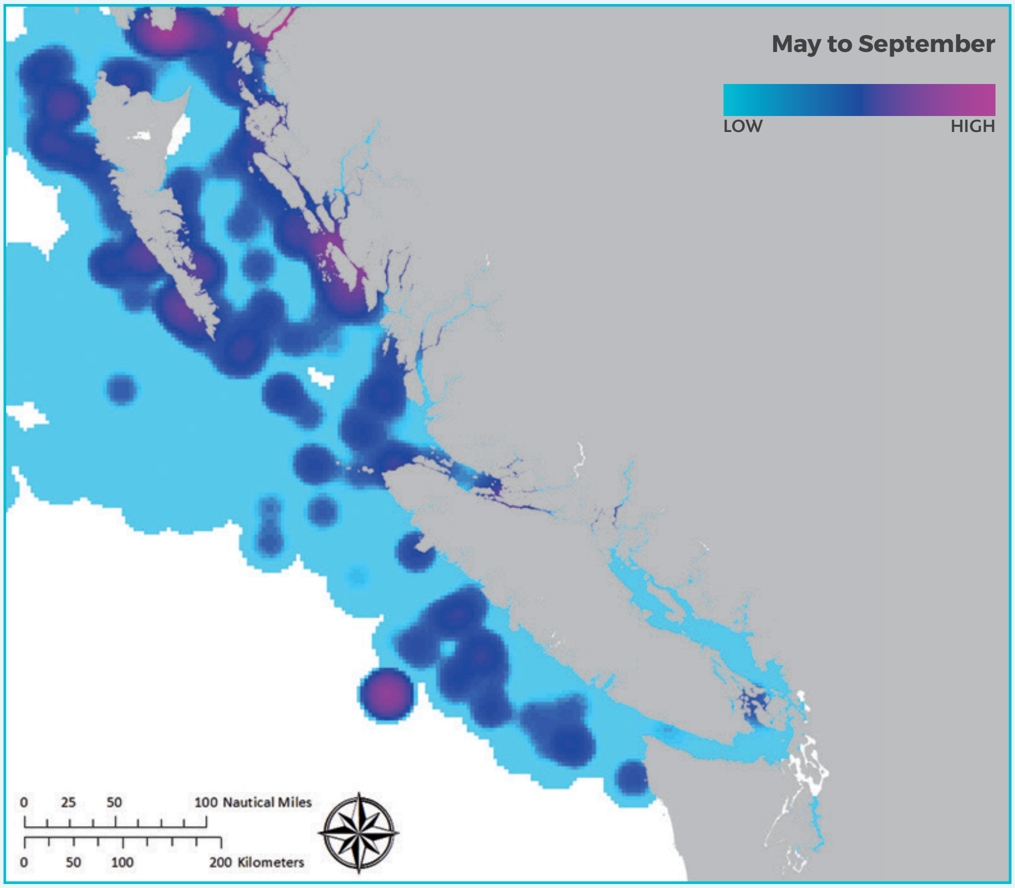
Endemic to North Pacific Ocean and adjacent Bering, Okhotsk, and Japan Sea. Widely distributed year-round in B.C.

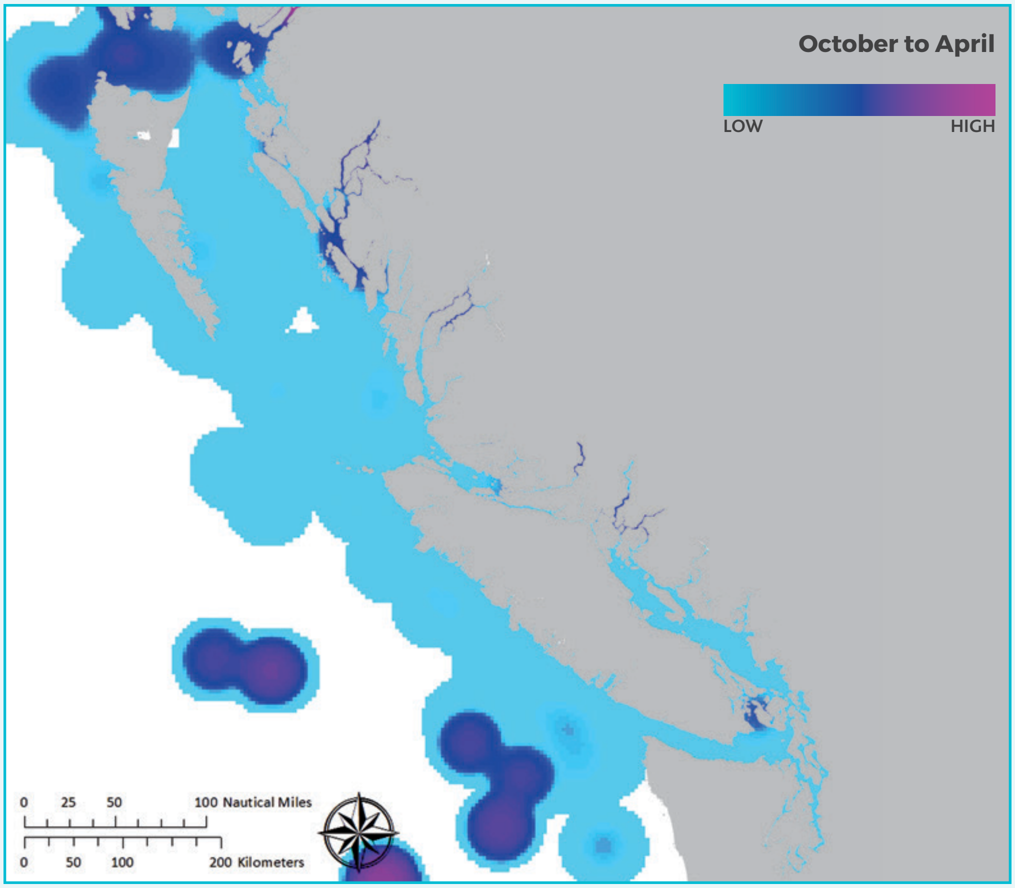
Vulnerability of the Species

Dall's porpoise have a tendency to approach vessels and bow-ride, which may increase the risk of vessel strike.

An additional threat to Dall's porpoise in B.C. is entanglement in fishing gear[19].

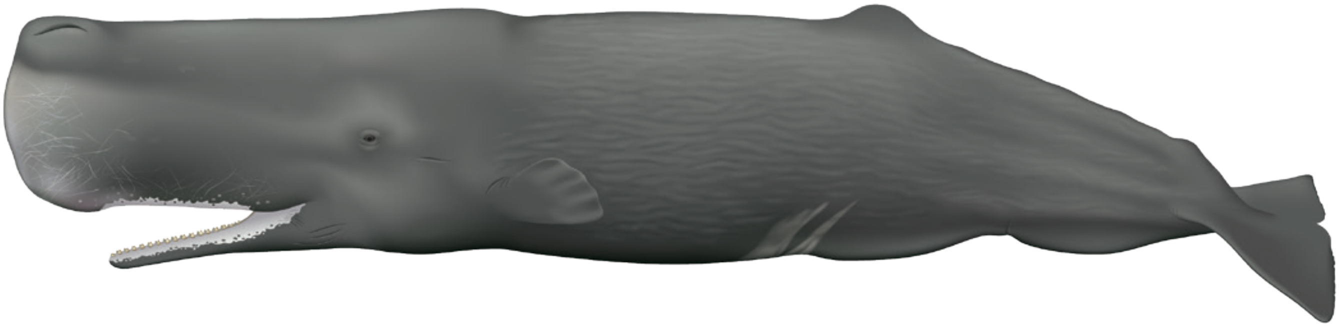
Relative Abundance of Dall's Porpoise in B.C. Waters





SPERM WHALE

Physeter macrocephalus



Average Adult Length: 11-13 m / 36-42 ft

COSEWIC Status 1996

Not at Risk	Special Concern	Threatened	Endangered	Extirpated
NR	SC	TH	EN	EX

Dorsal Fin

Triangular/rounded hump, followed by knuckles toward tail fluke.

Appearance

Dark brownish-grey in colour. Distinct, huge square-shaped head. Blowhole located very far forward on the head and on the left side (not centred). Skin appears wrinkled. Each half of tail fluke is the shape of a right triangle, with a distinctive "V" notch in the middle. Distinctive low, bushy blow from near the front of the head, angled to the left.

Behaviour

Lifts broad triangular trail flukes high in air before diving. Takes long dives, often 30-40 minutes in length.

Distribution

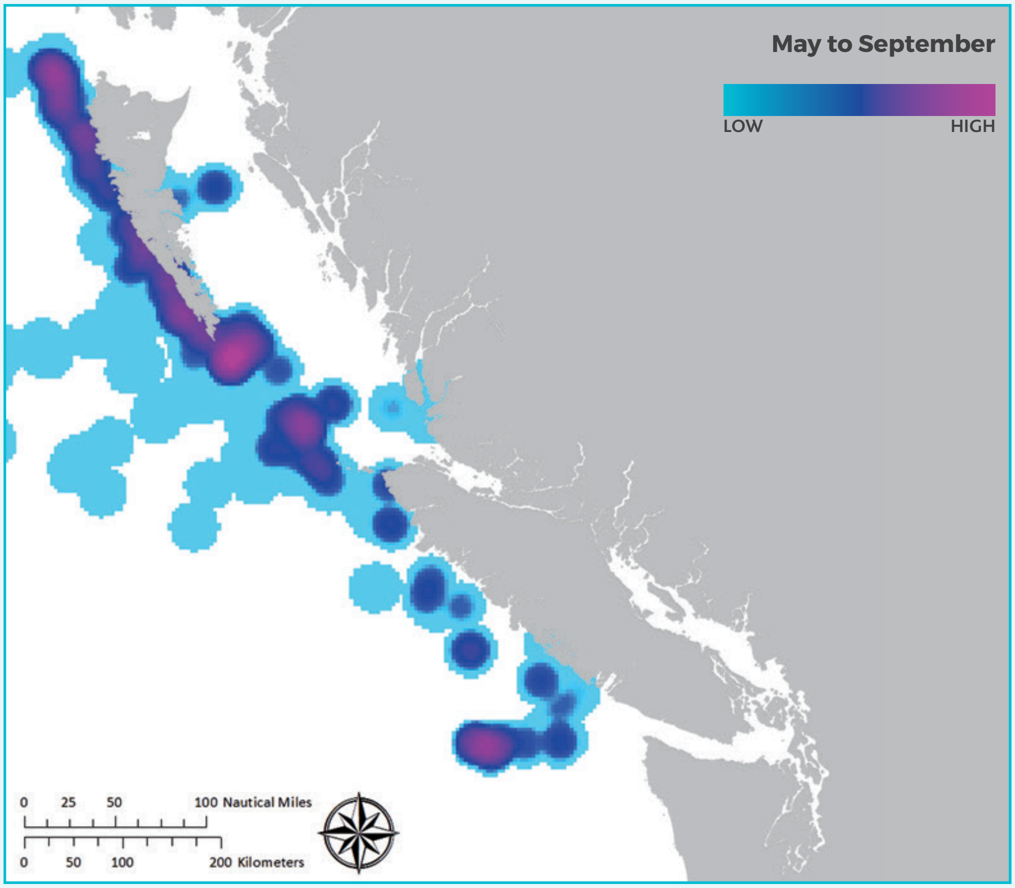
One of the most widespread cetaceans in the world. Found in productive coastal and deep waters surrounding oceanic islands. During the summer months, females and their young tend to be found further offshore than males. In B.C., primarily found along and off the continental shelf edge[19].

Vulnerability of the Species

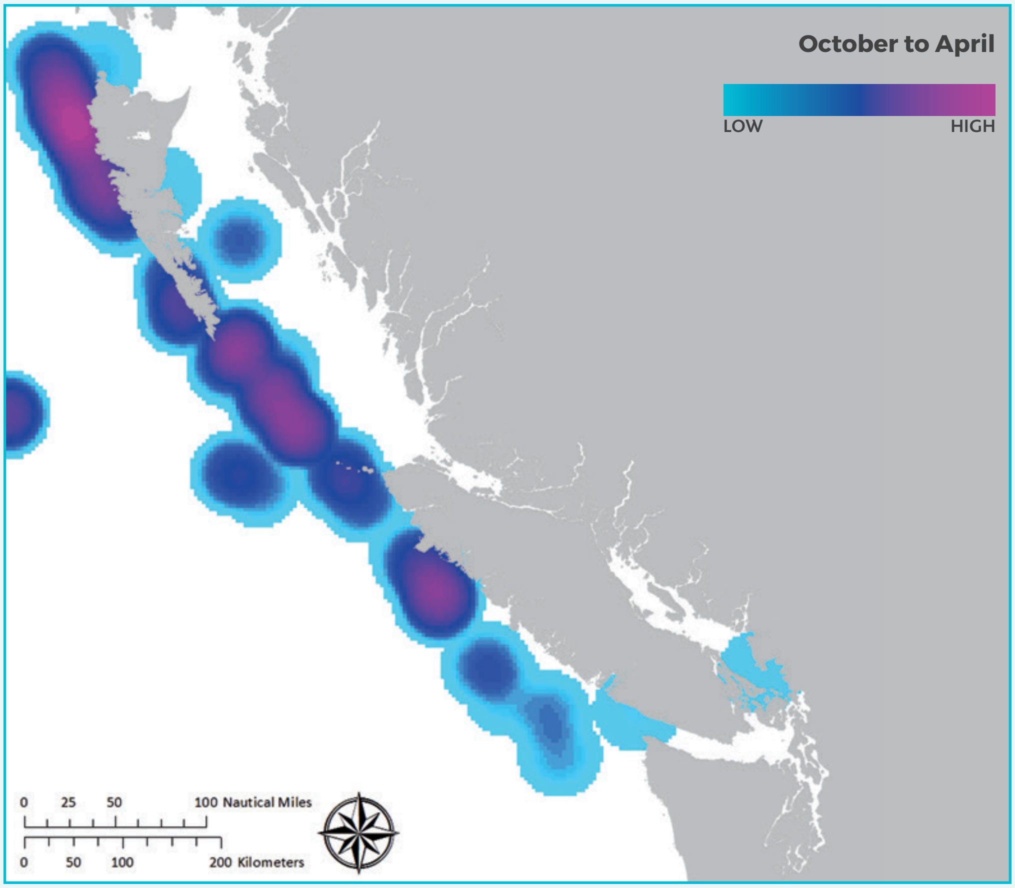
Sperm whales are vulnerable to vessel strikes[29]. Strikes to this species may be underreported or observed due to their far offshore distribution, causing carcasses to sink before stranding (Spaven *et al*. 2013).

Further threats to sperm whales include depredation (whales taking fish off fishing lines) and ingestion of marine debris[19].

Relative Abundance of Sperm Whale in B.C. Waters




J. Towers



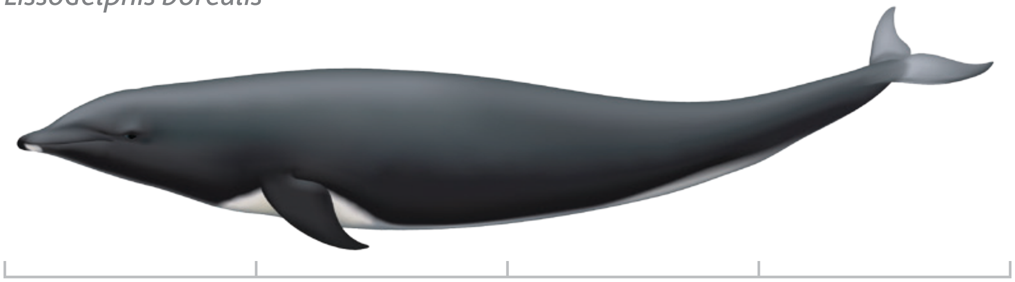

Oliver Hausemann


Alana Phillips

LESS COMMON TOOTHED WHALES

Northern Right Whale Dolphin

Lissodelphis borealis



Average Adult Length: 2-3 m / 7-10 ft

Description
Slender black body with white belly. Prominent beak with white tip. Only dolphin species in the North Pacific with no dorsal fin. Very small pectoral flippers often held close to the body.

Risso's Dolphin

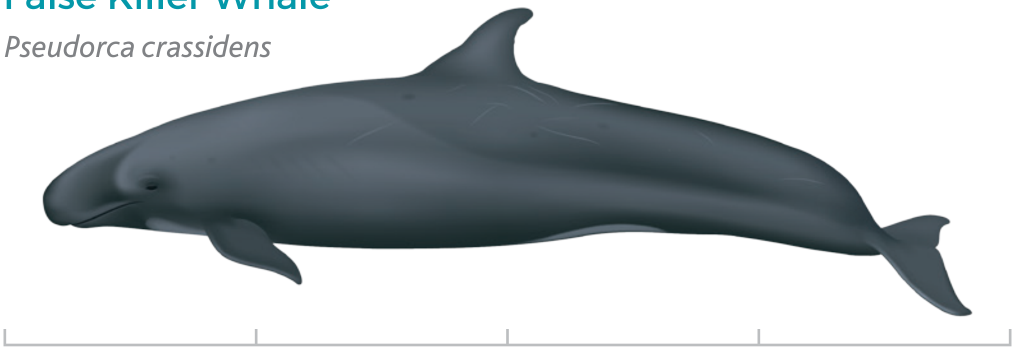
Grampus griseus

Average Adult Length: 4 m / 13 ft

Description
Grey body, often with conspicuous lighter grey scratches all over. Heavily scarred individuals appear almost white. Dorsal fin is large. Dorsal fin and pectoral flippers are a darker grey than body. Head appears to be blunt with a prominent forehead. No beak visible. Forehead has distinctive furrow down the centre.

False Killer Whale

Pseudorca crassidens



Average Adult Length: 5-6 m / 16-20 ft

Description

Body is completely black with no white or grey markings. Dorsal fin is small and curved. Pectoral fins bulge along front edge. Rounded and prominent forehead.

Baird's Beaked Whale

Berardius bairdii

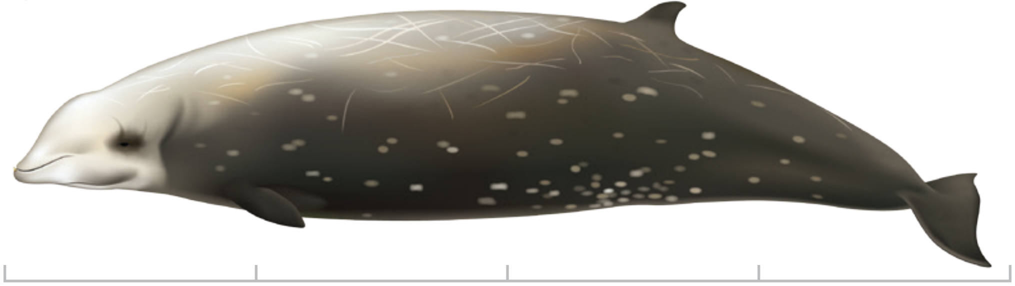
Average Adult Length: 10 m / 33 ft

Description

Brownish-grey back with irregular white patches on the belly. Adults may show linear scarring. Dorsal fin is slightly rounded and short, located 2/3 of the way down body. Adults have protruding teeth visible on the front of their lower jaw, which extends beyond the upper jaw. Long, prominent beak with a bulging forehead.

Cuvier's Beaked Whale

Ziphius cavirostris



Average Adult Length: 5-6 m / 16-20 ft

Description

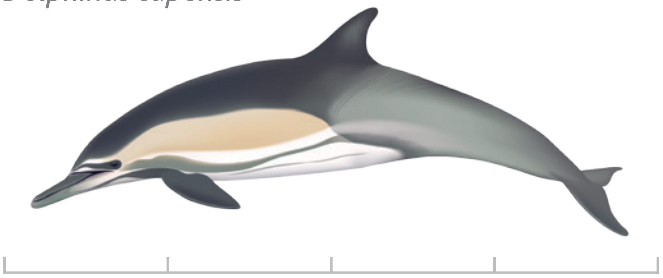
Rusty brown to slate grey back with white head. Small white circular scars and heavy linear scarring may be evident. Dorsal fin is small, curved, and located 2/3 down body. Adult males may have visible protruding teeth on front of their lower jaw, which extends beyond upper jaw. Stubby head.

RARE SPECIES

Other very rare species may occur off the coast of B.C. infrequently. If you feel that you have spotted one of these rare species, please take photos and alert the B.C. Cetacean Sightings Network as soon as possible at sightings@vanaqua.org or 1.866.I.SAW.ONE (1.866.472.9663).

LONG-BEAKED COMMON DOLPHIN

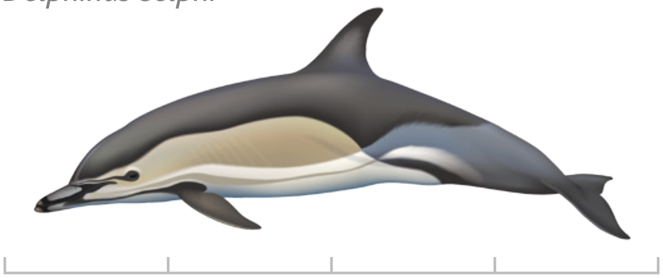
Delphinus capensis



Average Adult Length: 2 m / 6.5 ft

SHORT-BEAKED COMMON DOLPHIN

Delphinus delphi



Average Adult Length: 2 m / 6.5 ft

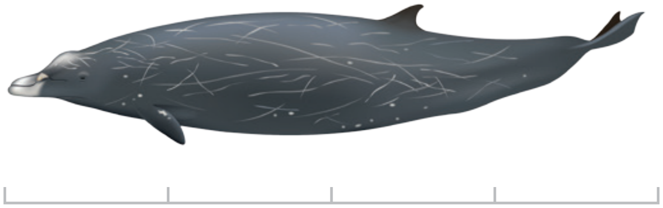
STEJNEGER'S BEAKED WHALE

Mesoplodon stejnegeri

Average Adult Length: 5.5 m / 18 ft

HUBB'S BEAKED WHALE

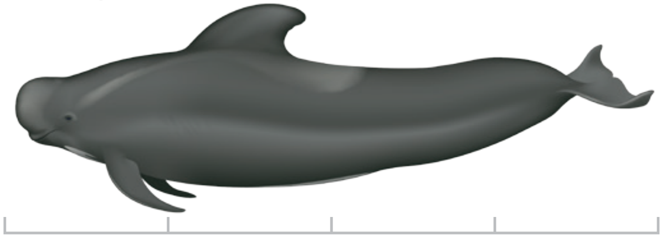
Mesoplodon carlhubbsi



Average Adult Length: 5 m / 16 ft

SHORT-FINNED PILOT WHALE

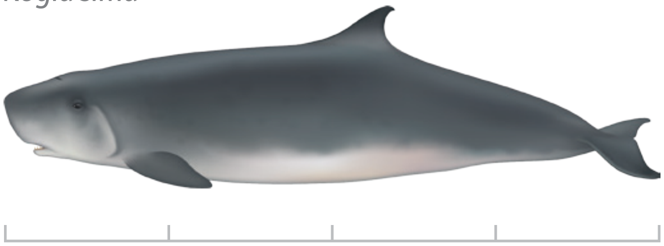
Globicephalus macrorhynchus



Average Adult Length: 5.5-7 m / 18-23 ft

DWARF SPERM WHALE

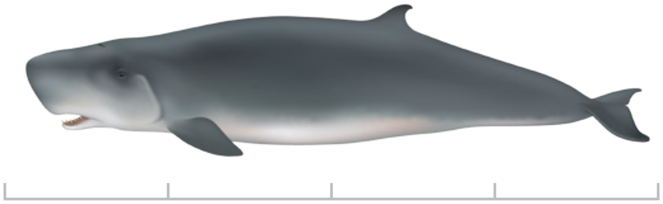
Kogia sima



Average Adult Length: 2.5 m / 8 ft

PYGMY SPERM WHALE

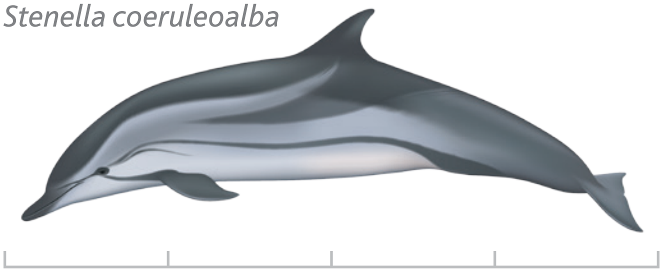
Kogia breviceps



Average Adult Length: 3.5 m / 11 ft

STRIPED DOLPHIN

Stenella coeruleoalba



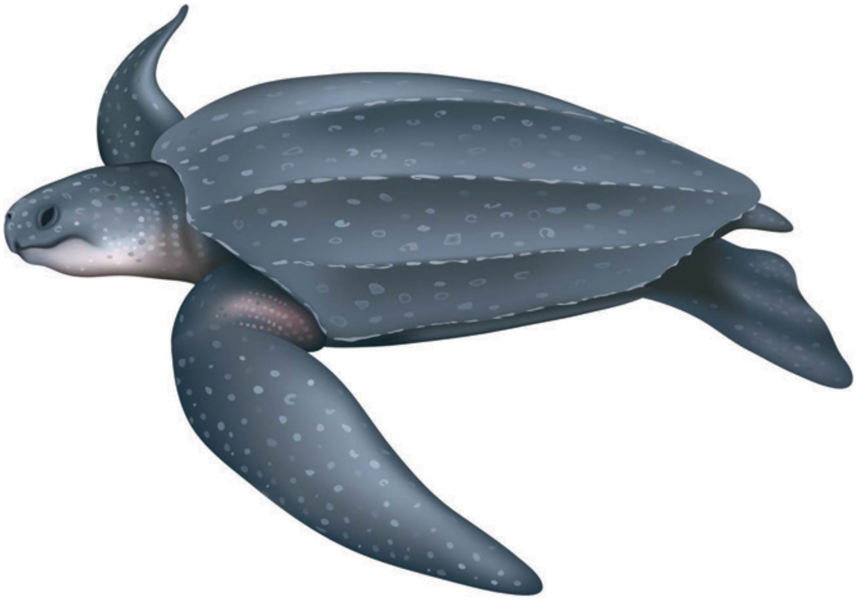
Average Adult Length: 2.5 m / 8 ft

Turtles

Scott Eckert

LEATHERBACK SEA TURTLE

Dermochelys coriacea



Average Adult Length: 3 m / 9 ft

SARA Status 2012

Not at Risk	Special Concern	Threatened	Endangered	Extirpated
NR	SC	TH	[✓ EN]	EX

Appearance

Body is dark grey to black and may be covered with many white spots. No hard shell is present, instead shell is leathery. Prominent ridges run down the back (looks similar to the underside of a boat). Body is tear-shaped and tapers to a point at the rear. A pink-orange spot may be visible on the back of the head. Often only the head and front 1/3 of the back are seen when surfacing.

Behaviour

Solitary. Surfaces to breathe for a few minutes after undertaking a long dive. Holds head above the water, then slowly sinks back down.

Distribution

Make extensive feeding migrations to the waters off B.C. from nesting beaches in tropical regions in Southeast Asia and the South Pacific. Most frequently seen off B.C.'s coast in offshore and coastal waters between July and September, but may be spotted year-round. Often observed in the same areas where *Mola mola* (sunfish), sharks, or large numbers of jellies are seen.

Vulnerability of the Species

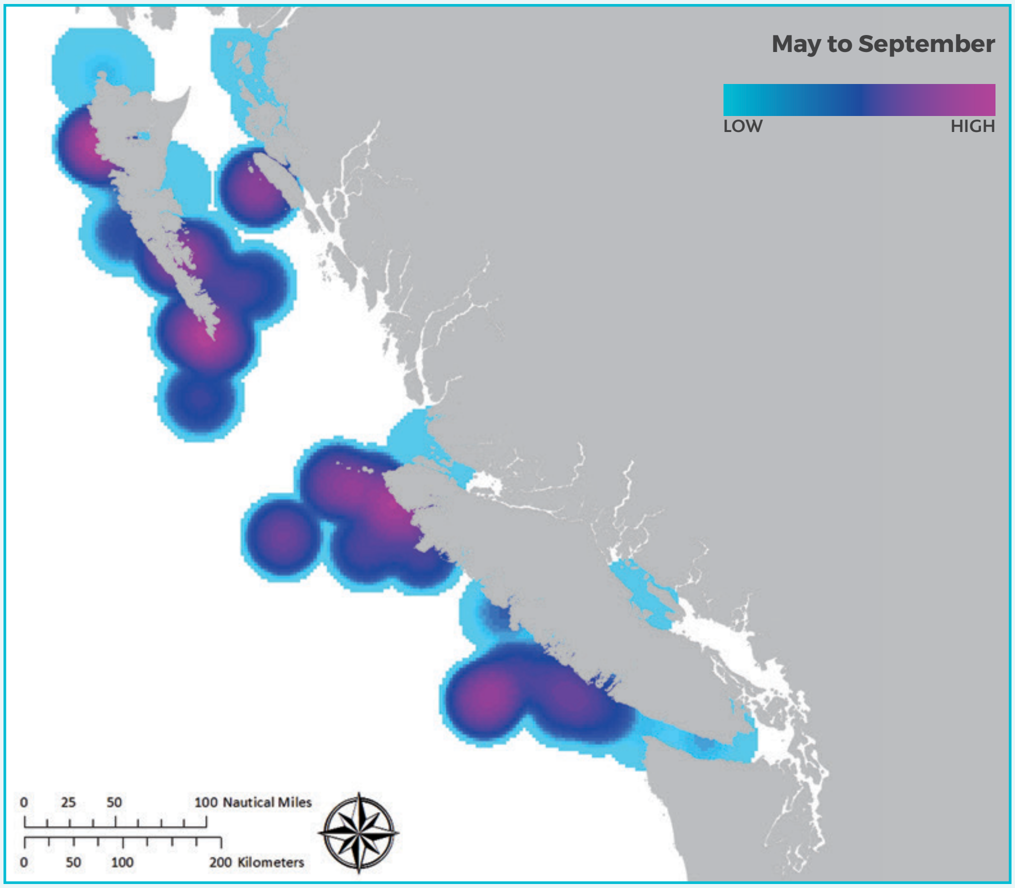
The endangered status of leatherback sea turtles make vessel strikes a particular concern, as mortality of even a few individuals can have a significant impact on their population status.

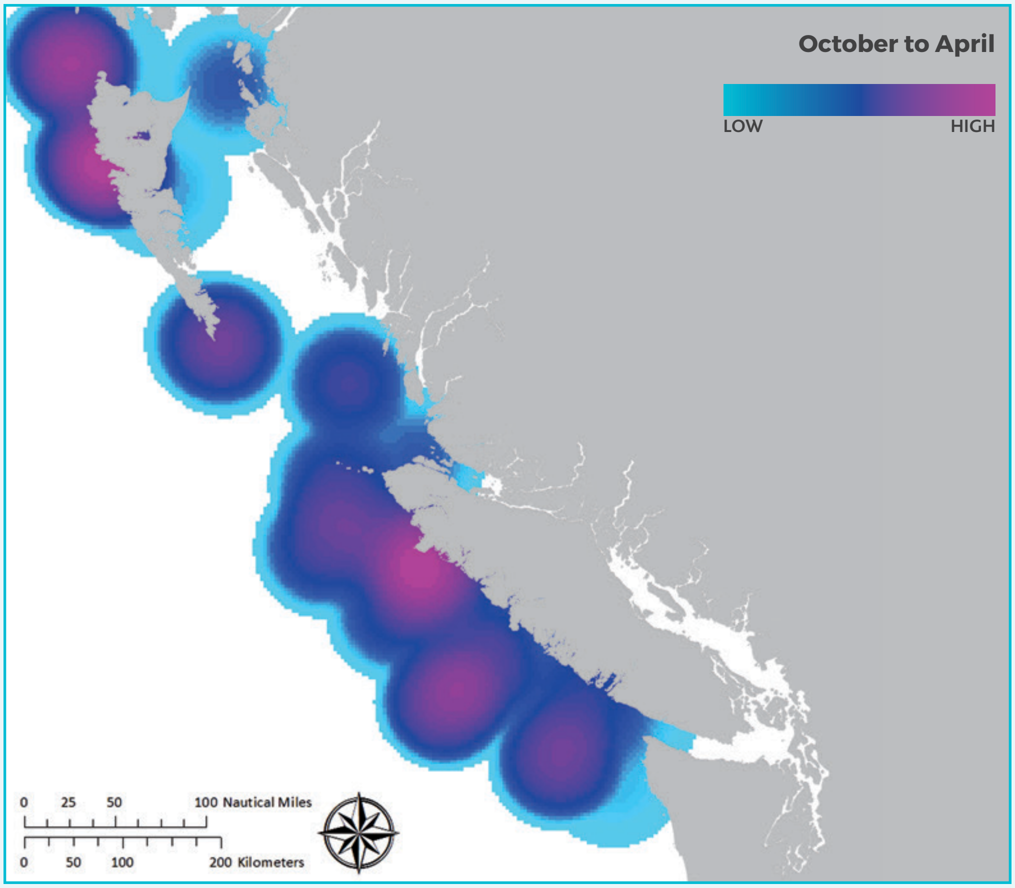
Leatherback sea turtles are a slow moving species, and spend a significant amount of time at or just below the surface when feeding and travelling, making them particularly vulnerable to vessel strikes[7].

Further threats to leatherback sea turtles include accidental capture, entanglement, ingestion of debris, diseases and parasites, predation, oil exploration and extraction, contamination, and aquaculture.

NOTE: While not a cetacean, leatherback sea turtles are included in this guide as they are a species found off the coast of B.C. that is vulnerable to vessel impacts. Any sightings of leatherback sea turtles (alive or dead) are very valuable to scientists, and should be reported immediately (see page 16).

Relative Abundance of Leatherback Sea Turtles in B.C. Waters






Scott Eckert

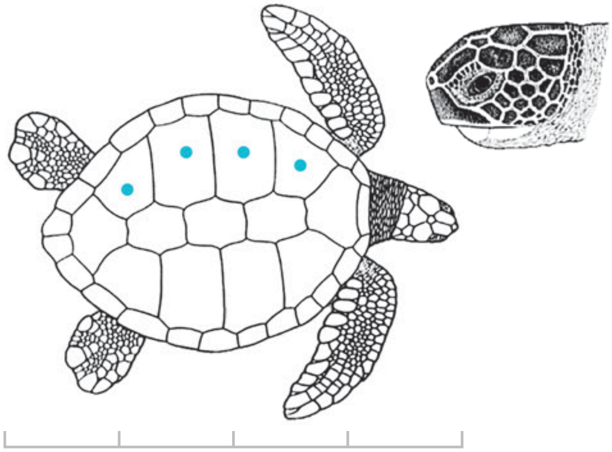

Steve Skorupinski


Scott Eckert

RARE SEA TURTLE SPECIES

GREEN SEA TURTLE

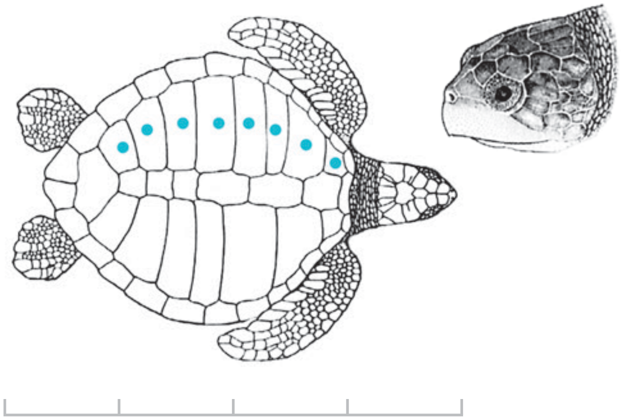
Chelonia mydas



Average Adult Length: 1.5 m / 5 ft

OLIVE RIDLEY SEA TURTLE

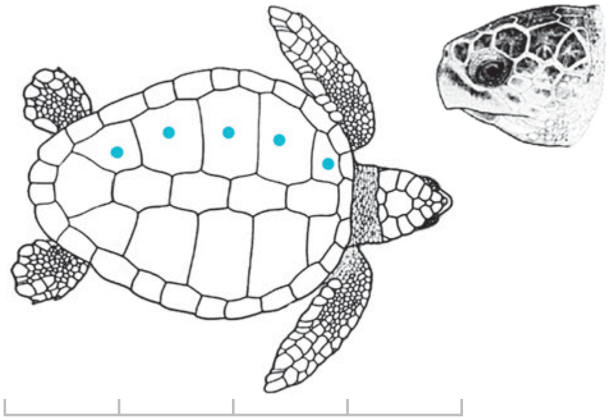
Lepidochelys olivacea



Average Adult Length: 1 m / 3 ft

LOGGERHEAD SEA TURTLE

Caretta caretta



Average Adult Length: 1.2 m / 4 ft

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IR4-11 Underwater Noise – Vessel Source Levels: Triple-E Class Ships

Information Source(s)

Marine Shipping Addendum: Section 7.6

EIS Volume 2: Section 9.8; Appendix 9.8-B

Context

In Section 7.6 of the Marine Shipping Addendum, the Proponent indicated that measured source levels of the Triple-E-class container ship (400m) were not available and were estimated using measurements of smaller container ships (up to 367 metres) with a 1.67 decibel (dB) adjustment to account for the larger size. Appendix 9.8-B of the EIS indicated that the 1.67 dB adjustment was applied to category 1 source levels for future scenarios that included vessel traffic from the proposed Project as a conservative assumption to account for anticipated increase in the size of container ships calling on the proposed Project. Given that Maersk Triple-E class ships are considered in the basis of the Project's design, information is required to verify whether the adjustment used in the model is reflective of actual Triple-E class source levels.

Information Request

Provide information on the measured source level of Triple-E class ships.

Apply this information to verify the assumption that adding 1.67 dB to the source level measurements of smaller container ships (up to 367 metres) will accurately predict source levels for a Triple-E class ship.

VFPA Response

Provide information on the measured source level of Triple-E class ships.

Section 7.6 of the Marine Shipping Addendum indicated that measured source levels of the Triple-E-class container ship (400 m) were not available and were estimated using measurements of smaller container ships (up to 367 m) with a 1.67 decibel (dB) adjustment to account for the larger size. As of June 2017, source levels for Triple-E class container ships are not available.

Apply this information to verify the assumption that adding 1.67 dB to the source level measurements of smaller container ships (up to 367 metres) will accurately predict source levels for a Triple-E class ship.

Given source levels for Triple-E container ships are not available, it is not technically possible to apply this information to verify the +1.67 dB assumption. However, there are several points that confirm the use of the +1.67 dB correction as a valid and conservative assumption, as discussed below.

Firstly, as recently stated by DFO in its response to DFO IR-02 (CEAR Document #959[1]), "for modeling purposes it [the 1.67 dB source level correction assumption] is probably the best information available at the present time."

Secondly, the +1.67 dB adjustment for container ship source levels based on the Ross Power law (Ross 1976) represents the most conservative approach to predicting underwater noise levels from marine shipping associated with the Project. In comparison, ship source level measurements presented in McKenna et al. (2013) would predict a smaller, less conservative adjustment of +0.5 dB for a Triple-E class container ship.

Thirdly, as recently pointed out by DFO (DFO IR-02 in CEAR Document #959), "the general trend is that designers and builders of newer ships now are actively working on making their ships quieter". Therefore, it is possible that future Triple-E class containers ships may be designed to reduce underwater noise levels. Consequently, the potential effects of underwater sound to marine species, as presented in the EIS, could be less in the future.

Lastly, as indicated in IR4-13, two conservative assumptions were applied to underwater noise modelling, which overestimate the amount of underwater sound produced during Project operation. Underwater noise modelling, as presented in the EIS, assumed that all 260 vessel calls to RBT2 will be made by Triple-E container ships (18,000 twenty-foot equivalent units (TEUs)). Current fleet forecasts (see IR4-01) show this to be a conservative assumption because vessels of 15,000 TEUs may not call on RBT2 until after 2030 (and therefore 15,000 TEU vessels are more likely representative of vessels calling on RBT2 during Project operation). Secondly, given larger vessels can carry more TEU containers, fewer than 260 vessel calls at RBT2 would actually occur if all calls to RBT2 were made by Triple-E container ships. Therefore, predictions of underwater sound presented in the EIS from marine shipping associated with the Project are conservative and precautionary.

References

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[1] CEAR Document #959 From Fisheries and Oceans Canada to the Review Panel re: Response to Information Requests issued by the Review Panel on April 5, 2017 (See Reference Document 951).

IR4-12 Underwater Noise – Methodology Verification

Information Source(s)

EIS Volume 2: Appendix 9.8-A

Context

In Appendix 9.8-A of the EIS, the Proponent modelled the underwater noise for two scenarios:

- Berthing of an E-class container ship (Emma Maersk design vessel) with three tugs and a line boat at 4 knots (kts); and
- E-class container ship approaching terminal at 6 kts with four tugs approaching container ship at 12 kts.

As stated by the Proponent, the berthing scenario involved using source levels of the *Vienna Express*, which has a length of 335 m. For the container ship approach scenario, the Proponent used the *CMA CGM Attila and Zim Los Angeles*, both which have a length overall of 336 m. However, modelled source levels for the container ship approach scenario were adjusted to account for a larger vessel (398 m). This was done because source levels for a 398 m vessel were not available. It is unclear whether the Proponent also adjusted the modelled source level for the container ship berthing scenario to match a vessel length of 398 m. Clarification is required to determine whether the appropriate source level was applied in the container ship berthing modelling scenario.

Information Request

Clarify whether the modelled source level for the container ship berthing scenario is based on a 398 m container ship.

If the modelled source level for a 398 m container ship was not used, provide a rationale for why it was not used.

VFPA Response

The modelled source level for the container ship berthing scenario represents a 398 m container ship. A Triple-E vessel was modelled during berthing (a correction factor was applied in the EIS to estimate Triple-E vessel source levels during berthing). See section below for modifications made to Section 3.4.1.6 of EIS Appendix 9.8-A to better describe how vessel source levels were modelling during berthing.

This approach is considered appropriate for the following reasons:

- Noise from berthing originates primarily from the tugs (as was observed during berthing measurements taken at Roberts Bank); this is because tugs and the line boat produce high levels of cavitation noise as they position the container ship into its berth at the terminal; berthing scenario source levels are from measurements of two ship-assist tugs berthing a 335 m container ship at Roberts Bank (i.e., three vessels in total), corrected to account for two additional support tugs that would be required for berthing a 398 m vessel;

- It would be inappropriate to adjust the container ship source level for a berthing operation according to the Ross Power Law (as was done for a 398 m vessel underway; see IR4-11) because the tugs and line boat are the predominant contributors of underwater noise during berthing, not the container ship; and
- A correction based on the number of vessels leads to a higher source level than a correction based on the length of the container ship, and is therefore a more conservative assumption. Measured source levels of the 335 m *Vienna Express* currently calling at Deltaport were used to simulate the source level of a non-transiting (e.g., a vessel that is berthing and hence producing much less underwater noise than one that is transiting) 398 m container ship whose movements are controlled by three tugs and a line boat, and the measured source levels of the tugs and line boats positioning the container ship were adjusted to predict the overall underwater noise produced during the berthing scenario (EIS Appendix 9.8-A). The approach taken to estimate the contribution of underwater noise from tugs during container ship berthing was also determined to be appropriate and valid by DFO (see DFO IR-03 Response in CEAR Document #959[1]).

Changes to Section 3.4.1.6 of EIS Appendix 9.8-A

Relevant text from Section 3.4.1.6 of EIS Appendix 9.8-A has been extracted and modified (below) to better describe how vessel source levels were modelled during berthing (underlined text is new information provided here) and to support the response to this information request:

"Container ship berthing consists of an E-class container ship, plus three berthing tugs and a line boat which assist in manoeuvring the container ship into the terminal. Specifics of the berthing operation are described in more detail in the CCIP ship navigation report (AECOM Canada Ltd. 2012). Source levels for berthing of an E-class container ship by three berthing tugs were derived from measurements of the *Vienna Express* (length 335 m) berthing with the two tugs *Seaspan Resolution* and *Seaspan Raven* (Warner et al. 2013). Source levels used in the modelling were based on measured sound levels from the highest two minutes of recording. Sound levels during the berthing operation were assumed to originate primarily from the tugs, not the container ship, since tugs produced high levels of cavitation noise as they pushed the container ship into its berth. This assumption was only employed in order to calculate an adjustment to the measured source levels for berthing of an E-class container ship. It should be emphasised that, despite this assumption, noise from the container ship itself was still included in the modelled source level of the berthing operation. Modelled source levels for an individual berthing tug were determined by splitting the measured sound power from the berthing operation equally between the two tugs (i.e., reducing the aggregate source

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[1] CEAR Document #959 From Fisheries and Oceans Canada to the Review Panel re: Response to Information Requests issued by the Review Panel on April 5, 2017 (See Reference Document 951).

levels by 3 dB, equivalent to halving the sound power) and extrapolating to lower frequencies (10 to 40 Hz) using the source level of the 50 Hz band (169.4 dB re 1 µPa at 1 m). This source level (<u>including the contribution of both tugs and container ship</u>) was applied to each of the three tugs in the berthing operation; the spectrum is shown in Figure A-12. <u>This was equivalent to multiplying the measured sound power of the berthing operation by a factor of 1.5, and adding the contribution of a line boat.</u>"

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IR4-13 Underwater Noise – Vessel Source Levels: Adjustments

Information Source(s)

Proponent Response to IR1-03 (CEAR Doc#897)

TDR Underwater Noise - Ship Sound Signature Analysis Study (CEAR Doc#936)

EIS Volume 2: Appendix 9.8-B

Context

In Section 3 of Appendix IR1-03-A, the Proponent indicated that the future development of 22,000 twenty-foot equivalent unit (TEU) vessels will be by means of increasing length, with 430-433 metres being the likely dimension. The Proponent indicated that it is realistic to anticipate that 22,000 TEU vessels will be deployed on the Asia-Europe trades and may have a role on the Transpacific trades in the future. The Proponent further stated that 450 metres length overall is a realistic upper limit for vessel length in the foreseeable future for vessels of 24,000 TEUs, but this shift would be complex and would involve significant infrastructure and container crane investments. As stated by the Proponent in the Technical Data Report, Underwater Noise - Ship Sound Signature Analysis Study, increased vessel size was found to lead to increased source levels.

The regional monthly cumulative noise exposure study and the focused daily temporal noise exposure study presented in Appendix 9.8-B of the EIS was carried out for 4 scenarios: one existing conditions scenario represented by the year 2012, and three future scenarios represented by the year 2030. Given that in its response to Review Panel information request IR1-03, the Proponent described vessels of size 22,000-24,000 TEUs to be reasonably foreseeable, further information is required to determine what type of adjustment for source level is suitable for vessels of this size, and to predict their likely contribution to underwater noise levels in the regional study area and focused study area as defined in Appendix 9.8-B of the EIS.

Information Request

Discuss the source level adjustment(s) that may be suitable for the following vessel types:

- 22,000 TEUs with a length overall of 430 metres; and
- 24,000 TEUs with a length overall of 450 metres.

Describe how the results of the underwater noise modeling would change if vessels of size 22,000-24,000 TEUs were included in the future scenarios.

VFPA Response

Discuss the source level adjustment(s) that may be suitable for the following vessel types: 22,000 TEUs with a length overall of 430 metres; and 24,000 TEUs with a length overall of 450 metres.

At present, it is not possible to identify what source level adjustments may be suitable for the 22,000 to 24,000 twenty-foot equivalent unit (TEU) capacity vessel types, as 22,000/24,000 TEU vessels are currently under design development. Therefore, no information is available regarding the elements of these vessels that may generate underwater noise (e.g., engine size, propulsion type and number of propellers, cruising speed, hull coefficients, and other pertinent data).

Furthermore, DFO recently stated that "the general trend is that designers and builders of newer ships now are actively working on making their ships quieter" (DFO IR-02 of CEAR Document #959[1]). With this global trend towards quieter vessels, it is therefore possible that inclusion of 22,000 and 24,000 TEU vessels in the underwater noise modelling would reduce the amount of projected underwater sound from vessel operation in the future.

Describe how the results of the underwater noise modeling would change if vessels of size 22,000-24,000 TEUs were included in the future scenarios.

As indicated above, measured source levels for 22,000 and 24,000 TEU vessels are not available and therefore it is not possible to estimate how underwater noise assessment results presented in the EIS would change by including these vessels in the assessment. However, underwater noise modelling in the EIS was based on several conservative assumptions, and consequently the assessment would likely not change by including 22,000 and 24,000 TEU vessels to the model, as described below.

Prediction of underwater noise was related to the size of container ships assumed to call on RBT2. Underwater noise modelling assumed a conservative scenario that all vessels (260 calls), during operation in 2030, would be Triple-E class (18,000 TEU) vessels. As measured source levels of the Triple-E-class container ship (400 m) are not available, they were estimated using measurements of smaller container ships (up to 367 m) calling at Deltaport with a +1.67 decibel (dB) adjustment to account for the larger size (see IR4-11).[2] As indicated in the response to IR4-01, container ships greater that 15,000 TEU are not expected to call on RBT2 by 2030 based on trends in the fleet, and some Triple-E class vessels, as well as some new generation 22,000 and 24,000 TEU vessels, may call on RBT2 during the life of the Project. The forecast of these larger vessel classes calling at RBT2 after 2030 is dependent on global market and trade conditions, and thus, is speculative. Therefore, the approach described in the EIS was conservative and overestimated the amount of underwater

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[1] CEAR Document #959 From Fisheries and Oceans Canada to the Review Panel re: Response to Information Requests issued by the Review Panel on April 5, 2017 (See Reference Document 951).

[2] In comparison, ship source level measurements presented in McKenna et al. (2013) would predict a smaller, less conservative adjustment of +0.5 dB for a Triple-E class container ship.

noise produced by shipping associated with RBT2 operation, by assuming all 260 container ships calling on RBT2 in 2030 would be by Triple-E class vessels. Therefore, inclusion of larger vessels (22,000 or 24,000 TEU) into underwater noise modelling, would likely not change the modelling. It is also possible that inclusion of 22,000 and 24,000 TEU vessels in the underwater noise modelling would reduce the amount of projected underwater sound from vessel operation in the future, as newer ships currently in design are expected to be quieter.

As described in the response to IR4-02, larger vessels such as the 18,000 TEU Triple-E class, or the newly developing 22,000/24,000 TEU classes, can transport more containers on each vessel. Therefore, fewer ships are required to handle the same container consignment for the 2.4 million TEU terminal design capacity. For example, if the vessels calling on RBT2 included 50% over 10,000 TEU, 156 container ships would be projected to arrive (i.e., from 5 voyages per week down to 3).

In summary, the use of 260 vessel calls of the Triple-E class ship during operations and the source level adjustment used are conservative assumptions and likely overestimate levels of underwater noise produced during RBT2 operation, and shipping associated with RBT2, compared to the most likely vessel size distribution that will call on RBT2.

References

McKenna, M. F., S. M. Wiggins, and J. A. Hildebrand. 2013. Relationship Between Container Ship Noise Levels and Ship Design, Operational and Oceanographic Conditions. Scientific Reports 3(1760). 10p.

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IR4-14 Underwater Noise – Vessel Source Levels: Contribution of Small Vessels

Information Source(s)

EIS Volume 2: Section 9.8; Appendix 9.8-B

Marine Shipping Addendum: Section 9.2; Appendix A of Appendix 10-A

Proponent Response to IR1-05 (CEAR Doc#897)

Context

As stated by the Proponent in Section 9.8 and Appendix 9.8-B of the EIS, modelling of underwater noise did not include the contribution from small recreational or commercial vessels, including whale-watching vessels, since they were sparsely represented in the Vessel Traffic Operations and Support System (VTOSS).

Further, the Proponent indicated that since source levels of small boats are relatively low, errors stemming from the omission of their contribution to underwater noise are expected to be geographically limited to specific areas with high concentrations of small vessels. The Proponent indicated that the inclusion of these small vessels would not change the relative difference in the underwater noise levels between scenarios.

However, it is stated in Appendix 9.8-B that certain kinds of underwater noise may be particularly important in relation to the potential effects on mammals, such as commercial whale-watching boats. Information about small vessels is available in Section 9.2 and Table A-1 of Appendix A of Appendix 10-A of the Marine Shipping Addendum.

Further information is required to determine the contribution of small vessels to noise levels for the 4 modelled scenarios.

Information Request

Estimate the contribution of small vessels to noise levels for existing conditions and all 3 future scenarios, for both the regional study area and focused study area. Present the results in a table similar to Table 2-6 and Table 3-3 of Appendix 9.8-B of the EIS.

VFPA Response

Additional information regarding the contribution of small vessels, including recreational and whale-watching vessels, to underwater noise levels for existing conditions and all future scenarios is presented for the regional study area and the focused study area below.[1]

The four model scenarios described in EIS Appendix 9.8-B are as follows:

- S1: Existing commercial vessel traffic;
- S2: Future commercial vessel traffic with no new projects except RBT2, and future incremental vessel traffic associated with RBT2 (includes existing and expected conditions)[2];
- S3: Future commercial vessel traffic due to certain and foreseeable projects without RBT2, or incremental vessel traffic associated with RBT2 (includes existing and expected conditions); and
- S4: Future commercial vessel traffic due to certain and foreseeable projects, with RBT2, and incremental shipping traffic associated with RBT2 (includes existing and expected conditions).

As indicted in the context, some small vessels with Marine Traffic Automatic Identification System (AIS) capability were included in the 2010 Vessel Traffic Operations and Support System (VTOSS) dataset[3] used for the underwater noise model presented in EIS Appendix 9.8-B; however, they were sparsely represented in this available dataset. Further information on the contribution of small recreational and whale-watching vessels in the regional and specific geographic areas in the focused study areas was acquired from a study completed by the VFPA-led Enhancing Cetacean Habitat and Observation (ECHO) Program (see Appendix IR4-05-A of IR4-05). This study included the larger dataset of small vessels (recreational and whale-watching) with AIS capability from 2015 Marine Traffic AIS, and a simulated traffic density of the whale-watching fleet in the Salish Sea based on data from the Whale Museum's Soundwatch program. The objective of this study was to show the relative contribution of each vessel sector to total underwater noise in the regional area (which also includes specific geographic areas within the focused model area). Additional discussion on small vessel traffic can be found in the response to IR4-05.

In summary, the relative difference in the underwater noise levels between scenarios and the incremental contribution of the Project does not change with the inclusion of additional information on small vessels in the regional study area, or specific geographic areas within

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[1] The regional and focused study areas are defined in Figure A-1 of EIS Appendix 9.8-B. Note that the 'focused study area' includes the Gulf Islands, Haro Strait, a large portion of Juan de Fuca Strait, and the Strait of Georgia.

[2] Expected conditions between 2012 and 2030 include no new projects but increases in vessel traffic at Westshore and Deltaport terminals (i.e., Deltaport Terminal Road and Rail Improvement Project).

[3] Federal regulations require vessels (other than fishing vessels) of 500 deadweight tons (DWT) or more not engaged on an international voyage and of 300 DWT or more engaged on an international voyage to carry Marine Traffic Automatic Identification System (AIS) transponders (Canadian Coast Guard 2013). In practice, some smaller recreational craft and fishing vessels also carry AIS transponders for safety reasons.

the focused model area. Conclusions on the potential effects of underwater noise on marine mammals from the Project, and marine shipping associated with the Project, as described in the EIS also remain unchanged. More details are provided in the sections below.

Regional Study Area

The underwater noise model described in Appendix 9.8-B of the EIS was updated with additional information on the contribution of small vessels, including recreational and whale-watching vessels. The model was re-run in 2017 to include the following (this new information is presented in this response):

- A larger dataset of small vessels with AIS capability from 2015 Marine Traffic AIS[4]; and
- A simulated traffic density of the whale-watching fleet in the focused model area based on data from the Whale Museum's Soundwatch program.[5]

Results are presented for the regional study area in **Table IR4-14-1**. Inclusion of this additional information did not substantively change information presented in Table 2-6 of EIS Appendix 9.8-B.

Table IR4-14-1 Monthly Mean Cumulative Commercial Vessel Traffic Noise Levels (Leq) for Existing and Future Scenarios (S1, S2, S3, S4) and Monthly Mean Increase Above Existing Conditions (S1) for Future Scenarios (S2, S3, S4) Modelled with 2010 VTOSS Data and Updated with 2015 AIS Data (Updated Table 2-6 of EIS Appendix 9.8-B)

Scenario	January		January Difference (δ) 2015-2010	July		July Difference (δ) 2015-2010
	2010 VTOSS (EIS)	2015 AIS Update		2010 VTOSS (EIS)	2015 AIS Update	
S1 (dB)	122.14	122.15	0.01	117.54	117.61	0.07
S2 (dB)	122.17	122.18	0.01	117.56	117.63	0.07
S2-S1 (δ)	0.03	0.03	0.00	0.02	0.02	0.00
S3 (dB)	122.20	122.21	0.01	117.59	117.66	0.07
S3-S1 (δ)	0.06	0.06	0.00	0.05	0.05	0.00
S4 (dB)	122.21	122.23	0.02	117.60	117.67	0.07
S4-S1 (δ)	0.08	0.08	0.00	0.06	0.06	0.00

Notes: dB = decibel. δ = difference. Differences may not be exact due to rounding.

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[4] Small vessels without AIS capability were not included in this updated model as no suitable data exists to independently estimate the overall size of the recreational fleet in the Salish Sea.

[5] See Appendix IR4-05-A of IR4-05 for methods used to develop this simulation.

Focused Study Area

As discussed above, due to the small contribution of small vessels to the overall underwater noise budgets in the regional study area for all scenarios (**Table IR4-14-1**), it is expected that existing underwater noise levels in specific geographic areas of vessel traffic in the focused model area will also not change. Table 3.3 of Appendix 9.8-B showing sound levels in specific geographic areas within the focused model area was not updated as values are not expected to change. Further information on the contribution of small recreational and whale-watching vessels in specific geographic areas within the focused model area can be found in Appendix IR4-05-A of IR4-05.

In summary, the relative difference in the underwater noise levels between scenarios and the incremental contribution of the Project does not change with the inclusion of additional information on small vessels in the regional study area, or specific geographic areas within the focused model area.

References

Canadian Coast Guard. 2013. Marine Communications and Traffic Services – Automatic Information System: Carriage Requirements. Available at http://www.ccg-gcc.gc.ca/eng/CCG/MCTS_Major_Projects. Accessed June 2017.

IR4-15 Underwater Noise – Impact Pile Driving

Information Source(s)

EIS Volume 2: Appendix 9.8-A

Context

As stated by the Proponent in Appendix 9.8-A of the EIS, vibratory piling methods are planned for the proposed Project. However, impact piling methods were also modelled because the need for impact piling cannot be ruled out at this stage of Project design. It was reported that impact pile driving was the only activity that had the potential to generate sound levels sufficiently high to injure marine mammals or fish. Additional information is required to determine the criteria and situations that would lead to the use of impact pile driving methods instead of vibratory pile driving methods.

Information Request

Describe the criteria and situation(s) that would lead to the use of impact pile driving methods instead of vibratory pile driving methods.

VFPA Response

As stated in Appendix 9.8-A of the EIS, vibratory pile driving methods will be used as much as technically possible. Impact pile driving methods are anticipated to be required when the axial (vertical) capacity of the piles need to be verified. Axial capacity is determined in the field by measuring impact blows per metre of displacement. No form of axial load verification exists using a vibratory installation method.

None of the 43 piles to be installed in the marine environment are likely to require axial load verification as none of these piles will carry a vertical load. The marine piles for RBT2 will only carry lateral loads, and thus it is expected that these piles can be fully installed using vibratory piling.

However, if during detail design it is determined that piles require capacity verification, vibratory methods will be used to drive the pile for the majority of its length, and the impact method will be used for the final 1 m to 2 m for this verification.

As outlined in EIS Sections 13.7.3, 14.7.1.1, and 15.8.3, underwater noise reduction and dampening methods and technologies will be implemented during Project construction to avoid or reduce potential adverse effects of pile driving and other construction activities on marine fish and marine mammals. Details pertaining to the management and monitoring of underwater noise will be addressed during the development of the Underwater Noise Management Plan (see EIS Section 33.3.7) and Construction Compliance Monitoring Plan (see EIS Section 33.3.1), respectively, prior to the start of construction activities (should the

Project be approved). The VFPA committed to the development of these plans to mitigate and monitor potential Project-related effects on marine species.

IR4-16 Marine Invertebrates – Juvenile Dungeness Crabs

Information Source(s)

EIS Volume 3: Section 12

TDR MI-2 Juvenile Dungeness Crabs: Table 4-1

Context

Fisheries and Oceans Canada is of the view that two of the conclusions discussed in the key findings section of the Juvenile Dungeness Crabs report are not supported by the data and has provided the context, below.

The first conclusion presented in the key findings section that there is substantial variability in densities of settling Dungeness crabs (bullet i) is based on only two years of data, and in the two years of sampling, surveys did not occur over the same time period. In 2012, there were four sampling periods between June and September. In 2013, however, there was only one sampling period (over 5 days) in early July.

Further, the Proponent cited a report from McMillan et al. (1995) that stated that timing of post-larval settlement varies from year to year, but generally occurs in late summer in waters of the Strait of Georgia and Puget Sound. The Proponent's second year of sampling, however, took place in early July and Fisheries and Oceans Canada is of the view that it cannot be used to corroborate the findings of the McMillan et al report. Comparisons made between the two sampling years, as shown in Table 4-1 of Juvenile Dungeness Crabs report, are therefore not appropriate. Fisheries and Oceans Canada concluded that the limitations surrounding the survey methods and the provision of only two years of data does not support the conclusion that there is high inter-annual variability.

The second conclusion in the key findings section is that 1+ crabs are largely absent from vegetated intertidal areas at low tide and prefer tidal channels in the low intertidal to subtidal zones (bullet iv). It does not appear, however, that tidal channels were included as a habitat type within the stratified random design and this conclusion appears to be made based on anecdotal observations. Fisheries and Oceans Canada is of the view that, if tidal channels were included in the survey, survey results and data should be included to substantiate this habitat preference.

The Juvenile Dungeness Crabs report identified the use of a stratified random design using various habitat types as strata including non-vegetated sand and mudflat. In practice, only two samples were taken in non-vegetated sand/mud habitat and only in one of the sampling years. Additionally, no results were provided for the non-vegetated habitat stratum beyond the statement that no crabs were observed on bare sand/mud substrate in either year, yet the discussion compared open sand/mud habitat results to the other vegetated habitat types.

It is unclear why non-vegetated habitats were not sampled as part of the stratified random design, leaving a large area of non-vegetated area northwest of the Deltaport terminal un-sampled, despite the methods suggesting that non-vegetated areas would be surveyed. It is also unclear why the non-vegetated habitats were excluded in the results.

A rationale for excluding non-vegetated habitats in the survey methodology and results is required. Limitations on the statements provided in the results and discussion should be clearly identified, or further information related to juvenile Dungeness crab presence in non-vegetated areas should be provided to support the statements in the key findings.

The Proponent identified density and suitable habitat area as an indicator in their assessment of Dungeness crab, but has not provided information related to juvenile habitat abundance in non-vegetated habitats. This information is required in order to understand potential effects of the Project on juvenile Dungeness crab.

Information Request

Provide a rationale for excluding non-vegetated habitats in the Juvenile Dungeness Crabs survey methodology and results.

Provide additional information and analysis of the presence, abundance, and use of non-vegetated habitat by juvenile Dungeness crabs in the local assessment area to support the statements in the key findings.

Identify limitations of the statements and uncertainty surrounding the conclusions presented in Juvenile Dungeness Crabs report and the EIS related to juvenile Dungeness crab use of non-vegetated habitats in the local assessment area and relating to inter-annual variability in crab density at the report locations.

VFPA Response

Provide a rationale for excluding non-vegetated habitats in the Juvenile Dungeness Crabs survey methodology and results.

There are several reasons why non-vegetated habitats were excluded in the juvenile Dungeness crab survey methodology and results, as described below.

First, a literature review was conducted prior to developing the survey design, which indicated that juvenile crab presence in vegetated habitats is consistently much higher, often orders of magnitude higher, than non-vegetated habitats. These literature findings align with previous studies at Roberts Bank, including those conducted for the Federal Environmental Assessment Review Office (FEARO) review in the early 1980s and for the Deltaport Third Berth environmental assessment in the early 2000s (Waddell 1986; Triton 2004; Hemmera 2009). These previous studies indicated that juvenile crabs prefer vegetated habitat and are typically not found in non-vegetated habitat which offers little refuge from predation, the biggest driver of mortality at this stage.

Second, observations recorded in the literature of low use of non-vegetated habitat by crabs were verified empirically in 2012 by locating two sampling stations in bare sand/mud; no crabs were found at these non-vegetated sites. Furthermore, treks through bare sand/mud habitat while travelling between sampling stations (usually tens to hundreds of metres apart) at low tide yielded no incidental observations of crabs in these areas, as stated in Section 4.1

of the Juvenile Dungeness Crabs Technical Data Report (TDR MI-2 in Appendix AIR10-C of Additional Information Request #10[1]).

Lastly, the objective of the survey was to document habitat preferences of juvenile crabs so that their spatial distribution relative to Project activities and components could be better understood. Accordingly, bare sand/mud stations were not included in the survey design so that appropriate effort could be focussed on habitat areas that crabs prefer, and thus where crabs are more likely to be found.

Provide additional information and analysis of the presence, abundance, and use of non-vegetated habitat by juvenile Dungeness crabs in the local assessment area to support the statements in the key findings.

A summary of additional information from the scientific literature on the presence, abundance, and use of non-vegetated habitat by juvenile Dungeness crabs is presented below in **Table IR4-16-1** to support statements in the key findings. Note that the assessment of juvenile crabs included consideration of life stages of Dungeness crab from larval stage to non-sexually mature sub-adults.

Table IR4-16-1 Literature Review on Use of Non-vegetated Habitats by Juvenile Dungeness Crabs

Source	Description
Waddell 1986	0^+ Dungeness crabs[a] were only observed in areas providing refuge from predation.
Triton 2004	Juvenile Dungeness crabs were more abundant in *Enteromorpha*[2] than in any other habitat; early life stages of Dungeness crab appear to require a combination of two macrophytes (i.e., *Ulva* and eelgrass) to settle.
Hemmera 2009	Juvenile Dungeness crabs were present in half of the sites surveyed (5 out of 10) and were associated with both eelgrass and *Ulva* hummocks. None were found in areas without cover.
Armstrong et al. 1992	>300 juvenile first instar (J1) Dungeness crabs/m^2 were reported in shell habitat but <5 J1 crabs/m^2 were observed on bare mud.
Fernandez et al. 1993	Certain age classes of juvenile Dungeness crab (final larval stage (megalopae) and young-of-the year, 0^+) select habitats where the risk of predation is lowest (i.e., vegetated/shell hash habitats).
Eggleston and Armstrong 1995	Abundance of early juvenile Dungeness crab is dramatically higher in intertidal shell habitats (i.e., 300 post-settlement crab/m^2 and >20 crab/m^2 three to four months after settlement) compared to adjacent open mudflat habitat (>1 crab/m^2).
McMillan et al. 1995	Seasonal densities of juvenile Dungeness crabs were highest in mixed sand and gravel with an overstory of attached or drift macroalgae, intermediate in eelgrass, and lowest on open sand.

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[1] AIR-12.04.15-10 in CEAR Document 388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

Source	Description
Dinnel et al. 1986	Young-of-year Dungeness crabs were highly associated with all types of vegetative material in the intertidal areas of Lummi Bay; very few young crabs were found where protective cover was lacking.

Notes:

a. Juvenile crabs can be broadly divided into three age classes: 0^+, 1^+, and $>1^+$. 0^+ refers to the young-of-year or recently settled age class, in their first year, while 1^+ refers to crab in their second year, etc.

b. *Enteromorpha* has since been reclassified as *Ulva* and will be referred to as *Ulva* from here on.

Identify limitations of the statements and uncertainty surrounding the conclusions presented in Juvenile Dungeness Crabs report and the EIS related to juvenile Dungeness crab use of non-vegetated habitats in the local assessment area and relating to inter-annual variability in crab density at the report locations.

Overall, no limitations on statements and/or potential uncertainty surrounding the conclusions of TDR MI-2 were identified. Conclusions on juvenile crab habitat use in the local assessment area (LAA) were based on multiple lines of evidence, including empirical data contained in TDR MI-2 (as referenced in the context), the habitat suitability model (see EIS Appendix 12-A), and ecological literature related to Dungeness crabs; previous environmental assessments in the RBT2 area; incidental observations during the field work of no crab presence in bare sand/mud areas adjacent to survey locations; and evidence from two unvegetated sampling stations (conducted in 2012) indicating that juvenile crabs exhibit a strong preference for vegetated areas.

Similarly, conclusions relating to inter-annual variability are not based solely on two years of data (as the information request suggests); rather, EIS conclusions consider the previous studies in the area (FEARO assessment; Deltaport Third Berth environmental assessment; and T2 Baseline Studies which, together, span over 30 years) and ecological literature relevant to Dungeness crab settlement in Pacific Northwest estuaries (e.g., Armstrong et al. 1989; McConnaughey et al. 1992; Dumbauld et al. 1993; McMillan et al. 1995; Visser et al. 2004) supplemented by two years of additional baseline data (2012/2013), which collectively indicate large inter-annual variability in crab densities across their geographic range.

Potential Limitations and Uncertainty Surrounding Conclusions Related to Juvenile Dungeness Crab Use of Non-vegetated Habitats

Sampling non-vegetated areas, despite literature and empirical based evidence that juvenile crabs are largely absent from such areas, would likely have resulted in many 'zero counts' which may have biased overall conclusions on juvenile crab densities and habitat use on Roberts Bank. Such potential biases include predicting an under-representation of juvenile crab densities in the LAA (e.g., fewer crabs using the LAA). Hence, the approach taken to focus on vegetated habitats is more conservative given EIS conclusions are based on the presence of more crabs, which increases the potential for interacting with the Project.

Further, multiple lines of evidence were used to draw EIS conclusions, including empirical data contained in TDR MI-2 (as referenced in the context), the habitat suitability model (see EIS Appendix 12-A), previous studies in the area (from 1980s to present), and extensive ecological literature specific to crab settlement in Pacific Northwest estuaries. Supporting information aligns with empirical data collected during 2012/2013 surveys with regard to non-vegetated habitat and, together, all lines of evidence suggest Roberts Bank provides settlement and rearing habitat for Dungeness crabs, and that some areas (i.e., vegetated with *Ulva* or eelgrass) are more important for juvenile crabs than others (i.e., bare sand/mud).

Limitations Relating to Inter-annual Variability in Crab Density

The context section of this information request states "The first conclusion presented in the key findings section that there is substantial variability in densities of settling Dungeness crabs (bullet i) is based on only two years of data, and in the two years of sampling, surveys did not occur over the same time period. In 2012, there were four sampling periods between June and September. In 2013, however, there was only one sampling period (over 5 days) in early July."

To clarify, the first conclusion is not based solely on two years of data (as the information request suggests). This conclusion draws on multiple lines of evidence, such that previous studies in the area (e.g., FEARO studies, Deltaport Third Berth environmental assessment, T2 baseline report, collectively spanning over 30 years) were supplemented by the 2012/2013 surveys in addition to extensive ecological literature specific to crab settlement in Pacific Northwest estuaries.

While sampling in 2012 and 2013 did not occur on the exact same calendar days, all sampling was conducted within the crab settlement window (identified as ~May/June to September by Gunderson et al. (1990); McMillan et al. (1995); Dunham et al. (2011)). Timing of 2013 surveys was adapted to July (from August as planned; still within known settlement window timing) because *Ulva*, a large influencing factor in juvenile crab recruitment, was observed by field scientists to have prematurely (earlier than expected) drifted into the study area at this time, and because *Ulva*'s presence in the area is ephemeral. Had studies been undertaken in August 2013, they would not have included the presence of *Ulva*, which notably decreased in spatial extent in the LAA by that August (see Section 3.2 of TDR MI-2 and Section 5.0 of TDR MVB-1 (in Appendix AIR10-C of AIR-12.04.15-10)). Therefore, a study undertaken in August 2012 rather than July, would not have adequately captured the influence of this important yet fleeting habitat type on juvenile crabs.

Further, the context section of this information request states "the Proponent cited a report from McMillan et al. (1995) that stated that timing of post-larval settlement varies from year to year, but generally occurs in late summer in waters of the Strait of Georgia and Puget Sound. The Proponent's second year of sampling, however, took place in early July and Fisheries and Oceans Canada is of the view that it cannot be used to corroborate the findings of the McMillan et al report. Comparisons made between the two sampling years, as shown in Table 4-1 of Juvenile Dungeness Crabs report, are therefore not appropriate. Fisheries and Oceans Canada concluded that the limitations surrounding the survey methods and the provision of only two years of data does not support the conclusion that there is high inter-annual variability."

To clarify, the McMillan et al. (1995) paper states that "Settlement occurs progressively later at higher latitudes, except in the Strait of Georgia where, in most years, settlement extends from late June through September [*underline added for emphasis*]. In some years, multiple pulses of settlement are reported for inland waters, corresponding to cohorts of early settling coastal stocks and later settling inland stocks." Based on the McMillan et al. (1995) paper, the 2013 sampling event occurred within the stated settlement window and between-year comparisons are therefore considered valid. The peak presence of *Ulva* (in large proportions of the LAA) in July of 2013, and not August 2013, is evidence of its high inter-annual variability (Loveland et al. 1984, Lotze et al. 2000, Schaadt 2005). Such differences in timing of *Ulva* presence have been noted previously in the literature (Schaadt 2005) and including at Roberts Bank (Hemmera et al. 2009). Hemmera et al. (2009) suggested that the difference between the 2003 survey (Triton 2004), which occurred in late August, and their surveys, which were conducted in early and late July, were due to differences in timing, as *Ulva* is very ephemeral spatially and temporally, making it difficult to predict cover and biomass from one week to the next (Schaadt 2005).

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IR4-17 Marine Invertebrates Marine Fish and Fish Habitat – Effects Assessment: Area and Type of Fish and Invertebrate Habitat

Information Source(s)

EIS Volume 3: Section 11; Section 12; Section 13; Section 17

Context

In sections 11 to 13 of the EIS, the Proponent provided descriptions of changes in habitat availability for marine invertebrates and marine fish sub-components, as well as the extent of direct loss of marine vegetation sub-components. The Proponent also conducted field surveys documenting habitat and fish use in support of this assessment.

However, a comprehensive accounting of the temporary and permanent physical changes to fish habitat that could occur as a result of the Project was not provided. This information is needed to understand the temporary and permanent effects to fish (including marine invertebrates) and their habitats predicted to occur as a result of the proposed Project.

Information Request

Provide a summary that presents the extent of the area (m^2 or ha) and type (intertidal sand, subtidal rock, eelgrass, subtidal sand with sea pens, etc.) of fish and invertebrate habitat that is likely to be affected, directly or indirectly, by each component of the proposed Project including, but not limited to, the terminal, causeway, tug basin and intermediate transfer pit.

This summary should include:

- the fish and invertebrate species that are likely to be affected by each Project component;
- the life stages of the individuals of those species;
- the geographical extent, frequency, magnitude, and duration of the potential effects on fish and fish habitat, including invertebrates, for each Project component; and
- the likelihood that the potential effects on fish and fish habitat, including invertebrates, will occur.

VFPA Response

The Panel has requested a summary that presents the extent of the area and type of fish and invertebrate habitat that is likely to be affected by each component of the proposed Project. The VFPA has provided this information in its response below (areal extent information is provided in **Appendix IR4-17-B**); however, the effects of the Project were assessed based on an ecosystem level and productivity approach in accordance with requirements of the federal *Fisheries Act*.

The requested summary is provided in **Appendix IR4-17-A** and **Appendix IR4-17-B**. The rationale for and the approach taken in these appendices is explained below.

In 2012, the VFPA convened the Productive Capacity Technical Advisory Group (TAG). A key recommendation of the Productive Capacity TAG was to take an ecosystem-level approach (and model) and use productivity as the primary metric to analyse changes in productive capacity as a result of the Project. Based on this recommendation, the VFPA developed and used the Roberts Bank ecosystem model (RB model). The results of the assessment of potential effects of the Project are presented as changes to productivity for valued components and sub-components based on weight of evidence[1]. This ecosystem and productivity approach is aligned with federal policy goals and objectives (see Preamble to Part 1 (Ecosystem Modelling IR3-01 to IR3-24) of CEAR Document #984[2] for further discussion). For example, The Fisheries Protection Policy Statement (DFO 2013a) states the following in Section 1.0:

> "*The Fisheries Protection Policy Statement, 2013 supports changes made to the Fisheries Act in 2012. These changes focus our efforts on <u>protecting the productivity</u> of commercial, recreational and Aboriginal fisheries".* [Emphasis added.]

Further guidance on productivity is provided in more detail in Section 8.4 (a) of the Fisheries Protection Policy Statement.

In addition, the Fisheries Productivity Investment Policy (DFO 2013b), which provides guidance on undertaking effective measures to offset serious harm to fish, states the following in Section 2.1:

> "The *objective of offsetting is to counterbalance unavoidable serious harm to fish and the loss of fisheries <u>productivity</u> resulting from a project".* [Emphasis added.]

Hence, Productive Capacity TAG recommendations, the RB model, and RBT2 environmental assessment of marine biophysical valued components (and identification of mitigation measures using the RB model) are aligned with federal legislation and related policy targets, and their focus on an ecosystem and productivity approach.

Appendix IR4-17-A (tables extracted from the EIS) presents compiled productivity summaries (prior to mitigation) based on weight of evidence for marine vegetation, marine invertebrates, and marine fish. These three valued components considered together and the summaries provided express the Project's effects to 'fish and fish habitat' as defined by the *Fisheries Act.* For example, eelgrass is a marine vegetation species that was assessed as a

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[1] Direct and indirect effects of the Project to fish and invertebrate species were analysed by the RB model as one line of evidence; other sources of information, including field study results, other models, precedents from prior projects, and literature sources were also used to draw conclusions.

[2] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document #928).

sub-component but it is also considered fish habitat; by having assessed potential effects of the Project to eelgrass, the potential effects to fish habitat are therefore also assessed.

Appendix IR4-17-B presents summaries of marine fish and marine invertebrate sub-components[3] that may be affected, directly or indirectly, by each component of the proposed Project (including terminal, causeway, and tug basin, in construction). As specifically requested by the Panel, the areal extent of fish and invertebrate habitat types (in hectares) that will be directly affected by the terminal, causeway, and tug basin is also provided. The mechanisms affecting productivity applicable to the sub-component are described and the life stage potentially affected is indicated. Additional information on indirect effects on modelled functional groups is also provided in IR3-02 of CEAR Document #984.

The methodology applied to assess the effects of the Project as described in EIS Section 8.1.7, applies effect criteria ratings—including geographical extent, frequency, magnitude, and duration—to residual effects only (i.e., after the application of technically and economically feasible mitigation measures) and is based on standard environmental assessment methods (see for example CEA Agency (2015)). However, to address this information request, these effect criteria have been applied to all effects (prior to or following mitigation; i.e., relevant mitigation measures and productivity gains from on-site offsetting have been included in the table where appropriate). Definitions for effect criteria ratings reflect those valued component-specific definitions presented in EIS Table 12-13 (for marine invertebrates) and EIS Table 13-14 (for marine fish). Finally, notes concerning the likelihood of potential effects are provided.

Should the Project be approved, the VFPA will work with DFO to obtain a *Fisheries Act* Authorization. As such, additional technical details on Project effects to the ongoing productivity of commercial, recreational, and Aboriginal fisheries, following mitigation and offsetting, will be developed in detail at that time[4].

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[3] Sub-components and/or representative species were selected to represent all species, as it would be impractical to provide characterisations for and assess effects on every fish or invertebrate species. The information provided for representative species, therefore, is representative of the conditions of (and effects on) the other species that are represented; all fish or invertebrate species are represented by marine biophysical valued components, sub-components, or representative species and are identified in Tables IR9-1 and IR9-2 of IR-7.31.15.09 (CEAR Document #314).

[4] For further information concerning the application of the *Fisheries Act* and *Fisheries Act* Authorizations, see Fisheries Protection Policy Statement (October 2013), available at http://www.dfo-mpo.gc.ca/pnw-ppe/pol/PolicyStatement-EnoncePolitique-eng.pdf.

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Appendices

Appendix IR4-17-A	Productivity Summary (Prior To Mitigation) Based on Weight of Evidence: Marine Vegetation, Marine Fish, Marine Invertebrates
Appendix IR4-17-B	Project Components and Mechanisms Affecting Productivity

APPENDIX IR4-17-A

PRODUCTIVITY SUMMARY (PRIOR TO MITIGATION) BASED ON WEIGHT OF EVIDENCE: MARINE VEGETATION, MARINE FISH, MARINE INVERTEBRATES

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APPENDIX IR4-17-A: Productivity Summary (Prior to Mitigation) Based on Weight of Evidence: Marine Vegetation, Marine Fish, Marine Invertebrates

Tables IR4-17-A1, **IR4-17-A2**, and **IR4-17-A3** below are compiled and reproduced from the EIS (see EIS Sections 11.6, 12.6, and 13.6, respectively). Together, the tables summarise the productivity changes to sub-components from all Project activities.

The ‘comments’ column summarises how quantitative and qualitative information on productivity change is integrated, and provides rationale for each entry in the ‘conclusion’ column.

For example, there are two different lines of evidence available for determining the change in native eelgrass productivity from all Project components. Changes in productivity to native eelgrass were empirically estimated to both gain between 4 to 8 tonnes (due to wave shadow) and decrease by 14.9 tonnes (due to direct mortality related to footprint of 2.9 tonnes and a conservatively estimated indirect mortality due to predicted sedimentation of 12 tonnes; see EIS Section 11.6.3.1 for further discussion on empirical estimates of gains and losses to native eelgrass). Therefore, taken together, empirical estimates of change in productivity are between -6.9 tonnes to -11.9 tonnes loss (i.e., 4 to 8 tonnes + -14.9 tonnes). When this empirical estimate is coupled with the RB model estimate of a 11 tonne gain, overall changes are slight and unlikely to be measurable against natural variation and, therefore, no long-term adverse effects are anticipated for this sub-component. The resulting conclusion is a ‘negligible’ productivity change.

Table IR4-17-A1 Marine Vegetation Productivity Summary (Prior to Mitigation) Based on Weight of Evidence

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project**	Comments
	Gain	Loss	Gain	Loss		
Eelgrass						
Native	4 to 8†	14.9	11	-	Negligible	• Temporal loss due to direct mortality is negligible (2.9 t, 0.7% of total existing biomass). • Empirically estimated loss includes direct loss (2.9 t, 0.7% of total existing biomass) and assumes entire area of increased sedimentation (12 t) will be lost (worst-case scenario and not likely). • Changes in sedimentation will offset some gains from the wave shadow.
Non-native	◇	0.3*	-	0.05	Negligible	• Temporal loss due to direct mortality is only 1.7% of total existing biomass and considered negligible. • Changes in total suspended sediment (TSS) and salinity negligible. • Empirical gain due to longer-term sediment deposition anticipated from Project in localised areas.
Intertidal Marsh						
Intertidal Marsh	◇	1.1*	335	-	Minor Increase	• Temporal loss due to direct mortality is negligible (1.1 t, less than 0.1% of total existing biomass). • Empirically estimated losses will be offset by longer-term sediment deposition anticipated from Project in localised areas. • Based on scientific literature, changes in salinity may increase intertidal marsh productivity.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project**	Comments
	Gain	Loss	Gain	Loss		
Macroalgae						
Ulva	-	258.8*	-	583	Negligible	• Temporal loss due to direct mortality is negligible (258.8 t, 1.5% of total existing biomass). • Ecosystem modelling predicted food web-related adverse effects, which are considered to be overestimated based on macrofauna increases. • Opportunistic, and reproduces asexually and sexually; therefore, it will recolonise quickly. • Ephemeral nature and large abiotic (e.g., TSS and salinity) tolerance will result in negligible change in productivity.
Rockweed	-	82.6*	-	-	Minor Decrease	• Temporal loss of rockweed due to direct mortality is a minor decrease in productivity (82.6 t, 27.5% of total existing biomass). • Ecosystem modelling predicted food web-related adverse effects, which are considered to be overestimated (i.e., macrofauna). • Proposed terminal will create more substrate for rockweed attachment.
Kelp	-	1.9*		53	Negligible	• Temporal loss due to kelp direct mortality is negligible (1.9 t, 0.5% of total existing biomass).
Biomat						
Biomat	-	-	-	356	Negligible	• Studies indicate biomat is increasing naturally (not related to Project). • The ecosystem model and environmental preferences do not fully capture how biomat establishes and propagates. • Based on scientific literature, predicted salinity changes due to the Project will have a negligible effect on biomat. • Increase in waterfowl was modelled to have a large negative effect on biomat but is not supported by scientific literature.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project**	Comments
	Gain	Loss	Gain	Loss		
Biofilm						
Marine Biofilm	◇	◇	-	420	Negligible	• Empirical studies indicate a loss of marine-influenced biofilm productivity due to changes in salinity. • Changes in productivity due to changes in wave height are predicted to be negligible. • Shorebird foraging opportunity model indicates short-term (during large than average freshet) minor decreases in biofilm associated with salinity decreases and an overall short-term minor increase during an average freshet (see EIS Appendices 15-B and 15-C). • Increases in predators are contributing to estimated loss; however, empirical studies have shown that there is a large surplus of biofilm at Roberts Bank.
Freshwater Biofilm			1,470	-		• Empirical studies indicate increase in freshwater-influence biofilm productivity due to changes in salinity. • Changes in productivity due to changes in wave height are predicted to be negligible. • Changes in wave height due to model inputs are overestimating increase by 622 t. • Increase is deemed to be an overestimation. Some of the predicted biomass increase is within the existing marsh at Brunswick Point; thus, the biomass increase in this area is not anticipated and is approximately 10% to 15% (311 t to 467 t; average: 389 t) of the predicted increase.

Notes: Quantitative productivity estimates presented here do not include anticipated productivity gains from mitigation . t = tonnes.

* Productivity loss due to direct mortality

† Estimate based on area affected by wave shadow (i.e., decrease in wave energy) due to the Project

◇ Productivity change predicted: quantitative productivity change estimate not available

** Professional opinion/conclusion on productivity change based on integration and consideration of all available lines of evidence (including empirical evidence, ecosystem model results, and other models or evidence of change). Change ratings (applicable to both increases and decreases): Negligible: 0% to 5% change; Minor: 6% to 30% change. Change ratings take into consideration physical and biological aspects of natural ecosystem variability.

Table IR4-17-A2 Marine Invertebrates Productivity Summary (Prior to Mitigation) Based on Weight of Evidence

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Infaunal and Epifaunal Invertebrate Communities	◇	-	788	-	Minor decrease	Minor increase	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., dredging). • Long-term increases (i.e., during operation phase) in productive potential predicted by ecosystem model likely driven by improved environmental conditions shoreward of the terminal (e.g., wave shadow). • Sensitivity analyses support potential for positive direction of change but suggest predicted increase likely an overestimate (i.e., up to 5%). • Shorebird Foraging Opportunity Model (SFOM, EIS Appendix 15-B) predicts a minor decrease in available biomass, and discrepancy between ecosystem model and SFOM results can be partially attributed to lack of food web impacts considered in SFOM and differences in spatial and temporal scales.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Bivalve Shellfish	-	◇	-	519	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., dredging). • Long-term increases (i.e., during operation phase) in productive potential predicted by ecosystem model primarily due to habitat loss associated with footprint, but also less favourable environmental conditions behind the terminal over the long-term (e.g., fine sediment deposition). • Sensitivity analyses suggest magnitude of decrease is slightly underestimated (i.e., by 2%). • Possess biological attributes (e.g., short generation time, broadcast spawning, pelagic larvae) that facilitate re-colonisation. • Quantitative and qualitative predictions around a minor decrease align.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Dungeness Crabs	-	◇	-	9	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., dredging). • Long-term (i.e., during operation phase) change predicted by ecosystem model (-3%) is negligible, falling within margin of error of the model (±5%). • Long-term decreases in productive potential predicted qualitatively/empirically primarily due to permanent habitat loss associated with footprint. • Changes in marine vegetation upon which crabs (particularly juveniles) depend are deemed negligible. • Sensitivity analyses suggest magnitude of decrease is slightly underestimated (i.e., by 2%). • Local populations are sustained by larvae originating over a large geographical area, which may help to replenish productivity losses.
Orange Sea Pens	-	◇	-	4	Moderate decrease	Moderate decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., dredging). • Long-term decreases (i.e., during operation phase) in productive potential predicted by ecosystem model primarily due to habitat loss associated with footprint. • Sensitivity analyses suggest magnitude of decrease is accurate. • Presence of terminal predicted to cause localised accelerations in current flow at edges, which may enhance food delivery rates and attract sea pens back to area over time. • Modelled and empirical predictions around a moderate decrease align.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Marine Invertebrates Valued Component Total Change	-	◇	+256	-	Minor decrease	Minor decrease	• Overall net increase in productive potential predicted by ecosystem model is entirely driven by high biomass of infaunal and epifaunal invertebrates, which are considered to be overestimates, and therefore skewing results. • Other three sub-components anticipated to experience minor to moderate decreases based on all lines of evidence.

Notes: Quantitative productivity estimates presented here do not include anticipated productivity gains from mitigation.

◇ Productivity change predicted: quantitative productivity change estimate not available.

* Professional opinion/conclusion on productivity change based on integration and consideration of all available lines of evidence (including empirical evidence, ecosystem model results, and other models or evidence of change). Productivity change ratings (applicable to both increases and decreases): Negligible: 0% to 5% change; Minor: 6% to 30% change; Moderate: 31% to 60% change. Change ratings take into consideration physical and biological aspects of natural ecosystem variability.

Table IR4-17-A3 Marine Fish Productivity Summary (Prior to Mitigation) Based on Weight of Evidence

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Pacific Salmon							
Chinook adult	-	◇	-	10	Minor decrease	Negligible	• Short-term decreases in productive potential due to minor acoustic impacts (conservatively assuming impact piling is required) from construction. • Longer-term decreases related to loss of habitat availability from terminal footprint, though this is unlikely to be a key mechanism, given Chinook adult are not likely habitat-limited in the local assessment area (LAA), with minimal feeding during return migration. • Sensitivity analyses suggest ecosystem model predictions are accurate.
Chinook juvenile	-	◇	0.1	-	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment), minor acoustic impacts (conservatively assuming impact piling is required), changes in lighting, and migration disruption. • Long-term minor decreases during operation due to changes in lighting and migration disruption, despite benefits from predicted increases in main food source (i.e., infaunal and epifaunal invertebrates). • Sensitivity analyses suggest increase predicted by ecosystem model is over-estimated (i.e., by 6%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction, acoustic, lighting, and migration mechanisms.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Chum adult	-	◇	-	5	Minor decrease	Negligible	• Short-term decreases in productive potential due to minor acoustic impacts (conservatively assuming impact piling is required) from construction. • Longer-term decreases related to loss of habitat availability from terminal footprint, though this is unlikely to be a key mechanism given adult chum are not likely habitat-limited in the LAA, with minimal feeding during return migration). • Sensitivity analyses suggest ecosystem model predictions are accurate.
Chum juvenile	-	◇	0.07	-	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment), minor acoustic impacts (conservatively assuming impact piling is required), changes in lighting, and migration disruption. • Long-term minor decreases during operation due to changes in lighting and migration disruption, despite benefits from predicted increases in main food source (i.e., infaunal and epifaunal invertebrates). • Sensitivity analyses suggest increase predicted by ecosystem model is over-estimated (i.e., by 4%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction, acoustic, lighting, and migration mechanisms.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Reef Fish							
Lingcod	-	◇	-	1	Minor decrease	Negligible	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment), minor acoustic impacts (conservatively assuming impact piling is required), and loss of habitat availability (i.e., small Project footprint overlap with artificial reefs). • Long-term change expected to be negligible due to neutral biotic interactions and increases in hard substrate due to Project infrastructure. • Sensitivity analyses suggest decrease predicted by ecosystem model over-estimated (i.e., by 2%). • Quantitative and qualitative predictions around a negligible change align.
Rockfish (including copper and quillback rockfish)	-	◇	-	2	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment), minor acoustic impacts (conservatively assuming impact piling is required), and loss of habitat availability (i.e., small Project footprint overlap with artificial reefs; minor decrease in macroalgae productive potential). • Long-term minor decreases due to biotic interactions (reduced prey). • Sensitivity analyses suggest decrease predicted by ecosystem model over-estimated (i.e., by 2%). • Quantitative and qualitative predictions around a minor decrease align.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Forage Fish							
Pacific sand lance	-	◇	1	-	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment) and minor acoustic impacts (conservatively assuming impact piling is required). • Long-term minor decreases due to reduction in availability and quality of both subtidal and intertidal sand, used as burying habitat, due to Project footprint. • Sensitivity analyses suggest increase predicted by ecosystem model over-estimated (i.e., by 3%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction or acoustic mechanisms.
Other forage fish (including surf smelt)	-	◇	-	8	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment) and minor acoustic impacts (conservatively assuming impact piling is required). • Long-term minor decreases due to reduction in availability and quality of both subtidal and intertidal sand, particularly beach spawning habitat in the high intertidal zone. • Sensitivity analyses suggest decrease predicted by ecosystem model slightly under-estimated (i.e., by 1%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction or acoustic mechanisms.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Pacific herring	-	◇	-	6	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment) and minor acoustic impacts (if either vibratory or impact pile driving employed). • Long-term minor decreases due to reduction in availability and quality of both subtidal and intertidal sand habitat. • Sensitivity analyses suggest decrease predicted by ecosystem model under-estimated (i.e., by 1%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction or acoustic mechanisms.
Shiner perch	◇	◇	2	-	Minor decrease	Minor increase	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment) and minor acoustic impacts (conservatively assuming impact piling is required). • Long-term minor increases due to biotic interactions (increased prey) and increased habitat availability from infrastructure placement (i.e., vertical, hard substrate). • Sensitivity analyses suggest increase predicted by ecosystem model over-estimated (i.e., by 5%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction or acoustic mechanisms.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Flatfish							
Other flatfish (including English sole)	-	◇	-	0.3	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment) and minor acoustic impacts (conservatively assuming impact piling is required), and increases in TSS. • Long-term minor decreases due to loss of highly productive subtidal sand habitat. • Sensitivity analyses suggest decrease predicted by ecosystem model over-estimated (i.e., by 1%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction or acoustic mechanisms.
Starry flounder	-	◇	1	-	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment) and minor acoustic impacts (conservatively assuming impact piling is required), and increases in TSS. • Long-term minor decreases due to loss of highly productive subtidal sand habitat. • Sensitivity analyses suggest increase predicted by ecosystem model over-estimated (i.e., by 4%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction or acoustic mechanisms.

Sub-component	Empirically Estimated / Other Evidence of Productivity Change (t)		Ecosystem Model Productivity Change (t)		Conclusion on Productivity Change due to Project*		Comments
	Gain	Loss	Gain	Loss	Construction	Operation	
Demersal Fish							
Small demersal fish (including threespine stickleback and Pacific staghorn sculpin)	-	◇	-	0.2	Minor decrease	Minor decrease	• Short-term decreases in productive potential due to direct mortality from construction activities (i.e., entrainment) and minor acoustic impacts (if impact pile driving employed). • Long-term minor decreases due to reduction in availability and quality of both subtidal and intertidal sand habitat. • Sensitivity analyses suggest decrease predicted by ecosystem model under-estimated (i.e., by 1%). • Discrepancy between ecosystem model and other lines of evidence attributed to inability of model to incorporate construction or acoustic mechanisms.
Marine Fish Valued Component Total Change	-	◇	-	28.3	Minor decrease	Minor decrease	• Ecosystem model predicts no change to minor decrease in marine fish productivity (≤ 5%) with the Project. • On a sub-component level, the ecosystem model predicts no change to minor decreases (≤ 5%) in the productivities of Pacific salmon, reef fish, forage fish, and small demersal fish; and no change to a minor increase (≤ 5%) in the productivity of flatfish. • Based on all lines of evidence, all sub-components are predicted to experience minor decreases in productivity during one or both phases of the Project, resulting in an overall minor decrease in marine fish productivity.

Notes: Quantitative productivity estimates presented here do not include anticipated productivity gains from mitigation.
◇ Productivity change predicted: quantitative productivity change estimate not available
* Professional opinion/conclusion on productivity change based on integration and consideration of all available lines of evidence (including empirical evidence, ecosystem model results, and other models or evidence of change). Change ratings (applicable to both increases and decreases): Negligible: 0% to 5% change; Minor: 6% to 30% change. Change ratings take into consideration physical and biological aspects of natural ecosystem variability.

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APPENDIX IR4-17-B

PROJECT COMPONENTS AND MECHANISMS AFFECTING PRODUCTIVITY

Appendix IR4-17-B: Project Components and Mechanisms Affecting Productivity

The tables presented in this appendix are compiled based on information in the EIS (see EIS Sections 11.0, 12.0, 13.0, 17.0 and 33.0) and have been amended to reflect that the intermediate transfer pit (ITP) is no longer required and silty fallout from vibro-replacement at the dredge basin is no longer anticipated (see the Preamble to Part 2 (General Information Requests IR3-25 to IR3-46) of CEAR Document #984). In addition, as requested by the Panel, the areal extent (in hectares) of fish and invertebrate habitat directly affected by the marine terminal, causeway, and tug basin is also included.

Each table presents requested information for sub-components of marine fish and invertebrates for fish and invertebrate habitat as defined by the *Fisheries Act*; for example, eelgrass is a marine vegetation species but also provides fish habitat, by having assessed potential effects to eelgrass, the potential effects to eelgrass habitat are also assessed) and includes information on mitigation measures and on-site offsetting proposed in the EIS. The mechanisms affecting productivity applicable to the valued component sub-component are described and the life stage potentially affected is indicated; relevant mitigation measures are discussed as are productivity gains from on-site habitat development (where appropriate). Further, an effects criteria rating is provided and are defined the same as those identified for residual effects in EIS Table 12-13 (for marine invertebrates) and EIS Table 13-14 (for marine fish).

For example, marine terminal land construction was identified as having a mechanism affecting productivity of “changes in habitat availability (direct effect)” on bivalves. In the *Z. marina* habitats, larvae, juvenile, and adult bivalves may experience effects locally (effects are limited to Roberts Bank within the local assessment area), frequently (as the activity occurs repeatedly during construction), and for the long-term (as the potential effect is limited to specific construction activities). The overall effect criteria magnitude was determined as 'low' on the basis that eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in eelgrass productivity in the local assessment area, offsetting short-term losses during construction.

Table IR4-17-B1 Project Components and Mechanisms Affecting Productivity: Invertebrates - Infaunal and Epifaunal Communities

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Direct mortality (direct effect)		●	●	●	Local	Frequent	Low	Long-term	Mortality assumed for all areas under terminal and dredge pocket footprints; however, such communities are inherently dynamic and employ life history strategies that enable them to rapidly recover from disturbance.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		●	●	●					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions; limited mortality possible around end of disposal pipeline (-45 m) where maximum plume concentrations predicted, though this does not overlap with areas of highest infaunal/epifauna invertebrate productivity. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for infauna/epifauna to be affected via sediment and water quality pathways
	Change in water quality: changes to salinity (indirect effect)		●	●	●					Effects of salinity on infaunal/epifaunal productivity may be positive or negative depending on the species. Declines in some species can be masked by increases in others, such that overall changes will be difficult to detect and measure. Predicted changes are seasonal, in response to spring freshet.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	●	●					Higher infaunal and epifaunal invertebrate abundance, biomass, and diversity are correlated with smaller grain sizes; thus, deposition of fine sediments north of the terminal, therefore, is anticipated to create Deposition of fine sediments north of the terminal is anticipated to create more favourable environmental conditions than currently exist in the LAA, increasing productivity.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (13.65 ha)	●	●	●					Infauna and epifauna are substrate associated (i.e., not directly associated with orange sea pens) such that loss of sea pen habitat unlikely to drive productivity changes. However, infauna/epifauna share the shallow sandy seabed with sea pens, and loss of such habitat will lead to associated productivity declines (see "sand" below). Infauna/epifauna distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Sparse Sea Pen (62.46 ha)	●	●	●					Infauna and epifauna are substrate associated (i.e., not directly associated with orange sea pens) such that loss of sea pen habitat unlikely to drive productivity changes. However, infauna/epifauna share the shallow sandy seabed with sea pens, and loss of such habitat will lead to associated productivity declines (see "sand" below). Infauna/epifauna distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Kelp (0.029 ha)	n/a	n/a	n/a					Infaunal communities are not associated with kelp or rocky reef habitat; require soft sediment in which to burrow.
		Mud (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with mud habitat; therefore, no effects expected.
		Rock (0.58 ha)	n/a	n/a	n/a					Infaunal communities are not associated with rock habitat; require soft sediment in which to burrow.
		Sand (35.36 ha)	●	●	●					Terminal placement will reduce available subtidal sand habitat. However, productivity is highest in intertidal, distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Ulva (1.21 ha)	●	●	●					*Ulva* is an ephemeral drift algae that deposits on top of sand/mud substrate, both provide habitat for infaunal/epifaunal communities. Epifauna, such as amphipods and isopods, also graze directly on *Ulva* .
		Z. japonica (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with non-native eelgrass habitat; therefore, no effects expected.

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
		Z. marina (2.78 ha)	•	•	•					Infaunal and epifaunal communities in eelgrass beds are structurally different and more diverse than those in nearby bare sediments. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in available eelgrass habitat in the LAA, offsetting short-term losses during construction.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	•	•					Unlikely to be a major driver of productivity change, though decreases in some predator groups predicted.
Widened Causeway	Direct mortality (direct effect)		•	•	•	Site-specific	Frequent	Low	Short-term	Mortality assumed for all areas under causeway footprint; however, such communities are inherently dynamic and employ life history strategies that enable them to rapidly recover from disturbance.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					This component not expected to generate a major TSS plume; where major plumes are expected (e.g., dredging for Marine Terminal Land Development), modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for infauna/epifauna to be affected via sediment and water quality pathways
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	•	•	•					Biofilm is not a habitat for invertebrates, but for the mud that it grows on, it is.
		Intertidal Marsh (12.22 ha)	•	•	•					Soft sediment substrate that supports marsh plants also supports infaunal and epifaunal communities. Intertidal marsh lost to causeway footprint is considered low quality and low function - it is discontinuous, fringing, and typically shows sparse to intermediate vegetation cover with a high proportion of bare space. Predicted increases in marsh productivity post-Project (from wave shadow and salinity) and onsite offsetting will result in a net increase in marsh productivity in the LAA.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					Causeway footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					Causeway footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Kelp (n/a)	n/a	n/a	n/a					Causeway footprint does not overlap with kelp habitat; therefore, no effects expected.
		Mud (0.21 ha)	•	•	•					Causeway footprint will minimally reduce available mud habitat. Meiofaunal abundance are most abundant in top few centimetres of muddy sediments. Distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Rock (4.8 ha)	n/a	n/a	n/a					Infaunal communities are not associated with rock habitat; require soft sediment in which to burrow.
		Sand (0.37 ha)	•	•	•					Causeway footprint will minimally reduce available sand habitat. Coarser grain sizes (i.e., sand) less preferable to fines because they may inflict physical limitations. Distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Ulva (17.07 ha)	•	•	•					*Ulva* is an ephemeral drift algae that deposits on top of sand/mud substrate, both provide habitat for infaunal/epifaunal communities. Epifauna, such as amphipods and isopods, also graze directly on *Ulva*.
		Z. japonica (2.97 ha)	•	•	•					Infaunal and epifaunal communities in eelgrass beds are structurally different and more diverse than those in nearby bare sediments. Predicted increases in non-native eelgrass productivity post-Project (from wave shadow) will result in a net increase in available eelgrass habitat in the LAA.
		Z. marina (0.47 ha)	•	•	•					Infaunal and epifaunal communities in eelgrass beds are structurally different and more diverse than those in nearby bare sediments. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in available eelgrass habitat in the LAA, offsetting short-term losses during construction.

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
Expanded Tug Basin	Direct mortality (direct effect)		●	●	●	Local	Frequent	Low	Short-term	Mortality assumed for areas under dredge footprint; however, such communities are inherently dynamic and employ life history strategies that enable them to rapidly recover from disturbance.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Infauna/epifauna are considered relatively resilient to high TSS levels and predicted Project-related TSS concentrations are well below published concentrations of harm. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for bivalve shellfish to be affected via sediment and water quality pathways
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Kelp (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with kelp habitat; therefore, no effects expected.
		Mud (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with mud habitat; therefore, no effects expected.
		Rock (0.45 ha)	n/a	n/a	n/a					Infaunal communities are not associated with rock habitat; require soft sediment in which to burrow.
		Sand (1.13 ha)	●	●	●					Involves conversion of intertidal to subtidal sandflat, both are infauna/epifauna habitat, though intertidal areas considered more productive.
		Ulva (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with *Ulva* habitat; therefore, no effects expected.
		Z. japonica (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with non-native eelgrass habitat; therefore, no effects expected.
		Z. marina (2.68 ha)	●	●	●					Infaunal and epifaunal communities in eelgrass beds are structurally different and more diverse than those in nearby bare sediments. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in available eelgrass habitat in the LAA, offsetting short-term losses during construction.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

Table IR4-17-B2 Project Components and Mechanisms Affecting Productivity: Invertebrates - Bivalve Shellfish

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Direct mortality (direct effect)		•	•	•	Local	Frequent	Low	Long-term	Mortality assumed for all areas under terminal and dredge pocket footprints; however, such communities are inherently dynamic and employ life history strategies that enable them to rapidly recover from disturbance. Also, the Project will increase the amount of hard substrate available within the LAA, which will benefit epifaunal bivalves including Pacific oysters and bay mussels.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Bivalves are considered relatively resilient to high TSS levels and predicted Project-related TSS concentrations are well below published concentrations of harm. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for bivalve shellfish to be affected via sediment and water quality pathways
	Change in water quality: changes to salinity (indirect effect)		•	•	•					Bivalve species within the LAA are expected to respond differently to salinity, depending on species and stage of maturity. Bay mussels and Macoma clams frequently occupy habitats with low salinity and large riverine influence, so productivity change not expected. Heart cockles and Pacific oyster productivity concentraed in low intertidal zone, with limited spatial overlap with areas of predicted salinity change. Littleneck clam productivity expected to decrease in mid-intertidal, though changes still within range of tolerance. Effect is expected to be seasonal, and most pronounced at peak of spring freshet.
	Changes in sedimentation and coastal processes (indirect effect)		•	•	•					Fine sediment deposition behind terminal will reduce habitat quality for species that prefer sandier substrates, or for larvae that require clean substrate to settle.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (13.65 ha)	•	•	•					Bivalve shellfish are substrate associated (i.e., not directly associated with orange sea pens) such that loss of sea pen habitat unlikely to drive productivity changes. However, infaunal bivalves share the shallow sandy seabed with sea pens, and loss of such habitat will lead to associated productivity declines (see "sand" below). Bivalve distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Sparse Sea Pen (62.46 ha)	•	•	•					Bivalve shellfish are substrate associated (i.e., not directly associated with orange sea pens) such that loss of sea pen habitat unlikely to drive productivity changes. However, infaunal bivalves share the shallow sandy seabed with sea pens, and loss of such habitat will lead to associated productivity declines (see "sand" below). Bivalve distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Kelp (0.029 ha)	n/a	n/a	n/a					Bivalve shellfish do not use kelp as habitat; require soft sediment in which to burrow or hard substrate to attach.
		Mud (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with mud habitat; therefore, no effects expected.
		Rock (0.58 ha)	n/a	n/a	n/a					Infaunal bivalves are not associated with rock, as they require soft sediment in which to burrow.
		Sand (35.36 ha)	•	•	•					Terminal placement will reduce available subtidal sand habitat for infaunal bivalves. However, distribution is extremely patchy in space, and bivalve communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand. Terminal infrastructure will increase hard attachment substrate for Bay mussels and Pacific oysters.
		Ulva (1.21 ha)	n/a	n/a	n/a					Bivalve shellfish are substrate associated (i.e., not directly associated with *Ulva*) such that loss of *Ulva* habitat unlikely to drive productivity changes. However, infaunal bivalves share the shallow sandy seabed with *Ulva* , and loss of such habitat will lead to associated productivity declines (see "sand" above).
		Z. japonica (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with non-native eelgrass habitat; therefore, no effects expected.

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
		Z. marina (2.78 ha)	●	●	●					Cockles in particular are known to be associated with native eelgrass beds. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in eelgrass productivity in the LAA, offsetting short-term losses during construction.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	●	●					Biotic interactions considered neutral to positive. Declines predicted in some predator groups while groups with strong positive effects show a mixture of increases and decreases.
Widened Causeway	Direct mortality (direct effect)		n/a	●	●	Site-specific	Frequent	Low	Short-term	Mortality assumed for all areas under causeway footprint; however, despite initial short-term losses, the Project will increase the amount of hard substrate available within the LAA , which will benefit epifaunal bivalves including Pacific oysters and bay mussels.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					This component not expected to generate a major TSS plume; where major plumes are expected (e.g., dredging for Marine Terminal Land Development), modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for bivalve shellfish to be affected via sediment and water quality pathways
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	●	●	●					Biofilm is not a habitat for invertebrates, but for the mud that it grows on, it is.
		Intertidal Marsh (12.22 ha)	n/a	n/a	n/a					Soft sediment substrate that supports marsh plants also supports bivalve species. Intertidal marsh lost to causeway footprint is considered low quality and low function - it is discontinuous, fringing, and typically shows sparse to intermediate vegetation cover with a high proportion of bare space. Predicted increases in marsh productivity post-Project (from wave shadow and salinity) and onsite offsetting will result in a net increase in marsh productivity in the LAA.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					Causeway footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					Causeway footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Kelp (n/a)	n/a	n/a	n/a					Causeway footprint does not overlap with kelp habitat; therefore, no effects expected.
		Mud (0.21 ha)	●	●	●					Causeway footprint will minimally reduce available mud habitat, used by Pacific littleneck and *Macoma* clams, among other species. Distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Rock (4.8 ha)	n/a	n/a	n/a					Infaunal bivalves are not associated with rock, as they require soft sediment in which to burrow. Causeway widening will result in a minimal - and temporary - reduction in rock habitat for epifaunal bivalves. A net increase in rock habitat is expected from placement of Project infrastructure and, onsite offsetting in the form of rocky reefs will further increase rock habitat in the LAA.
		Sand (0.37 ha)	●	●	●					Minimal spatial overlap with infaunal bivalve habitat; though distribution is extremely patchy in space, and communities in the LAA are unlikely to be habitat-limited; further, there is ample area remaining for these communities to establish and expand.
		Ulva (17.07 ha)	●	●	●					Bivalve shellfish are substrate associated (i.e., not directly associated with *Ulva*) such that loss of *Ulva* habitat unlikely to drive productivity changes. However, infaunal bivalves share the shallow sandy seabed with *Ulva* , and loss of such habitat will lead to associated productivity declines (see "sand" above).
		Z. japonica (2.97 ha)	●	●	●					Bivalve shellfish are substrate associated (i.e., not directly associated with non-native eelgrass) such that loss of eelgrass habitat unlikely to drive productivity changes. However, infaunal bivalves share the shallow sandy seabed with non-native eelgrass, and loss of such habitat will lead to associated productivity declines (see "sand" above).

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
		Z. marina (0.47 ha)	●	●	●					Cockles in particular are known to be associated with native eelgrass beds. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in eelgrass productivity in the LAA, offsetting short-term losses during construction.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
Expanded Tug Basin	Direct mortality (direct effect)		●	●	●	Local	Frequent	Low	Short-term	Mortality assumed for all areas under dredge footprint; however, such communities are inherently dynamic and employ life history strategies that enable them to rapidly recover from disturbance.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		●	●	●					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Bivalves are considered relatively resilient to high TSS levels and predicted Project-related TSS concentrations are well below published concentrations of harm. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for bivalve shellfish to be affected via sediment and water quality pathways
	Change in water quality: changes to salinity (indirect effect)		●	●	●					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
		Biofilm (0.01 ha)	n/a	n/a	n/a					This component will not overlap with biofilm.
	Changes in habitat availability (direct effect)	Intertidal Marsh (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Kelp (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with kelp habitat; therefore, no effects expected.
		Mud (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with mud habitat; therefore, no effects expected.
		Rock (0.45 ha)	●	●	●					Infaunal bivalves are not associated with rock, as they require soft sediment in which to burrow. Causeway widening will result in a minimal - and temporary - reduction in rock habitat for epifaunal bivalves. A net increase in rock habitat is expected from placement of Project infrastructure and, onsite offsetting in the form of rocky reefs will further increase rock habitat in the LAA.
		Sand (1.13 ha)	●	●	●					Involves conversion of intertidal to subtidal sandflat, both are (infaunal) bivalve shellfish habitat.
		Ulva (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with *Ulva* habitat; therefore, no effects expected.
		Z. japonica (n/a)	n/a	n/a	n/a					Tug basin footprint does not overlap with non-native eelgrass habitat; therefore, no effects expected.
		Z. marina (2.68 ha)	n/a	n/a	n/a					Cockles in particular are known to be associated with native eelgrass beds. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in eelgrass productivity in the LAA, offsetting short-term losses during construction.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

Table IR4-17-B3 Project Components and Mechanisms Affecting Productivity: Invertebrates - Dungeness Crabs

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)				Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Gravid	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Direct mortality (direct effect)		n/a	n/a	●	●	Local	Frequent	Low	Long-term	Some mortality assumed for all areas under terminal and dredge pocket footprints; however, adults highly mobile and capable of moving away from disturbance . No spatial overlap with juvenile rearing habitat (intertidal). Mitigation in the form of proposed salvages (which will relocate crabs away from containment dyke) and fisheries sensitive window for gravid crabs reduces spatial and temporal overlap with this component.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Published concentrations of harm are orders of magnitude higher than those expected for the Project. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for Dungeness crabs to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a	n/a					No spatial overlap between areas of predicted salinity change and adult Dungeness crab distribution. Larvae and juveniles have high tolerance to low salinities.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a	n/a					Areas of predicted scour and deposition are highly localised and Dungeness crabs are mobile and capable of relocating when environmental conditions become sub-optimal. Depositional thicknesses are not predicted to exceed 1.7 mm,well within range of ambient conditions.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a	n/a					Terminal footprint does not overlap with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (13.65 ha)	n/a	n/a	●	●					There is no evidence to suggest obligate functional relationships between orange sea pens and Dungeness crabs; it is more likely that they share the same habitat preferences such that loss of sea pen habitat unlikely to drive productivity changes. However, loss of shallow subtidal sand, which provides habitat for adult and gravid life stages, will lead to associated productivity declines (see "sand" below).
		Sparse Sea Pen (62.46 ha)	n/a	n/a	●	●					There is no evidence to suggest obligate functional relationships between orange sea pens and Dungeness crabs; it is more likely that they share the same habitat preferences such that loss of sea pen habitat unlikely to drive productivity changes. However, loss of shallow subtidal sand, which provides habitat for adult and gravid life stages, will lead to associated productivity declines (see "sand" below).
		Kelp (0.029 ha)	n/a	n/a	n/a	n/a					Dungeness crab are a soft-substrate associated species and, thus, do not use kelp as habitat.
		Mud (n/a)	n/a	n/a	n/a	n/a					Terminal footprint does not overlap with mud habitat; therefore, no effects expected.
		Rock (0.58 ha)	n/a	n/a	n/a	n/a					Dungeness crab are a soft-substrate associated species and, thus, do not use rock as habitat.
		Sand (35.36 ha)	n/a	n/a	●	●					Terminal placement will reduce available subtidal sand habitat for adult Dungeness crabs and gravid female crabs (note there is limited empirical evidence showing limited use of the terminal footprint as brooding habitat), and lead to associated productivity declines. However, substantial amounts of highly and moderately suitable habitat outside the terminal and wharf footprints will remain available.
		Ulva (1.21 ha)	●	●	n/a	n/a					*Ulva* is heavily used as settlement and rearing habitat by post-larval (i.e., megalopae) and juvenile Dungeness crabs. While some *Ulva* loss is unavoidable, it is considered an opportunistic alga that is capable of swift re-establishment both via spore dispersal and drift movement. The marine vegetation assessment concluded that *Ulva* productivity is unlikely to be affected by the Project over the long term.
		Z. japonica (n/a)	n/a	n/a	n/a	n/a					Terminal footprint does not overlap with non-native eelgrass habitat; therefore, no effects expected.
		Z. marina (2.78 ha)	n/a	●	●	n/a					Both juvenile and adult life stages of Dungeness crab are known to associate with native eelgrass beds. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in available eelgrass habitat in the LAA, offsetting short-term losses during construction.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	●	●	n/a					Predicted decreases in major prey items (bivalve shellfish) likely contributing to productivity loss.

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)				Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Gravid	Geographic Extent	Frequency	Magnitude	Duration	
Widened Causeway	Direct mortality (direct effect)		●	●	●	n/a	Site-specific	Frequent	Low	Short-term	Potential for some mortality; however, mitigation in the form of proposed salvages (which will relocate crabs away from containment dyke) will minimize mortality. Further, crabs in the intertidal zone will be protected by the juvenile salmon fisheries sensitive window over the spring and summer.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a	n/a					This component not expected to generate a major TSS plume; where major plumes are expected (e.g., dredging for Marine Terminal Land Development), modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	●	●	n/a					Biofilm is not a habitat for invertebrates, but for the mud that it grows on, it is.
		Intertidal Marsh (12.22 ha)	n/a	n/a	n/a	n/a					Dungeness crab do not associate with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (n/a)	n/a	n/a	n/a	n/a					Causeway footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a	n/a					Causeway footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Kelp (n/a)	n/a	n/a	n/a	n/a					Causeway footprint does not overlap with kelp habitat; therefore, no effects expected.
		Mud (0.21 ha)	n/a	●	●	n/a					Larval and young-of-year crabs do not associate with bare mud substrate, as they are vulnerable and use vegetative cover as refuge from predation. Sub-adult crabs, as well as adults, can be found on mud bottoms; however, loss is minimal relative to spatial extent of intertidal mudflat remaining in LAA.
		Rock (4.8 ha)	n/a	n/a	n/a	n/a					Dungeness crab are a soft-substrate associated species and, thus, do not use rock as habitat.
		Sand (0.37 ha)	n/a	●	●	n/a					Larval and young-of-year crabs do not associate with bare sand substrate, as they are vulnerable and use vegetative cover as refuge from predation. Sub-adult crabs, as well as adults, can be found on sand bottoms; however, loss is minimal relative to spatial extent of intertidal sandflat remaining in LAA.
		Ulva (17.07 ha)	●	●	n/a	n/a					*Ulva* is heavily used as settlement and rearing habitat by post-larval (i.e., megalopae) and juvenile Dungeness crabs. While some *Ulva* loss is unavoidable, it is considered an opportunistic alga that is capable of swift re-establishment both via spore dispersal and drift movement. The marine vegetation assessment concluded that *Ulva* productivity is unlikely to be affected by the Project over the long term, and ample intertidal sand/mudflat remains for it to deposit over.
		Z. japonica (2.97 ha)	●	●	n/a	n/a					Non-native eelgrass is heavily used as settlement and rearing habitat by post-larval (i.e., megalopae) and juvenile Dungeness crabs. Loss represents only 1.7% of *Z. japonica* biomass in the LAA; further, long term increases are predicted as a result of the wave shadow and associated deposition of finer sediments.
		Z. marina (0.47 ha)	●	●	●	n/a					Larval, juvenile, and adult life stages of Dungeness crab are known to associate with native eelgrass beds. Predicted increases in eelgrass productivity post-Project (from wave shadow) and onsite offsetting (i.e., eelgrass transplants) will result in a net increase in eelgrass productivity in the LAA, offsetting short-term losses during construction.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
	Direct mortality (direct effect)		●	●	●	●					Some mortality assumed for all areas under dredge footprint, particularly larval/juvenile entrainment; however, adults highly mobile and capable of moving away from disturbance . Mitigation in the form of proposed salvages (which will relocate crabs away from containment dyke) and fisheries sensitive windows for gravid crabs (winter) and juvenile salmon (spring/summer) reduces spatial and temporal overlap with this component.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	●	●	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Published concentrations of harm are orders of magnitude higher than those expected for the Project. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for Dungeness crabs to be affected via sediment and water quality pathways.

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)				Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Gravid	Geographic Extent	Frequency	Magnitude	Duration	
Expanded Tug Basin	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a	n/a	Local	Frequent	Low	Short-term	This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a	n/a					Tug basin footprint does not overlap with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (n/a)	n/a	n/a	n/a	n/a					Tug basin footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a	n/a					Tug basin footprint does not overlap with orange sea pen habitat; therefore, no effects expected.
		Kelp (n/a)	n/a	n/a	n/a	n/a					Tug basin footprint does not overlap with kelp habitat; therefore, no effects expected.
		Mud (n/a)	n/a	n/a	n/a	n/a					Tug basin footprint does not overlap with mud habitat; therefore, no effects expected.
		Rock (0.45 ha)	n/a	n/a	n/a	n/a					Dungeness crab are a soft-substrate associated species and, thus, do not use rock as habitat.
		Sand (1.13 ha)	n/a	●	●	n/a					Involves conversion of intertidal to subtidal sandflat, both are Dungeness crab habitat; however, juvenile habitat is predominantly intertidal while adult habitat is predominantly subtidal.
		Ulva (n/a)	n/a	n/a	n/a	n/a					Tug basin footprint does not overlap with *Ulva* habitat; therefore, no effects expected.
		Z. japonica (n/a)	n/a	n/a	n/a	n/a					Tug basin footprint does not overlap with non-native eelgrass habitat; therefore, no effects expected.
		Z. marina (2.68 ha)	n/a	●	●	●					Through onsite offsetting, eelgrass habitat used by Dungeness crab will increase.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

Table IR4-17-B4 Project Components and Mechanisms Affecting Productivity: Invertebrates - Orange Sea Pens

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Direct mortality (direct effect)		●	●	●	Local	Frequent	Moderate	Long-term	This is the major mechanism of productivity loss for juveniles and adults, as sea pens are predominantly sessile and unable to move away from Project construction activities. Potential implications for larval settlement which may be governed in part by cues from existing sea pens. Results of a pilot transplant program are encouraging, and a larger scale transplant is being considered to partially mitigate effects.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Sea pens are passive suspension feeders and cope well with elevated TSS levels. Disposal pipeline (-45 m CD) is the Project activity that will generate the largest TSS plume and while sea pens occur at this depth, they do so at lower densities as their optimal depth range is shallower; at Roberts Bank, the dense portion of the aggregation occurs between depths of −3.5 m CD to −18 m CD, and therefore will not come into contact with the most concentrated TSS plumes.
	Change in water quality: changes to salinity (direct effect)		n/a	n/a	n/a					No spatial overlap between areas of predicted salinity change (intertidal) and orange sea pen distribution (subtidal).
	Changes in sedimentation and coastal processes (indirect effect)		n/a	●	●					Effects of scour are expected to be beneficial for orange sea pens because flow accelerates as water moves around the structure, thereby increasing food delivery to sea pens; thus, terminal expected to create favourable feeding conditions at its edges, which may attract sea pens back to the area over time.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with intertidal marsh habitat; therefore, no effects expected.
		Dense Sea Pen (13.65 ha)	●	●	●					Permanent losses of soft subtidal sediment from the Project footprint will affect orange sea pen habitat and is considered a major driver of predicted productivity losses. Net increase in highly suitable habitat is predicted due to accelerations of bottom current velocities around terminal edges, which may enhance food delivery rates. Results of a pilot transplant program are encouraging, and a larger scale transplant is being considered to partially mitigate effects.
		Sparse Sea Pen (62.46 ha)	●	●	●					Permanent losses of soft subtidal sediment from the Project footprint will affect orange sea pen habitat and is considered a major driver of predicted productivity losses. Net increase in highly suitable habitat is predicted due to accelerations of bottom current velocities around terminal edges, which may enhance food delivery rates. Results of a pilot transplant program are encouraging, and a larger scale transplant is being considered to partially mitigate effects.
		Kelp (0.029 ha)	n/a	n/a	n/a					Orange sea pens are a soft-substrate associated species and, thus, do not use kelp as habitat.
		Mud (n/a)	n/a	n/a	n/a					Terminal footprint does not overlap with mud habitat; therefore, no effects expected.
		Rock (0.58 ha)	n/a	n/a	n/a					Orange sea pens are a soft-substrate associated species and, thus, do not use rock as habitat.
		Sand (35.36 ha)	●	●	●					Permanent losses of soft subtidal sediment from the Project footprint will affect orange sea pen habitat and is considered a major driver of predicted productivity losses; however, not all sand habitat is suitable to support orange sea pens. Net increase in highly suitable habitat is predicted due to accelerations of bottom current velocities around terminal edges, which may enhance food delivery rates. Results of a pilot transplant program are encouraging, and a larger scale transplant is being considered to partially mitigate effects.
		Ulva (1.21 ha)	n/a	n/a	n/a					Orange sea pens do not associate with native eelgrass; therefore, no effects expected.
		Z. japonica (n/a)	n/a	n/a	n/a					There is no spatial overlap between orange sea pens (subtidal) and non-native eelgrass (intertidal); therefore, no effects expected.
		Z. marina (2.78 ha)	n/a	n/a	n/a					Orange sea pens do not associate with native eelgrass; therefore, no effects expected.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					Biotic interactions are not expected to influence orange sea pen productivity, especially when considered against the magnitude of direct mortality and habitat loss.
	Direct mortality (direct effect)		n/a	n/a	n/a					

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Widened Causeway	Change in water quality: changes to salinity (direct effect)		n/a	n/a	n/a	n/a	n/a	n/a	n/a	Sea pen distribution is entirely subtidal; no spatial overlap with this component
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					
		Intertidal Marsh (12.22 ha)	n/a	n/a	n/a					
		Dense Sea Pen (n/a)	n/a	n/a	n/a					
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					
		Kelp (n/a)	n/a	n/a	n/a					
		Mud (0.21 ha)	n/a	n/a	n/a					
		Rock (4.8 ha)	n/a	n/a	n/a					
		Sand (0.37 ha)	n/a	n/a	n/a					
		Ulva (17.07 ha)	n/a	n/a	n/a					
		Z. japonica (2.97 ha)	n/a	n/a	n/a					
		Z. marina (0.47 ha)	n/a	n/a	n/a					
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					
Expanded Tug Basin	Direct mortality (direct effect)		n/a	n/a	n/a	n/a	n/a	n/a	n/a	Sea pen distribution is entirely subtidal; no spatial overlap with this component
	Change in water quality: changes to salinity (direct effect)		n/a	n/a	n/a					
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					
		Intertidal Marsh (n/a)	n/a	n/a	n/a					
		Dense Sea Pen (n/a)	n/a	n/a	n/a					
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					
		Kelp (n/a)	n/a	n/a	n/a					
		Mud (n/a)	n/a	n/a	n/a					
		Rock (0.45 ha)	n/a	n/a	n/a					
		Sand (1.13 ha)	n/a	n/a	n/a					
		Ulva (n/a)	n/a	n/a	n/a					
		Z. japonica (n/a)	n/a	n/a	n/a					

Project Component	Mechanisms Potentially Affecting Productivity	Invertebrate Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
		Z. marina (2.68 ha)	n/a	n/a	n/a					
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					

Table IR4-17-B5 Project Components and Mechanisms Affecting Productivity: Marine Fish - Pacific Salmon

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially			Potential Effects Criteria Rating				Likelihood
			Egg/Fry	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Injury or direct mortality (direct effect)		n/a	●	n/a	Local	Frequent	Low	Long-term	Eggs/fry in freshwater so no interaction; juveniles rear and forage in intertidal marsh, so little spatial overlap between dredge footprint and juvenile salmon distribution; adults highly mobile so no interaction. Mitigation in the form of proposed salvages (which will relocate juvenile salmon away from containment dyke) reduces spatial overlap with this component.
	Change in acoustic environment (direct effect)		n/a	●	●					Conservatively assuming impact piling is required; vibratory methods are preferred and, if used, no acoustic effects predicted. Other than piling, no activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling. An Underwater Noise Management Plan will be implemented so that sound levels that may cause harm to fish are not exceeded.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions; Pacific salmon adapted to naturally high TSS concentrations, particularly in-river. Project-related TSS plume not expected to extend onto tidal flats and interact with juvenile salmon rearing. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for Pacific salmon to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					Salmon are transitioning between fresh and salt water while in estuary; predicted salinity changes will remain in ideal growth range.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					Salmon occupy pelagic waters and are not directly associated with the seabed.
	Changes in the light environment (direct effect)		n/a	●	●					Artificial lighting expected to have both positive (i.e., increase foraging opportunities) and negative (i.e., elevate predation risk) effects on Pacific salmon productivity. Implementation of a Light Management Plan will minimise any measurable adverse effects on Pacific salmon productivity.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (0.03 ha)	n/a	n/a	n/a					Salmon are not associated with kelp, found at Roberts Bank in more wave-exposed areas, such as attached on man-made rocky subtidal reefs; so no interaction.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud habitat.
		Rock (0.58 ha)	n/a	●	●					Juveniles outmigrating and adults during spawning migration may associate with rip-rap slopes at the existing terminal. However, engineered rip-rap slopes are not natural representative features at Roberts Bank. Mattress rock and rip-rap will be installed for stability and to prevent scour at berth pocket and at toe of caissons.
		Sand (35.36 ha)	n/a	●	●					This component may affect juvenile outmigration (assuming linear travel) and reduce wetted area available to adults. Through onsite offsetting, eelgrass and intertidal marsh areas used by juvenile salmon will increase.
		Dense Sea Pen (13.65 ha)	n/a	n/a	n/a					Salmon are not associated with benthic habitat, so no interaction.
		Sparse Sea Pen (62.46 ha)	n/a	n/a	n/a					Salmon are not associated with benthic habitat, so no interaction.
		Ulva (1.21 ha)	n/a	●	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Juvenile salmon rearing in shore-tied habitats along existing terminal may benefit from structural complexity provided by Ulva. This component will affect a small fraction of ephemeral Ulva.
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not affect non-native eelgrass.
		Z. marina (2.78 ha)	n/a	●	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Juveniles rear, forage, and seek refuge in eelgrass beds. Native eelgrass will be affected in the footprint of the proposed terminal. Through onsite offsetting, eelgrass habitat used by juvenile salmon will increase.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	●	●					Increases predicted in prey groups with strong positive effects, and decreases predicted in prey groups with strong negative effects, on Pacific salmon
	Injury or direct mortality (direct effect)		n/a	n/a	n/a					Mitigation in the form of fisheries sensitive timing window and proposed salvages (which will relocate juvenile salmon away from containment dyke) eliminates temporal and spatial overlap with this component.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					No activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					This component not expected to generate a major TSS plume.

Widened Causeway	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	This component will not drive changes to salinity; only terminal placement will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive changes to sedimentation and coastal processes; only terminal placement will.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Association with biofilm habitat incidental of juvenile salmon rearing and foraging in adjacent intertidal marsh.
		Intertidal Marsh (12.22 ha)	n/a	●	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Juveniles rear and forage in intertidal marsh. Area loss along causeway is predominantly sparse, fringing marsh that is considered low quality. Large increase in intertidal marsh productivity predicted with Project, due to optimized growing conditions in wave shadow. Onsite offsetting will further increase intertidal marsh habitat.
		Kelp (n/a)	n/a	n/a	n/a					Salmon are not associated with kelp, found at Roberts Bank in more wave-exposed areas, such as attached on man-made rocky subtidal reefs; so no interaction.
		Mud (0.21 ha)	n/a	●	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Rearing juveniles associate with a variety of habitats, including mudflats, along the Roberts Bank causeway. Onsite offsetting will increase mudflat habitat in quiescent areas along the widened causeway.
		Rock (4.80 ha)	n/a	●	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Rearing juveniles associate with a variety of habitats, including rip-rap, along the Roberts Bank causeway. Engineered rip-rap slopes are not natural representative features at Roberts Bank. Onsite offsetting will further increase more productive habitats such as intertidal marsh.
		Sand (0.37 ha)	n/a	●	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Rearing juveniles associate with a variety of habitats, including sandflats, along the Roberts Bank causeway. Sandflat habitat is not limiting at Roberts Bank. Onsite offsetting will increase other more productive habitats such as intertidal marsh.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					Salmon are not associated with benthic habitat, so no interaction. This component will not affect sea pen habitat.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					Salmon are not associated with benthic habitat, so no interaction. This component will not affect sea pen habitat.
		Ulva (17.75 ha)	n/a	●	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Juvenile salmon rearing in shore-tied habitats along Roberts Bank causeway may benefit from structural complexity provided by Ulva. This component will affect primarily ephemeral Ulva mixed with non-native eelgrass.
		Z. japonica (2.97 ha)	n/a	●	n/a					Construction of new shoreline may affect juvenile outmigration (assuming linear travel). Juvenile salmon associate with a variety of intertidal habitats, including rearing in eelgrass beds. Onsite offsetting will increase eelgrass areas.
		Z. marina (0.47 ha)	n/a	●	n/a					Construction of new shoreline may affect juvenile outmigration (assuming linear travel). Juvenile salmon associate with a variety of intertidal habitats, including rearing in eelgrass beds. Onsite offsetting will increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
	Injury or direct mortality (direct effect)		n/a	●	n/a					Juvenile entrainment in dredge possible; eggs/fry in freshwater so no interaction; adults highly mobile so no spatial overlap expected. Mitigation in the form of proposed salvages (which will relocate juvenile salmon away from containment dyke) reduces spatial overlap with this component.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					No activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions; Pacific salmon adapted to high TSS concentrations. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for Pacific salmon to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					Salmon are transitioning between fresh and salt water while in estuary; predicted salinity changes will remain in ideal growth range.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					Salmon occupy pelagic waters and are not directly associated with the seabed.

Expanded Tug Basin	Changes in the light environment (direct effect)		n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (n/a)	n/a	n/a	n/a					This component will not overlap with kelp.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.45 ha)	n/a	•	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Rearing juveniles associate with a variety of habitats, including rip-rap, in the inter-causeway area. Engineered rip-rap slopes are not natural representative features at Roberts Bank. Additional rip-rap to be installed for slope and crest protection around the perimeter of the expanded tug basin.
		Sand (1.13 ha)	n/a	•	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Rearing juveniles associate with a variety of habitats, including sandflats, in the inter-causeway area. Sandflat habitat is not limiting at Roberts Bank.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (n/a)	n/a	n/a	n/a					This component will not overlap with *Ulva* .
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass areas.
		Z. marina (2.68 ha)	n/a	•	n/a					Eggs/fry in freshwater so no interaction; adults hold in deeper subtidal waters before initiating upriver migration, so no interaction. Juvenile salmon associate with a variety of intertidal habitats, including rearing in eelgrass beds. Onsite offsetting will increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

Table IR4-17-B6 Project Components and Mechanisms Affecting Productivity: Marine Fish - Reef Fish

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Injury or direct mortality (direct effect)		n/a	●	n/a	Local	Frequent	Low	Long-term	Larval rockfish entrainment in dredge possible; eggs (lingcod) and adults at rocky reefs so no to limited spatial overlap with dredge area.
	Change in acoustic environment (direct effect)		n/a	●	●					Conservatively assuming impact piling is required; vibratory methods are preferred and, if used, no acoustic effects predicted. Other than piling, no activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for reef fish to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					Reef fish occupy subtidal waters off face of existing terminals; therefore, there is no spatial overlap with predicted areas of salinity change.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					Reef fish are associated with hard substrate (reefs, rip rap, caissons) and are not directly associated with the seabed. Further, reef fish distribution does not overlap with areas of predicted geomorphic change.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					Little evidence of light either positively or negatively influencing reef fish; artificial reefs occur at -0.5 to -3.0 m CD, so attenuation of light is expected.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (0.03 ha)	●	●	●					This component will minimally overlap with artificial rocky reef habitat, and attached kelp. Rockfish eggs fertilised and developed internally, and larvae pelagic; so no interaction. This component may interact with lingcod egg masses, as they have previously been recorded on the reefs; lingcod larvae are pelagic. Juveniles and adults inhabit kelp beds associated with reefs or rip-rap slope. Onsite offsetting, through the creation of additional rocky reefs, as well as rip-rap placement associated with the proposed terminal, will result in a net increase in suitable substrate for kelp to attach and grow.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.58 ha)	●	●	●					This component will minimally overlap (2.3 m^2) with artificial rocky reef habitat. Rockfish eggs fertilised and developed internally, and larvae pelagic; so no interaction. This component may interact with lingcod egg masses, as they have previously been recorded on the reefs; lingcod larvae are pelagic. Juveniles and adults inhabit kelp beds associated with reefs or rip-rap slope. Onsite offsetting, through the creation of additional rocky reefs, as well as rip-rap placement associated with the proposed terminal, will result in a net increase in rocky fish habitat.
		Sand (35.36 ha)	n/a	●	●					Rockfish eggs fertilised and developed internally, lingcod egg masses deposited under rocks, in rocky crevices; larvae pelagic; so no interaction. Rockfish juveniles/adults prefer hard-bottom habitats, so no interaction. Lingcod juveniles/adults found predominantly on rocky reefs, but also occur over soft-bottom habitats, so some interaction. Sandflat habitat not limiting at Roberts Bank.
		Dense Sea Pen (13.65 ha)	n/a	●	●					Rockfish eggs fertilised and developed internally, lingcod egg masses deposited under rocks, in rocky crevices; larvae pelagic; so no interaction. Rockfish juveniles/adults prefer hard-bottom habitats, so no interaction. At Roberts Bank, lingcod have been observed in sea pen beds, so this component will result in an interaction. A transplant program is proposed to partially mitigate direct mortality of orange sea pens from terminal construction.
		Sparse Sea Pen (62.46 ha)	n/a	●	●					Rockfish eggs fertilised and developed internally, lingcod egg masses deposited under rocks, in rocky crevices; larvae pelagic; so no interaction. Rockfish juveniles/adults prefer hard-bottom habitats, so no interaction. At Roberts Bank, lingcod have been observed in sea pen beds, so this component will result in an interaction. A transplant program is proposed to partially mitigate direct mortality of orange sea pens from terminal construction.
		Ulva (1.21 ha)	n/a	n/a	n/a					Rockfish eggs fertilised and developed internally, lingcod egg masses deposited under rocks, in rocky crevices; larvae pelagic; so no interaction. Rockfish juveniles/adults prefer hard-bottom habitats, so no interaction. Lingcod juveniles/adults found predominantly on rocky reefs, but also occur over soft-bottom habitats, but no association with *Ulva* .
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
		Z. marina (2.78 ha)	n/a	•	•					Rockfish eggs fertilised and developed internally, lingcod egg masses deposited under rocks, in rocky crevices; larvae pelagic; so no interaction. Rockfish juveniles/adults prefer hard-bottom habitats, so no interaction. Lingcod juveniles/adults found predominantly on rocky reefs, but also occur over soft-bottom habitats, and may associate with eelgrass beds, so some interaction. Onsite offsetting, through the creation of additional rocky reefs, as well as rip-rap placement associated with the proposed terminal, will result in a net increase in rocky habitat. suitable for reef fish. Onsite offsetting will also increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	•	•					Predicted reductions in prey base have the potential to reduce rockfish productivity in particular.
Widened Causeway	Injury or direct mortality (direct effect)		n/a	n/a	n/a	n/a	n/a	n/a	n/a	There is no spatial overlap between reef fish distribution and this Project component.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					No activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					This component not expected to generate a major TSS plume; where major plumes are expected (e.g., dredging for Marine Terminal Land Development), modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					Reef fish are associated with hard bottom substrate and occupy subtidal waters, such that there is no overlap with areas of predicted geomorphic change.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with intertidal biofilm areas.
		Intertidal Marsh (12.22 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the subtidal artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with intertidal marsh areas.
		Kelp (n/a)	n/a	n/a	n/a					Kelp is found at Roberts Bank in more wave-exposed areas, such as attached on man-made rocky subtidal reefs; so no spatial overlap with this component.
		Mud (0.21 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the subtidal artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with intertidal mudflats.
		Rock (4.80 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the subtidal artificial reefs and rip-rap along the Roberts Bank terminal, but not in the shallow intertidal associated with rip-rap slope adjacent to the causeway; so no spatial overlap with this component.
		Sand (0.37 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the subtidal artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with intertidal sandflats.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (17.75 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the subtidal artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with *Ulva* occurring intertidally.
		Z. japonica (2.97 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the subtidal artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with intertidal eelgrass beds.
		Z. marina (0.47 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the subtidal artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with intertidal eelgrass beds.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
	Injury or direct mortality (direct effect)		n/a	•	n/a					Larval rockfish entrainment in dredge possible; eggs (lingcod) and adults at rocky reefs so no to limited spatial overlap with dredge area.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					No activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for reef fish to be affected via sediment and water quality pathways.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Expanded Tug Basin	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					Reef fish are associated with hard bottom substrate and occupy subtidal waters, such that there is no overlap with areas of predicted geomorphic change.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (n/a)	n/a	n/a	n/a					This component will not overlap with kelp.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.45 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with rip-rap slope at the tug basin.
		Sand (1.13 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with sandflat at the tug basin.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (n/a)	n/a	n/a	n/a					This component will not overlap with *Ulva* .
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.
		Z. marina (2.68 ha)	n/a	n/a	n/a					Reef fish at Roberts Bank commonly recorded on the artificial reefs and rip-rap along the Roberts Bank terminal, so no spatial overlap with native eelgrass beds at the tug basin.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

Table IR4-17-B7 Project Components and Mechanisms Affecting Productivity: Marine Fish - Forage Fish

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Injury or direct mortality (direct effect)	n/a	●	●	●	Local	Frequent	Low	Long-term	Juvenile/larval entrainment in dredge possible; buried adult Pacific sand lance vulnerable to dredging activities and dumping of fill in terminal basins, though majority of burying habitat is in deeper water (up to 80 m). Fisheries sensitive window for gravid Dungeness crabs will protect burying Pacific sand lance (PSL) over the winter. Fisheries-sensitive window for juvenile salmon will protect Pacific herring recruitment, surf smelt spawning, and shiner perch breeding periods.
	Change in acoustic environment (direct effect)	n/a	n/a	●	●					Conservatively assuming impact piling is required, which will initiate behavioural effects in Pacific herring 340-450 m from source; if vibratory methods used, then distance reduces to 20 m. Other than piling, no activity exceeds injury thresholds; highly localized behavioural effects (i.e., within 20 m of source) expected for Pacific herring,
	Change in water quality: increase in total suspended solid concentrations (direct effect)	n/a	n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for forage fish to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)	n/a	n/a	n/a	n/a					Project is expected to lower average salinities in specific areas of the intertidal zone, with limited spatial overlap with forage fish distribution; forage fish well adapted to a wide range of salinities.
	Changes in sedimentation and coastal processes (indirect effect)	n/a	n/a	●	●					Sediment deposition from Project activities (dredging, DAS, terminal placement) have the potential to reduce suitability of PSL burying habitat due to silt content (though PSL are not considered habitat limited in LAA).
	Changes in the light environment (direct effect)	n/a	n/a	●	●					Artificial lighting expected to have both positive and negative effects on forage fish productivity (i.e., increase foraging opportunities while also elevating predation risk)
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (0.03 ha)	●	●	●					Pacific herring may spawn on kelp; at Roberts Bank, however, herring spawn has been documented on eelgrass. Shiner perch may associate with kelp in deeper subtidal areas, but occupy wide range of habitats, with no single type preferred. This component will minimally overlap with artificial rocky reef habitat, and attached kelp. Onsite offsetting, through the creation of additional rocky reefs, as well as rip-rap placement associated with the proposed terminal, will result in a net increase in suitable substrate for kelp to attach and grow.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.58 ha)	n/a	●	●					Eggs deposited on gravel beach or eelgrass habitat, or develop internally for shiner perch, larvae pelagic, so no interaction. Juveniles/adults school primarily in shallow nearshore waters, in eelgrass beds; adult spawning either on gravel beach or eelgrass; shiner perch may associate with rocky substrates, but occupy wide range of habitats, with no single type preferred. Onsite offsetting, through the creation of additional rocky reefs, as well as rip-rap placement associated with the proposed terminal, will result in a net increase in rocky fish habitat.
		Sand (35.36 ha)	●	●	●					Terminal placement will result in loss of subtidal sand habitat, and sediment grain size within the berth pocket will be rendered unsuitable for PSL burying following construction activities; note that there is no direct empirical evidence of PSL burying in the LAA. PSL, surf smelt are obligate beach spawners. Through onsite offsetting, sandy gravel beach habitat suitable for forage fish spawning will increase.
		Dense Sea Pen (13.65 ha)	n/a	n/a	n/a					Forage fish are pelagic, exhibiting schooling behaviour in nearshore estuarine habitats, and not associating with benthic habitats such as sea pen beds; so no interaction.
		Sparse Sea Pen (62.46 ha)	n/a	n/a	n/a					Forage fish are pelagic, exhibiting schooling behaviour in nearshore estuarine habitats, and not associating with benthic habitats such as sea pen beds; so no interaction.
		Ulva (1.21 ha)	n/a	n/a	n/a					Association with *Ulva* likely incidental during forage fish spawning on sandy gravel beach; so no interaction with this component.
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.
		Z. marina (2.78 ha)	●	●	●					Pacific herring spawn on eelgrass. Rearing juvenile and adult forage fish associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
	Changing abundances of predators relative to their prey (indirect effect)		n/a	●	●					Predicted declines in primary prey as well as declines in functional groups with positive effects on forage fish.
Widened Causeway	Injury or direct mortality (direct effect)		●	●	●	Site-specific	Frequent	Low	Short-term	Potential to overlap with beach spawning adults and eggs/larvae. Spawning surf smelt will be protected by fisheries-sensitive window for Pacific salmon, while spawning of PSL will not.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					This component is not expected to produce sound levels exceeding injury or behavioural thresholds.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					This component not expected to generate a major TSS plume; where major plumes are expected (e.g., dredging for Marine Terminal Land Development), modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	n/a	n/a					Forage fish do not associate with intertidal mudflats where biofilm occurs; surf smelt/PSL spawn on sandy gravel beaches; so no interaction with this component.
		Intertidal Marsh (12.22 ha)	n/a	n/a	n/a					No forage fish association with intertidal marsh; surf smelt/PSL spawn on sandy gravel beaches; so no interaction with this component.
		Kelp (n/a)	n/a	n/a	n/a					Kelp is found at Roberts Bank in more wave-exposed areas, such as attached on man-made rocky subtidal reefs; so no spatial overlap with this component.
		Mud (0.21 ha)	n/a	n/a	n/a					Forage fish do not associate with intertidal mudflats; surf smelt/PSL spawn on sandy gravel beaches; so no interaction with this component.
		Rock (4.80 ha)	n/a	●	●					Eggs deposited on gravel beach or eelgrass habitat, or develop internally for shiner perch, larvae pelagic, so no interaction. Juveniles/adults school primarily in shallow nearshore waters, in eelgrass beds; shiner perch may associate with rip-rap, but occupy a variety of habitats in the estuary. Engineered rip-rap slopes are not natural representative features at Roberts Bank. With onsite offsetting, sandy gravel beach habitat suitable for forage fish spawning will increase.
		Sand (0.37 ha)	●	n/a	●					Potential to overlap with beach spawning adults and eggs/larvae. Spawning surf smelt will be protected by fisheries-sensitive window for Pacific salmon, while spawning of PSL will not. Juveniles schooling in shallow nearshore waters, so no spatial overlap. With onsite offsetting, sandy gravel beach habitat suitable for forage fish spawning will increase.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (17.75 ha)	n/a	n/a	n/a					Association with *Ulva* likely incidental during forage fish spawning on sandy gravel beach; so no interaction with this component.
		Z. japonica (2.97 ha)	●	●	●					Potential to overlap with Pacific herring spawning adults and eggs/larvae. Herring spawn documented on native eelgrass, but possibility of spawning on non-native eelgrass not discounted. Other forage fish juveniles/adults also associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.
		Z. marina (0.47 ha)	●	●	●					Potential to overlap with Pacific herring spawning adults and eggs/larvae. Other forage fish juveniles/adults also associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
	Injury or direct mortality (direct effect)		n/a	●	n/a					Juvenile/larval entrainment in dredge possible; buried adult PSL vulnerable to dredging activities.
	Change in acoustic environment (direct effect)		n/a	●	●					Conservatively assuming impact piling is required, which will initiate behavioural effects in Pacific herring 340-450 m from source; if vibratory methods used, then distance reduces to 20 m.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Expanded Tug Basin	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for forage fish to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (n/a)	n/a	n/a	n/a					This component will not overlap with kelp.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.45 ha)	n/a	•	•					Eggs deposited on gravel beach or eelgrass habitat, or develop internally for shiner perch, larvae pelagic, so no interaction. Juveniles/adults school primarily in shallow nearshore waters, in eelgrass beds; shiner perch occupy a variety of habitats in the estuary, but may associate with rip-rap, so some interaction. Engineered rip-rap slopes are not natural representative features at Roberts Bank. With onsite offsetting, sandy gravel beach habitat suitable for forage fish spawning will increase. Additional rip-rap to be installed for slope and crest protection around the perimeter of the expanded tug basin.
		Sand (1.13 ha)	n/a	•	•					Eggs deposited on gravel beach or eelgrass habitat, or develop internally for shiner perch, larvae pelagic, so no interaction. Portion of sandflat predicted to be highly suitable PSL burying habitat to be affected during dredging; note however that there is no direct empirical evidence of PSL burying in the LAA.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (n/a)	n/a	n/a	n/a					This component will not overlap with *Ulva* .
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.
		Z. marina (2.68 ha)	•	•	•					Potential to overlap with Pacific herring spawning adults and eggs/larvae. Other forage fish juveniles/adults also associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

Table IR4-17-B8 Project Components and Mechanisms Affecting Productivity: Marine Fish - Flatfish

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Injury or direct mortality (direct effect)		•	•	•	Local	Frequent	Low	Long-term	Juvenile/larval entrainment in dredge likely because they live on or close to bottom substrate. Magnitude low for starry flounder because spawning occurs in higher estuarine environments, and eggs are near surface, such that spatial overlap with this component limited. Magnitude also low for English sole because of prolonged spawning period/multiple spawning peaks throughout the year.
	Change in acoustic environment (direct effect)		n/a	•	•					Conservatively assuming impact piling is required; vibratory methods are preferred and, if used, no acoustic effects predicted. Other than piling, no activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		•	•	•					Flatfish are most likely to be exposed to Project-related increases in TSS concentrations, given high abundance in subtidal waters. Behavioural disturbance possible in immediate vicinity of disposal pipeline (-45 m CD) where CCME high flow guideline is exceeded. Elsewhere, modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for flatfish to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					Starry flounder is extremely tolerant of low salinities and frequently penetrate freshwater. No spatial overlap between predicted areas of salinity change and English sole distribution, which is predominantly sub-tidal at depths >20 m.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	•	•					Depositional thicknesses are not predicted to exceed 1.7 mm while benthic fish can migrate vertically to the surface following burial, even when buried by more than 30 cm of sediment.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					Area of changes in the light environment is small relative to flatfish habitat in the LAA; construction phase lighting will be temporary and localised and mostly occur during the day; long-term changes in light unlikely to be experienced at subtidal depths where flatfish are most abundant.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (0.03 ha)	n/a	n/a	n/a					Flatfish associate with benthic sandy habitats, and not with kelp found at Roberts Bank in more wave-exposed areas, such as attached on man-made rocky subtidal reefs; so no interaction.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.58 ha)	n/a	n/a	n/a					Flatfish associate with benthic sandy habitats, and not with rocky substrates; so no interaction.
		Sand (35.36 ha)	•	•	•					Terminal placement will result in loss of subtidal sand habitat where flatfish are abundant. Portion of juvenile rearing protected by juvenile salmon fisheries-sensitive window. Portion of adult spawning protected by Dungeness crab fisheries-sensitive window.
		Dense Sea Pen (13.65 ha)	•	•	•					Some interaction with flatfish spawning. Flatfish juveniles/adults associate with sea pen beds for refuge from predators and strong currents. A transplant program is proposed to partially mitigate direct mortality of orange sea pens from terminal construction.
		Sparse Sea Pen (62.46 ha)	•	•	•					Some interaction with flatfish spawning. Flatfish juveniles/adults associate with sea pen beds for refuge from predators and strong currents. A transplant program is proposed to partially mitigate direct mortality of orange sea pens from terminal construction.
		Ulva (1.21 ha)	n/a	•	•					Flatfish eggs in deeper waters (either in surface or at depth), so no spatial overlap. Juveniles/adults abundant over sand, and may incidentally associate with *Ulva* , benefit from structural complexity.
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.
		Z. marina (2.78 ha)	n/a	•	•					Flatfish eggs in deeper waters (either in surface or at depth), over sand, so no interaction. Rearing juveniles and adults associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	•	•					Predicted increases in prey (macrofauna) and decreases in predators (pinnipeds) and competitors (diving waterbirds) is expected to positively affect starry flounder productivity. Biotic interactions considered negligible for English sole.
	Injury or direct mortality (direct effect)		n/a	n/a	n/a					This component does not overlap spatially with English sole distribution (20-150 m CD). Starry flounder is highly mobile and not habitat limited, therefore expected to move away from Project activities.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Widened Causeway	Change in acoustic environment (direct effect)		n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	This component is not expected to produce sound levels exceeding injury or behavioural thresholds.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					This component not expected to generate a major TSS plume; where major plumes are expected (e.g., dredging for Marine Terminal Land Development), modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	n/a	●	●					Flatfish eggs in deeper waters (in surface or at depth), so no interaction. Rearing juveniles and adults associate with a variety of habitats, including intertidal mudflats where biofilm occurs.
		Intertidal Marsh (12.22 ha)	n/a	n/a	n/a					Flatfish eggs in deeper waters (in surface or at depth), so no interaction. Rearing juveniles and adults abundant over subtidal sand, so no interaction with intertidal marsh.
		Kelp (n/a)	n/a	n/a	n/a					Kelp is found at Roberts Bank in more wave-exposed areas, such as attached on man-made rocky subtidal reefs; so no spatial overlap with this component.
		Mud (0.21 ha)	n/a	●	●					Flatfish eggs in deeper waters (in surface or at depth), so no interaction. Rearing juveniles and adults associate with a variety of habitats, including intertidal mudflats.
		Rock (4.80 ha)	n/a	n/a	n/a					Flatfish eggs in deeper waters (in surface or at depth), so no interaction. Rearing juveniles and adults associate with a variety of habitats, primarily with sand and mud, and generally avoid rocky areas, so no interaction.
		Sand (0.37 ha)	n/a	●	●					Flatfish eggs in deeper waters (in surface or at depth), so no interaction. Rearing juveniles and adults associate with a variety of habitats, including intertidal sandflats, though flatfish are not habitat limited in the LAA.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (17.75 ha)	n/a	●	●					Flatfish eggs in deeper waters (either in surface or at depth), so no spatial overlap. Juveniles/adults abundant over sand, and may incidentally associate with *Ulva* , benefit from structural complexity.
		Z. japonica (2.97 ha)	n/a	●	●					Flatfish eggs in deeper waters (in surface or at depth), so no interaction. Rearing juveniles and adults associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.
		Z. marina (0.47 ha)	n/a	●	●					Flatfish eggs in deeper waters (in surface or at depth), so no interaction. Rearing juveniles and adults associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
	Injury or direct mortality (direct effect)		n/a	●	●					Juvenile/larval entrainment in dredge likely because they live on or close to bottom substrate. Magnitude low for starry flounder because spawning occurs in higher estuarine environments, and eggs are near surface, such that spatial overlap with this component limited. Magnitude also low for English sole because of prolonged spawning period/multiple spawning peaks throughout the year.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					No activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for flatfish to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
		Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Expanded Tug Basin	Changes in habitat availability (direct effect)	Intertidal Marsh (n/a)	n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	This component will not overlap with intertidal marsh.
		Kelp (n/a)	n/a	n/a	n/a					This component will not overlap with kelp.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.45 ha)	n/a	n/a	n/a					Flatfish associate with a variety of habitats, primarily with sand and mud, and generally avoid rocky areas, so no interaction.
		Sand (1.13 ha)	•	•	•					Involves conversion of intertidal to subtidal mudflat, both are flatfish habitat. Portion of juvenile rearing protected by juvenile salmon fisheries-sensitive window. Portion of adult spawning protected by Dungeness crab fisheries-sensitive window.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (n/a)	n/a	n/a	n/a					This component will not overlap with *Ulva* .
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.
		Z. marina (2.68 ha)	n/a	•	•					Flatfish eggs in deeper waters (either in surface or at depth), over sand, so no interaction. Rearing juveniles and adults associate with eelgrass beds. Onsite offsetting will increase eelgrass areas.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

Table IR4-17-B9 Project Components and Mechanisms Affecting Productivity: Marine Fish - Demersal Fish

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Marine Terminal and Wharf	Injury or direct mortality (direct effect)		●	●	●	Local	Frequent	Low	Long-term	Larval/juvenile entrainment in dredge possible; limited spatial overlap between spawning areas in the high intertidal zone and dredging activities at depth; fisheries window for gravid crabs will protect adults in deeper waters over the winter.
	Change in acoustic environment (direct effect)		n/a	●	●					Conservatively assuming impact piling is required; vibratory methods are preferred and, if used, no acoustic effects predicted. Other than piling, no activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		●	●	●					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions; maximum plume concentrations predicted at end of disposal pipeline (-45 m), which does not overlap with areas of highest demersal fish productivity. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for demersal fish to be affected via sediment and water quality pathways.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					Demersal fish generally resilient to wide range of salinities. Threespine stickleback is anadromous. Limited spatial overlap between predicted areas of salinity change (mid to high intertidal) and adult Pacific staghorn sculpin distribution; and, no temporal overlap between presence of Pacific staghorn sculpin eggs and larvae (Feb-March) and seasonal salinity change (spring freshet, May to July).
	Changes in sedimentation and coastal processes (indirect effect)		n/a	●	●					Positive effect on productivity anticipated. Deposition is predicted in localised areas behind the terminal, potentially benefiting demersal fish species which recruit to, and forage over, shallow mud or sand habitat
	Changes in the light environment (direct effect)		n/a	n/a	n/a					Area of changes in the light environment is small relative to demersal fish habitat in the LAA; construction phase lighting will be temporary and localised and mostly occur during the day; long-term changes in light unlikely to be experienced in near bottom environments where demersal fish are most abundant.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (0.03 ha)	n/a	n/a	n/a					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates; so no interaction.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.58 ha)	n/a	n/a	n/a					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates; so no interaction.
		Sand (35.36 ha)	●	●	●					Demersal fish most abundant in intertidal areas, but some presence in subtidal sandy areas. Terminal placement will result in loss of subtidal sand habitat, so some interaction. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
		Dense Sea Pen (13.65 ha)	n/a	n/a	n/a					No association with sea pen beds documented. Demersal fish most abundant in intertidal areas.
		Sparse Sea Pen (62.46 ha)	n/a	n/a	n/a					No association with sea pen beds documented. Demersal fish most abundant in intertidal areas.
		Ulva (1.21 ha)	●	●	●					Demersal fish common over sand, and may incidentally associate with *Ulva* ; so some interaction.
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.
		Z. marina (2.78 ha)	●	●	●					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	●	●					Predicted increases in prey (macrofauna) likely to slightly positively influence demersal fish productivity.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Widened Causeway	Injury or direct mortality (direct effect)		n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	Demersal fish are highly mobile and not habitat limited, therefore expected to move away from Project activities. Limited spatial overlap between spawning areas in the high intertidal zone and west causeway footprint. Fisheries window for juvenile salmon will protect threespine stickleback spawning period.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					This component is not expected to produce sound levels exceeding injury or behavioural thresholds.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					This component not expected to generate a major TSS plume; where major plumes are expected (e.g., dredging for Marine Terminal Land Development), modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions.
	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a					This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (0.01 ha)	•	•	•					Demersal fish associate with a variety of intertidal habitats, including mudflats where biofilm occurs. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
		Intertidal Marsh (12.22 ha)	•	•	•					Demersal fish associate with a variety of habitats, including intertidal marsh. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
		Kelp (n/a)	n/a	n/a	n/a					Kelp is found at Roberts Bank in more wave-exposed areas, such as attached on man-made rocky subtidal reefs; so no spatial overlap with this component.
		Mud (0.21 ha)	•	•	•					Demersal fish associate with a variety of intertidal habitats, including mudflats. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
		Rock (4.80 ha)	n/a	n/a	n/a					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates; so no interaction.
		Sand (0.37 ha)	•	•	•					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (17.75 ha)	•	•	•					Demersal fish common over sand, and may incidentally associate with *Ulva* ; so some interaction.
		Z. japonica (2.97 ha)	•	•	•					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
		Z. marina (0.47 ha)	•	•	•					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates. Through onsite offsetting, eelgrass and intertidal marsh areas used by demersal fish will increase.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.
	Injury or direct mortality (direct effect)		n/a	•	•					Larval/juvenile entrainment in dredge possible; limited spatial overlap between spawning areas in the high intertidal zone and dredging activities in low intertidal; fisheries window for juvenile salmon will protect threespine stickleback spawning period; and, fisheries window for gravid crabs will protect adults in deeper waters over the winter.
	Change in acoustic environment (direct effect)		n/a	n/a	n/a					No activity exceeds injury thresholds and behavioural effects not anticipated based on acoustic modelling.
	Change in water quality: increase in total suspended solid concentrations (direct effect)		n/a	n/a	n/a					Modelled plume concentrations and depositional thicknesses are predicted to be within range of ambient conditions. Implementation of a Construction Environmental Management Plan and supporting plans will minimise potential for demersal fish to be affected via sediment and water quality pathways.

Project Component	Mechanisms Potentially Affecting Productivity	Habitat Type and Area of Overlap (ha)	Life Stage Potentially Affected (as applicable to the sub-component)			Potential Effects Criteria Rating				Likelihood
			Egg/Larvae	Juvenile	Adult	Geographic Extent	Frequency	Magnitude	Duration	
Expanded Tug Basin	Change in water quality: changes to salinity (indirect effect)		n/a	n/a	n/a	Site-specific	Frequent	Low	Short-term	This component will not drive changes to salinity; only terminal land development will.
	Changes in sedimentation and coastal processes (indirect effect)		n/a	n/a	n/a					This component will not drive geomorphic changes.
	Changes in the light environment (direct effect)		n/a	n/a	n/a					This component will not drive changes to the light environment.
	Changes in habitat availability (direct effect)	Biofilm (n/a)	n/a	n/a	n/a					This component will not overlap with biofilm.
		Intertidal Marsh (n/a)	n/a	n/a	n/a					This component will not overlap with intertidal marsh.
		Kelp (n/a)	n/a	n/a	n/a					This component will not overlap with kelp.
		Mud (n/a)	n/a	n/a	n/a					This component will not overlap with mud.
		Rock (0.45 ha)	n/a	n/a	n/a					Demersal fish most abundant in intertidal areas, particularly eelgrass beds and sandy substrates; so no interaction.
		Sand (1.13 ha)	n/a	n/a	n/a					Involves conversion of intertidal to subtidal mudflat, both are demersal fish habitat, so effects not anticipated.
		Dense Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with dense sea pen beds.
		Sparse Sea Pen (n/a)	n/a	n/a	n/a					This component will not overlap with sparse sea pen beds.
		Ulva (n/a)	n/a	n/a	n/a					This component will not overlap with *Ulva* .
		Z. japonica (n/a)	n/a	n/a	n/a					This component will not overlap with non-native eelgrass beds.
		Z. marina (2.68 ha)	n/a	n/a	n/a					Involves the conversion of intertidal to subtidal mudflat, both are demersal fish habitat, so effects not anticipated.
	Changing abundances of predators relative to their prey (indirect effect)		n/a	n/a	n/a					This component will not drive changes in biotic interactions; only land terminal development will.

IR4-18 Marine Invertebrates Marine Fish and Fish Habitat – Effects Assessment: Sensitive Life Histories Outside Salmon and Crab Windows

Information Source(s)

EIS Volume 3: Section 12.7.1.2; Section 13.7.1.2

Context

In the EIS, the Proponent stated that while timing windows have proven effective in reducing interactions between Project activities and juvenile salmon (Section 13.7.1.2) and crab (Section 12.7.1.2), other marine fish and invertebrate species with sensitive life periods outside these temporal windows could be adversely affected.

Identification of the seasonality of fish and invertebrate species and life stages affected by each project component would aid in the understanding of temporal effects due to Project construction and operation and is required in order to assess the adequacy of proposed mitigation and offsetting measures.

Information Request

Identify the fish and invertebrate species which occur in the local assessment area that have sensitive life history stages which are outside the juvenile salmon and crab fisheries sensitive windows.

Provide a summary of the effects of Project activities on different life stages of fish and invertebrates that occupy the local assessment area outside of the juvenile salmon and crab protection windows.

VFPA Response

Identify the fish and invertebrate species which occur in the local assessment area that have sensitive life history stages which are outside the juvenile salmon and crab fisheries sensitive windows.

Assessment Structure

Marine invertebrate and marine fish species known to occur in the local assessment area (LAA) and that have the potential to be affected by the Project, requested to be identified in this response, were previously identified in Tables IR9-1 and IR9-2 in Information Request #9 (IR-7.31.15-09 of CEAR Document #314[1]) and Additional Information Request #9

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[1] CEAR Document #314 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements (See reference document #271) for the Environmental Impact Statement.

(AIR-12.04.15-09 of CEAR Document #389[2]). For each species identified, previous submissions provided the associated sub-component and representative species along with rationale for why the selected representative species are an appropriate proxy (e.g., similar ecological niches, life history traits, or habitat preferences, as described above). To structure and streamline the assessment, four sub-components of marine invertebrates (infaunal and epifaunal communities, bivalve shellfish, Dungeness crab, and orange sea pen) and five sub-components of marine fish (Pacific salmon, reef fish, forage fish, flatfish, and demersal fish) were selected.

EIS Section 8.0 describes how valued components, sub-components, and representative species were selected, as it would be impractical to provide characterisations for and assess Project-related effects on every marine invertebrate and fish species that occurs in the LAA. However, it is important to note that all species with the potential to occur at Roberts Bank were considered in the assessment—either selected as sub-components themselves or representative species within a sub-component, or represented by another species (i.e., a proxy) with similar ecological niches, life history traits, or habitat preferences. The information provided for representative species, therefore, is representative of the conditions of (and effects on) the other species that are represented.

Sensitive life history stages outside the juvenile salmon and Dungeness crab fisheries-sensitive windows are presented in this response for marine invertebrate and marine fish *representative* species (and not all species known to occur at Roberts Bank), in line with the methodology presented in EIS Section 8.0.

Sensitive Life Periods for Marine Invertebrates and Marine Fish

For this response, and consistent with EIS Sections 12.0 and 13.0, sensitive life periods considered for marine invertebrates and marine fish[3] at Roberts Bank include the following:

- **Breeding:** stages leading to spawning/reproduction including courtship behaviour, nest building, and guarding;
- **Spawning/Reproduction:** the act of gamete release, mating (internal fertilisation), or live birth;
- **Brooding:** the phase in which females extrude and oxygenate eggs;
- **Recruitment:** the addition of individuals to local populations following settlement from the pelagic (planktonic) phase;
- **Egg development:** the phase that follows egg fertilisation, and culminates with egg hatching (and larval release), and includes stages of embryonic development (e.g., cell division, embryonic body and tail formation); and
- **Migration:** movement of species from one place to another; specifically, i) a relocation of the animal that is on a much greater scale, and involves movement of much longer duration, than those arising in its normal daily activities, or ii) a seasonal to-and-fro

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[2] CEAR Document #389 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Marine Shipping Addendum Completeness Review - Additional Information Requirements.

[3] Note that these sensitive life periods are not universally applicable across species. For example, Pacific oysters do not migrate and flatfish do not brood.

movement of populations between regions where conditions are alternately favourable or unfavourable (including one region in which breeding occurs) (Dingle and Drake 2007).

Sensitive life periods for marine invertebrates are presented in **Table IR4-18-1** and for adult and juvenile marine fish in **Tables IR4-18-2** and **IR4-18-3**, respectively. **Table IR4-18-1** summarises information included in EIS Section 12.5. Information presented in this response for adult and juvenile marine fish are also provided in EIS Tables 13-4 and 13-5, respectively.

Table IR4-18-1 Sensitive Life Periods of Marine Invertebrate Representative Species Expected to Occur Within the Local Assessment Area

Sub-component Representative Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Infaunal and Epifaunal Invertebrate Communities												
Macrofauna and meiofauna[a]	🟧	🟧	🟧	🟧	🟧	🟧🟥	🟥	🟥	🟥🟧	🟧	🟧	🟧
Bivalve Shellfish												
Pacific oyster[b]							🟥	🟥	🟨			
Pacific littleneck clam[c]				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟨	
Heart cockle[d]				🟧	🟧	🟧🟥	🟥	🟥	🟥🟧	🟧	🟧	🟨
Macoma clam[e]			🟧🟥	🟥	🟥	🟥🟧	🟨					
Bay mussel[f]				🟥	🟥	🟥	🟨					
Dungeness Crab												
Dungeness crab[g]	🟩	🟩	🟩	🟧	🟧	🟧	🟨	🟨	🟨	🟨🟩	🟩	🟩
Orange Sea Pen												
Orange sea pen[h]			🟧🟥	🟨⬜								

🟧 Spawning/reproduction
🟥 Peak spawning/reproduction
🟨 Recruitment[i]
🟩 Gravid/brooding phase

Notes:
a. Source: Thorson 1950, Crimaldi and Zimmer 2014
b. Source: Dethier 1982, Gillespie et al. 2012
c. Source: Quayle and Bourne 1972, DFO 2013
d. Source: Gallucci and Gallucci 1982
e. Source: Von Oertzen 1972
f. Source: Curiel-Ramirez and Caceres-Martinez 2004
g. Source: Shirley et al. 1987, O'Clair et al. 1996, Scheding et al. 2001
h. Source: Chia and Crawford 1973, Shimek 2011
i. Larval settlement and recruitment periods for spawning invertebrates (i.e., all except Dungeness crab) generally commence within 2 to 5 weeks of spawning and overlap with much of the spawning periods. Yellow highlights reflect the portion of settlement and recruitment periods after spawning has ended for these species.

Full references of sources identified in this table are included in EIS Sections 12.13 and 13.13.

Table IR4-18-2 Sensitive Life Periods of Adult Marine Fish Representative Species Expected to Occur Within the Local Assessment Area

Sub-component Representative Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Pacific Salmon												
Chum salmon[a]									🟩	🟢	🟩	🟩
Chinook salmon (overall)[b]			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Chinook salmon (stream-type)[c]			🟩	🟩	🟩	🟩	🟩	🟩	🟩			
Chinook salmon (ocean-type)[d]									🟩	🟩	🟩	
Reef Fish												
Lingcod[e]	🟧🟥	🟥🟧	🟧									🟧
Copper rockfish[f]	🟨	🟨	🟧	🟥	🟥	🟧	🟧				🟨	🟨
Quillback rockfish[f]	🟨	🟨	🟧	🟥	🟥	🟧	🟧				🟨	🟨
Forage Fish												
Pacific sand lance[g]	🟧	🟧									🟧	🟧
Pacific herring[h]		🟧🟥	🟥🟧	🟧	🟧⬜							
Shiner perch[i]				🟧	🟧	🟪	🟪	🟪	🟨	🟨		
Surf smelt[j]					🟧	🟧	🟧	🟧	🟧			
Flatfish												
English sole[k]	🟥	🟥	🟧	🟥	🟧	🟧	🟧	🟧	🟥	🟧	🟧	🟥
Starry flounder[l]		⬜🟧	🟥	🟧⬜								
Demersal Fish												
Threespine stickleback[m]				⬜🟨	🟨	🟨	🟨					
Pacific staghorn sculpin[n]	🟧	🟥	🟧	🟧						🟧	🟧	🟧

🟧 Spawning/reproduction
🟥 Peak spawning/reproduction
🟨 Breeding
🟪 Breeding and spawning/reproduction (i.e., occur simultaneously)
🟩 Spawning migration
🟢 Peak spawning migration

Notes:
a. Source: Salo 1991, Grant and Pestal 2009
b. Source: English et al. 2007
c. Source: Groot and Margolis 1991, Healey 1991, Boehlert 1997
d. Source: Healey 1991, McPhail 2007
e. Source: Cass et al. 1990
f. Source: Love et al. 2002
g. Source: Penttila 2007, de Graaf and Penttila 2011
h. Source: Hay and McCarter 2014
i. Source: Gordon 1965
j. Source: Therriault et al. 2002
k. Source: Kruse and Tyler 1983, Lassuy 1989
l. Source: Orcutt 1950
m. Source: Saimoto 1993, Triton 2004
n. Source: Mace 1983
Full references of sources identified in this table are included in EIS Sections 12.13 and 13.13.

Table IR4-18-3 Sensitive Life Periods of Juvenile Marine Fish Representative Species Expected to Occur Within the Local Assessment Area

Sub-component Representative Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Pacific Salmon												
Chum salmon[a]		🟦	🔷	🔷	🟦	🟦						
Chinook salmon[b]			🟦	🟦	🟦	🔷	🟦	🟦				
Reef Fish												
Lingcod[c]	🟧	🟧	🟧	🟧	🟩	🟩						
Copper rockfish[d]							🟩	🟩				
Quillback rockfish[d]							🟩	🟩				
Forage Fish												
Pacific sand lance[e]	🟧	🟧	🟧	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟧	🟧
Pacific herring[f]			🟧	🟧	🟧	🟩	🟩	🟩				
Shiner perch[g]				🟩	🟩	🟩	🟩	🟩	🟩			
Surf smelt[h]	🟩	🟩	🟩	🟩	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧
Flatfish												
English sole[i]	🟩	🟩	🟩	🟩	🟩	🟩	🟩				🟩	🟩
Starry flounder[j]	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Demersal Fish												
Threespine stickleback[k]	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Pacific staghorn sculpin[l]					🟩	🟩	🟩					

🟩 Recruitment
🟧 Egg development
🟦 Smolt seaward migration
🔷 Smolt peak seaward migration

Notes:
a. Source: Salo 1991, Grant and Pestal 2009
b. Source: Levings 1985, Cope 2012
c. Source: Cass et al. 1990
d. Source: Love et al. 2002
e. Source: Penttila 2007, de Graaf and Penttila 2011
f. Source: Hourston and Haegele 1980
g. Source: Gordon 1965
h. Source: Therriault et al. 2002
i. Source: Kruse and Tyler 1983, Lassuy 1989
j. Source: Orcutt 1950
k. Source: Saimoto 1993, Triton 2004
l. Source: Mace 1983

Full references of sources identified in this table are included in EIS Sections 12.13 and 13.13.

Overlap of Sensitive Life Periods with Juvenile Salmon and Crab Fisheries-Sensitive Windows

As outlined in Sections 12.7.1.2 and 13.7.1.2 in the EIS, to minimise direct mortality and physical injury from construction activities, fisheries-sensitive windows have been established by DFO for the protection of marine resources (and have been used previously at Roberts Bank).

To protect juvenile Pacific salmon, DFO guidelines restrict construction activities with the potential to result in adverse effects to juvenile Pacific salmon during a fisheries-sensitive window from March 1 to August 15, above –5.0 m Chart Datum (CD) (**Table IR4-18-4**). Further, a DFO fisheries-sensitive window to protect gravid female Dungeness crabs over the brood season extends from October 15 to March 30 below –5.0 m CD (**Table IR4-18-4**).

Table IR4-18-4 Fisheries and Oceans Canada Fisheries-sensitive Windows for the Protection of Juvenile Salmon and Gravid Female Dungeness Crabs

Fisheries-Sensitive Window	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Dungeness Crab (<-5.0 m CD)	🟥	🟥	🟥							◨	🟥	🟥
Juvenile Salmon (>-5.0 m CD)			🟥	🟥	🟥	🟥	🟥	◧				

🟥 DFO Dungeness crab and juvenile salmon fisheries-sensitive windows (EIS Sections 12.7.1.2 and 13.7.1.2, respectively).

Sensitive life periods of representative marine invertebrate and marine fish species are compared to the juvenile salmon fisheries-sensitive window (above -5.0 m CD) in **Table IR4-18-5**, and to the Dungeness crab fisheries-sensitive window (below -5.0 m CD) in **Table IR4-18-6**. Rationale on spatial and temporal overlap of sensitive life periods with Project-related construction activities is also provided.

Sensitive life periods for marine invertebrates are centred around the spring and summer months, approximately from late March through early September (**Table 4-18-1**), which is entirely covered by the juvenile salmon fisheries-sensitive window for all but the final month (late August and early September). Much of the marine invertebrate productivity in the LAA is concentrated across the intertidal sand/mudflats and in shallow sub-tidal areas (i.e., above -5.0 m CD) because this is where marine vegetation is most productive. Therefore, the juvenile salmon window encapsulates the majority of marine invertebrate sensitive life stages, both spatially and temporally.

Exceptions to the above are protected through the fisheries sensitive window for gravid Dungeness crabs (October 15 to March 31, below -5.0 m CD). This window also provides indirect protection for the spawning periods for orange sea pens and *Macoma* clams in early and late March, respectively as well as for infauna and epifauna and bivalves occurring at these depths.

Sensitive life periods for adult marine fish occur throughout the year with spawning/reproduction typically centered around the winter and spring months, approximately from December to June (**Table IR4-18-2**). Spawning in the intertidal and shallow subtidal areas of the LAA, typical of forage fish, occurs primarily in spring (with the exception of Pacific sandlance; **Table IR4-18-2**), and is covered by the juvenile salmon fisheries-sensitive window. Pacific sandlance spawn in the high intertidal during the winter months, outside the juvenile salmon fisheries-sensitive window; however, no Pacific sandlance spawning has been documented in the LAA (see EIS Section 13.5.3.1; **Table IR4-18-5**). In addition, adherence to environmental management plans (see EIS Section 33.3) will reduce the potential that Pacific sand lance will be affected by changes to water quality and sediment, or underwater noise during Project construction activities that will occur outside the fisheries-sensitive window.

Pacific herring spawning may start early during February, which would fall outside the juvenile salmon fisheries-sensitive window, but typically peaks in March (**Table IR4-18-2**), and is thus partially protected by the juvenile salmon fisheries-sensitive window. Pacific herring spawning is understood to be limited in the LAA relative to eastern Vancouver Island, where it is concentrated (based on literature (Gordon and Levings 1984, Hay and McCarter 2013, DFO 2016) and field studies undertaken at Roberts Bank by the VFPA from 2007 to 2015). In response to anecdotal reports by a member of the public of herring spawn on eelgrass on the north side of the Roberts Bank causeway in early April 2017 (CEAR Document #955[4]), the VFPA conducted a survey to document presence and distribution of herring spawning activity at Roberts Bank. Survey results are in agreement with existing conditions described in EIS Section 13.5.3.3, and confirm that while the LAA does support some spawn, it does not appear to be an important herring spawning area. Adherence to environmental management plans (see EIS Section 33.3) will reduce the potential that herring will be affected by changes to water quality and sediment, or underwater noise during Project construction activities that will occur outside the fisheries-sensitive window. Notwithstanding the above, a potential for interaction with the Project has been identified and a residual effect has been assessed as not significant (see EIS Section 13.8.1).

Spawning/reproduction in subtidal areas of the LAA, typical of reef fish, flatfish, and some demersal fish, occurs primarily during winter through to early spring (**Table IR4-18-2**), and is covered by the Dungeness crab fisheries-sensitive window. Exceptions include English sole, Pacific staghorn sculpin, and rockfish. English sole exhibit several spawning events throughout the year (with some occurring outside the Dungeness crab fisheries-sensitive window; **Table IR4-18-2**); however, English sole spawn in depths ranging from 50 m to 110 m (Lassuy 1989, McCain et al. 2005), thus no spatial overlap with Project construction activities is anticipated. Similarly, Pacific staghorn sculpin reproduction occurs partially outside the Dungeness crab fisheries-sensitive window (in fall and winter; **Table IR4-18-2**), however, spawning takes place away from freshwater influence, as eggs and larvae are not tolerant of low salinities (Tasto 1975). Thus, no spatial overlap with Project construction activities is anticipated. Lastly, rockfish reproduction occurs primarily in spring (outside the Dungeness crab fisheries-sensitive window; **Table IR4-18-2**), and has the potential to interact with the Project (see EIS Section 13.8.1). However, adherence to environmental management plans

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[4] CEAR Document #955 From Douglas Swanston to the Review Panel re: Comments on the Roberts Bank Terminal 2 Project.

(see EIS Section 33.3) will minimise the potential that rockfish will be affected by changes to water quality and sediment, or underwater noise during Project construction activities that will occur outside the fisheries-sensitive window. A potential residual effect to rockfish is thus assessed as negligible (see EIS Section 13.8.1).

Pacific salmon upriver migration occurs through deeper waters of the LAA and, depending on species, extends from spring through to late fall (**Table IR4-18-2**). Upriver migration of Pacific salmon partially overlaps with the Dungeness crab and the juvenile salmon fisheries-sensitive windows. Some interaction with the Project may occur for Pacific salmon migrating during late summer and early fall (**Table IR4-18-6**). However, adult migrating Pacific salmon are adapted to natural turbid conditions, and tend to move past the river mouth as quickly as possible taking advantage of flood tides (Quinn 2005, Welch et al. 2014); hence, any potential Project-related effect is considered negligible (see EIS Section 13.6.2). Further, environmental management plans will reduce the potential that salmon will be affected by changes to water quality and sediment, or underwater noise during Project construction activities that will occur outside the fisheries-sensitive window.

Sensitive life periods for juvenile marine fish, particularly peak outmigration of juvenile Pacific salmon and recruitment into the shallow waters of the LAA of juvenile forage fish, flatfish, and demersal fish, overlap with the juvenile salmon fisheries-sensitive window, with no anticipated interaction with the Project (**Table IR4-18-5**). Egg development of Pacific sandlance and surf smelt extends outside the juvenile salmon fisheries-sensitive window (**Table IR4-18-3**); however, no spawning has been documented for these forage fish in the LAA (see EIS Section 13.5.3). An interaction with the Project is anticipated for flatfish during recruitment in shallow waters of the LAA that extends beyond the juvenile salmon fisheries-sensitive window (**Table IR4-18-3**); a residual effect has been assessed as not significant (see EIS Section 13.8.1).

Sensitive life periods of juvenile marine fish that occur in the deeper waters of the LAA during fall and winter months are afforded protection with implementation of the Dungeness crab fisheries-sensitive window (**Table IR4-18-6**). Recruitment of flatfish that occurs in spring and summer and extends beyond the Dungeness crab fisheries-sensitive window is anticipated to interact with Project-related construction activities (**Table IR4-18-3**); a residual effect has been assessed as not significant (see EIS Section 13.8.1). Implementation of environmental management plans will further reduce the potential that juvenile marine fish will be affected by changes to water quality and sediment, or underwater noise during Project construction activities that will occur outside the fisheries-sensitive window.

Table IR4-18-5 Sensitive Life Periods of Marine Invertebrate and Adult and Juvenile Marine Fish Representative Species Relative to Juvenile Salmon Fisheries-Sensitive Window (Above -5.0 Metres Chart Datum)

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Legend													
🟩	Sensitive life periods protected by fisheries-sensitive window for juvenile salmon												
▨	Sensitive life periods not protected by fisheries-sensitive window for juvenile salmon; Project effects not anticipated												
🟨	Sensitive life periods not protected by fisheries-sensitive window for juvenile salmon; potential for Project effects												
Marine Invertebrates													
Macrofauna and meiofauna	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩🟨	🟨	🟨	🟨	🟨	Many species of infauna and epifauna occur within shallow intertidal waters at Roberts Bank where breeding, spawning, and recruitment occur predominantly in summer months. Sensitive life periods are protected by the juvenile salmon fisheries-sensitive window during much of the peak period, but not throughout the rest of the year. Spatial overlap with Project activities is anticipated for sensitive life periods outside the fisheries-sensitive window. With mitigation, a residual minor increase in productive potential is predicted (EIS Section 12.8.1).
Pacific oyster							🟩	🟩🟨	🟨				Bivalve shellfish occur within intertidal and shallow subtidal waters at Roberts Bank (i.e., Pacific oysters in the intertidal and shallow subtidal (Gillespie et al. 2012); Pacific littleneck clam primarily in the intertidal (Hancock et al. 1979); heart cockle in the low intertidal and shallow subtidal, especially in eelgrass areas (Clayton 2003) and within coarse sand to silt/clay (Gallucci and Gallucci 1982)). Sensitive life periods are protected by the juvenile salmon fisheries sensitive window partially, but not from mid-August to December. Spatial overlap with Project activities is anticipated for sensitive life periods outside the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 12.8.1).
Pacific littleneck clam				🟩	🟩	🟩	🟩	🟩🟨	🟨	🟨	🟨		
Heart cockle				🟩	🟩	🟩	🟩	🟩🟨	🟨	🟨	🟨	🟨	

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Macoma clam			🟩	🟩	🟩	🟩	🟩						*Macoma* clams inhabit intertidal and shallow subtidal habitats at Roberts Bank, at elevations where the juvenile salmon fisheries-sensitive window applies. Most occur in soft muddy substrates, muddy sand, and eelgrass beds. Sensitive life periods are entirely protected by the juvenile salmon fisheries-sensitive window.
Bay mussel				🟩	🟩	🟩	🟩						Bay mussels are common in the intertidal and subtidal zones of Roberts Bank (Burd et al. 2008). Sensitive life periods are entirely protected by the juvenile salmon fisheries-sensitive-window.
Dungeness crab	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩🟨	🟨	🟨▨	▨	▨	Adults migrate to shallow waters to breed from March to June, a period protected by the juvenile salmon fisheries-sensitive window. Larvae settle in intertidal and shallow subtidal estuarine areas (Rasmuson 2013), and juveniles rely heavily on habitats characterised by mixed sand or gravel with vegetated cover such as eelgrass. This sensitive recruitment period is protected from mid-May through mid-August by the juvenile salmon fisheries-sensitive window, but not afterwards during the time of egg settlement (McMillan et al. 1995). Some spatial overlap with Project activities is anticipated for sensitive life periods outside the fisheries-sensitive window. With mitigation, potential residual loss in productivity has been assessed as not significant (see EIS Section 12.8.1).

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Adult Marine Fish													
Pacific sand lance	▨	▨									▨	▨	Spawning occurs in the high intertidal outside the juvenile salmon fisheries-sensitive window. Suitable spawning habitat was identified on the north side of the Roberts Bank causeway, though no spawning has been documented in the LAA (see EIS Section 13.5.3.1). Forage fish are unlikely to spawn in the upper intertidal at Roberts Bank where moderate to dense cover of salt marsh vegetation dominates. The majority of Pacific sand lance burying habitat is in deeper waters (up to 80 m; Robinson et al. 2013), and spatial overlap with Project activities is not anticipated.
Pacific herring		🟨	🟩	🟩	🟩								Spawning occurs in the low intertidal and shallow subtidal, on marine vegetation; herring spawn is considered limited in the LAA relative to eastern Vancouver Island, where it is concentrated. Much of this sensitive life period, including peak spawning in early March, is protected by the juvenile salmon fisheries-sensitive window. Some overlap with Project activities is anticipated for spawning that may occur outside the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Shiner perch				🟩	🟩	🟩	🟩	🟩▨	▨	▨			Peak breeding occurs in shallow waters from April to August and is protected by the juvenile salmon fisheries-sensitive window. Adults migrate to deeper waters in the fall.

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Surf smelt					🟩	🟩	🟩	🟩▨	▨				Adults spawn in the upper intertidal intermittently between May and September; the majority of this sensitive life period is protected by the juvenile salmon fisheries-sensitive window. No surf smelt eggs were documented in the LAA during field studies conducted for the Project (see EIS Section 13.5.3.2). Forage fish are unlikely to spawn in the upper intertidal at Roberts Bank where moderate to dense cover of salt marsh vegetation dominates; no spatial overlap with Project activities is anticipated.
Starry flounder		🟨	🟩	🟩									Spawning occurs in shallow (<45 m), sheltered estuarine areas (Leet et al. 2001), between mid-February and April. Peak spawning (in March), and the majority of the spawning season, is protected by the juvenile salmon fisheries-sensitive window. Some interaction with Project activities is anticipated during the earliest portion of spawning activity that may occur in shallow waters outside the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Threespine stickleback				🟩	🟩	🟩	🟩						Breeding occurs typically in freshwater, hence, no spatial overlap with Project activities is anticipated. Some spawning has been reported in shallow brackish water (Bell et al. 1994, Mattern et al. 2007), but typically from April to August (Saimoto 1993). Thus, this sensitive life period is entirely protected by the juvenile salmon fisheries-sensitive window.
Juvenile Marine Fish													
Chum salmon		▨	🟩	🟩	🟩	🟩							Pacific salmon peak outmigration and estuarine rearing is protected by the juvenile salmon fisheries-sensitive window.
Chinook salmon (overall)			🟩	🟩	🟩	🟩	🟩	🟩▨					

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Pacific sand lance	▨	▨	▨	🟩	🟩	🟩	🟩	🟩▨	▨	▨	▨	▨	The majority of nearshore recruitment/rearing is protected by the juvenile salmon fisheries-sensitive window. No eggs or spawning activity were detected during field studies conducted for the Project (see EIS Section 13.5.3.1). The fine sediment associated with moderate to dense areas of marsh vegetation is likely not conducive to forage fish spawning (see EIS Section 13.5.3). Thus, no spatial overlap with Project activities is anticipated during Pacific sand lance egg development that may extend beyond the fisheries-sensitive window.
Pacific herring			🟩	🟩	🟩	🟩	🟩	🟩▨					The majority of egg development and nearshore recruitment/rearing are protected by the juvenile salmon fisheries-sensitive window.
Shiner perch				🟩	🟩	🟩	🟩	🟩▨	▨				The majority of nearshore recruitment/rearing is protected by the juvenile salmon fisheries-sensitive window. Juveniles move into deeper waters (>20 m) by mid-September and recruit into the adult population.
Surf smelt	▨	▨	🟩	🟩	🟩	🟩	🟩	🟩▨	▨	▨	▨	▨	Egg development and estuarine recruitment/rearing occur throughout the year. Portions of these sensitive life periods are protected by the juvenile salmon fisheries-sensitive window. No eggs or spawning were detected during field studies conducted for the Project (see EIS Section 13.5.3.2). The fine sediment associated with moderate to dense areas of marsh vegetation is likely not conducive to forage fish spawning (see EIS Section 13.5.3). Thus, no spatial overlap with Project activities is anticipated during surf smelt egg development that may extend beyond the fisheries-sensitive window.

Sub-component Representative Species	**Month**												**Comment on Spatial and Temporal Overlap with Project Activities**
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	
English sole	🟨	🟨	🟩	🟩	🟩	🟩	🟩				🟨	🟨	Juveniles typically rear in intertidal waters using mud, sand, eelgrass, and lower side channels (Toole et al. 1987, Rooper et al. 2003). As they grow, juveniles move into progressively deeper waters (Lassuy 1989). Portion of this sensitive life period is protected by the juvenile salmon fisheries-sensitive window. Spatial overlap with Project activities is anticipated during rearing outside the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Starry flounder	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩🟨	🟨	🟨	🟨	🟨	Juveniles rear in brackish water, over mud and sand (Moles and Norcross 1995, Leet et al. 2001). Portion of this sensitive life period is protected by the juvenile salmon fisheries sensitive-window. Spatial overlap with Project activities is anticipated during rearing that may extend beyond the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Threespine stickleback	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟩🟨	🟨	🟨	🟨	🟨	Juveniles are commonly found on sand and mudflats throughout the year. Portion of this sensitive life period is protected by the juvenile salmon fisheries sensitive-window. Spatial overlap with Project activities is anticipated during rearing outside the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Pacific staghorn sculpin					🟩	🟩	🟩						Juveniles recruit to shallow estuarine areas from May to July (Mace 1983). This sensitive life period is entirely protected by the juvenile salmon fisheries-sensitive window.

🟩	Sensitive life periods protected by fisheries-sensitive window for juvenile salmon
▨	Sensitive life periods not protected by fisheries-sensitive window for juvenile salmon; Project effects not anticipated
🟨	Sensitive life periods not protected by fisheries-sensitive window for juvenile salmon; potential for Project effects

Note: Orange sea pen, lingcod and rockfish primarily occupy waters below -5.0 m CD, including during sensitive life periods. Consequently, they are not included in this table.

Full references identified in this table are included in EIS Sections 12.13 and 13.13.

Table IR4-18-6 Sensitive Life Periods of Marine Invertebrate and Adult and Juvenile Marine Fish Representative Species Relative to Dungeness Crab Fisheries-Sensitive Window (Below -5.0 Meters Chart Datum)

Legend

🟩 Sensitive life periods protected by fisheries-sensitive window for Dungeness crab
▩ Sensitive life periods not protected by fisheries-sensitive window for Dungeness crab; Project effects not anticipated
🟨 Sensitive life periods not protected by fisheries-sensitive window for Dungeness crab; potential for Project effects

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Marine Invertebrates													
Macrofauna and meiofauna									🟨	🟨🟩	🟩	🟩	Many species of infauna and epifauna occur within subtidal waters below -5 m CD where breeding, spawning, and recruitment occur predominantly in summer months. These sensitive life stages are partially protected by the Dungeness crab fisheries-sensitive window, but not during peak spawning in the summer. Spatial overlap with Project activities is anticipated for sensitive life periods outside the fisheries-sensitive window. With mitigation, a residual increase in productive potential is predicted (see EIS Section 12.8.1).
Dungeness crab	🟩	🟩	🟩	🟨	🟨	🟨				🟩	🟩	🟩	Brooding of gravid females is entirely protected by the Dungeness crab fisheries-sensitive window. Spatial overlap with Project activities is anticipated for sensitive life periods occurring outside the fisheries-sensitive window. With mitigation, a residual loss in productivity has been assessed as not significant (see EIS Section 12.8.1).
Orange sea pen			🟩	🟨									Peak spawning is protected by the Dungeness crab fisheries-sensitive window; some spatial overlap with Project activities may occur during late spawning in April. With mitigation, a residual loss in productivity has been assessed as not significant (see EIS Section 12.8.1).

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Adult Marine Fish													
Chum salmon									▨	▨🟩	🟩	🟩	Adult chum and Chinook during their return migration tend to swim through deeper waters (occupying intermediate depths in the water column) that are cooler, more saline, and well-mixed (Quinn 2005, Welch et al. 2014). This sensitive life period is partially protected by the Dungeness crab fisheries-sensitive window, but not between April and mid-October. As such, some interaction with the Project is anticipated, albeit small as Pacific salmon migrating upriver tend to move past the river mouth as quickly as possible by taking advantage of flood tides (Quinn 2005, Welch et al. 2014).
Chinook salmon			🟩	▨	▨	▨	▨	▨	▨	▨🟩	🟩		
Lingcod	🟩	🟩	🟩									🟩	During winter (January to March), adult lingcod move into nearshore rocky habitats with high tidal current or wave action to spawn (Cass et al. 1990). This sensitive life period is protected by the Dungeness crab fisheries-sensitive window.
Copper rockfish	🟩	🟩	🟩	🟨	🟨	🟨	🟨				🟩	🟩	Rockfish associate with rocky substrates in deeper subtidal areas at Roberts Bank. Mating, which extends from November to March, is protected by the Dungeness crab fisheries-sensitive window. Live birth of young occurs between March and July (peaking in April-May), outside the fisheries-sensitive window; thus, some spatial overlap with Project activities is anticipated. With mitigation, a residual loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Quillback rockfish	🟩	🟩	🟩	🟨	🟨	🟨	🟨				🟩	🟩	
English sole	🟩	🟩	🟩	▨	▨	▨	▨	▨	▨	▨🟩	🟩	🟩	Spawning occurs throughout the year with peaks in the winter through to spring. This sensitive life period is partially protected by the Dungeness crab fisheries-sensitive window from mid-October through March. However, as spawning occurs at depths ranging from 50 m to 110 m (Lassuy 1989, McCain et al. 2005), no spatial overlap is anticipated with Project activities that may occur outside the fisheries-sensitive window.

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Starry flounder		⬜🟩	🟩	🟨⬜									Spawning occurs in shallow (<45 m), sheltered estuarine areas (Leet et al. 2001), and may occur below -5 m CD. Peak spawning is protected by the Dungeness crab fisheries-sensitive window. Some interaction with Project activities is anticipated during the tail-end portion of spawning activity that may occur in deeper waters outside the fisheries-sensitive window. With mitigation, a residual loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Pacific staghorn sculpin	🟩	🟩	🟩	🟨						🟨🟩	🟩	🟩	Spawning likely occurs in deeper waters at Roberts Bank away from freshwater influence, because eggs and larvae are not tolerant of low salinities (Tasto 1975). Spawning occurs from October through April, peaking in February (Tasto 1975). Most of this sensitive life period is protected by the Dungeness crab fisheries-sensitive window. Some spatial overlap with Project activities, such as dredging, is anticipated during the beginning and tail-end of the spawning activity, which may extend beyond the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Juvenile Marine Fish													
Lingcod	🟩	🟩	🟩	🟨	🟨	🟨							Egg development and initial juvenile recruitment to inshore areas are partially protected by the Dungeness crab fisheries-sensitive window. Some spatial overlap with Project activities is anticipated during transitioning of older juveniles to deeper sand or mud bottom habitats in spring (Jagielo and Wallace 2005), outside the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).

Sub-component Representative Species	Month												Comment on Spatial and Temporal Overlap with Project Activities
	J	F	M	A	M	J	J	A	S	O	N	D	
Copper rockfish							🟨	🟨					Juveniles recruit to nearshore hard-bottom habitats in July and August (Love et al. 2002), outside the Dungeness crab fisheries-sensitive window; thus, spatial overlap with Project activities is anticipated. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).
Quillback rockfish							🟨	🟨					
English sole	🟩	🟩	🟩	🟨	🟨	🟨	🟨				🟩	🟩	Recruitment primarily occurs at shallow elevations above -5 m CD, and as they grow, English sole move into progressively deeper waters. This sensitive life period is partially protected by the Dungeness crab fisheries-sensitive window; some spatial overlap with Project activities is anticipated in deeper areas where juvenile recruitment may occur outside the fisheries-sensitive window. With mitigation, a potential loss in productivity has been assessed as not significant (see EIS Section 13.8.1).

🟩 Sensitive life periods protected by fisheries-sensitive window for Dungeness crab
🟢 Sensitive life periods not protected by fisheries-sensitive window for Dungeness crab; Project effects not anticipated
🟨 Sensitive life periods not protected by fisheries-sensitive window for Dungeness crab; potential for Project effects

Note: Forage fish, and bivalve shellfish primarily occupy waters above -5.0 m CD, including during sensitive life periods. Consequently, they are not included in this table.

Full references identified in this table are included in EIS Sections 12.13 and 13.13.

Provide a summary of the effects of Project activities on different life stages of fish and invertebrates that occupy the local assessment area outside of the juvenile salmon and crab protection windows.

Project effects (productivity changes) on marine invertebrates and marine fish sub-components (species/life-history stages) that may result from Project activities, including those that may overlap with sensitive life periods of marine invertebrates and marine fish outside the fisheries-sensitive windows, have been assessed (EIS Sections 12.6 and 13.6) and were summarised in the text above and in **Tables IR4-18-5** and **IR4-18-6**.

Mechanisms by which interactions with the Project can influence productivity of marine invertebrates and marine fish (consistent with EIS Sections 12.6.1 and 13.6.1) are as follows:

1) Entrainment, burial, or physical disturbance during Project-related construction activities (e.g., dredging, structure placement), leading to injury and direct mortality of marine invertebrates and marine fish;
2) Changes in the acoustic environment as a result of underwater noise generated during Project-related construction and operation activities, leading to injury and mortality, or behavioural effects of marine fish;
3) Changes in water quality during Project-related construction activities as a result of induced turbidity, contaminant resuspension, and changes in coastal geomorphology (including changes in salinity); and during Project-related operation activities as a result of salinity changes and effluent discharge and other operational procedures, leading to long-term physiological stress and behavioural effects of marine invertebrates and marine fish;
4) Changes in sedimentation and coastal processes during Project-related construction activities, such as dredging, and terminal placement, leading to effects on individual performance or habitat quality for marine invertebrates and marine fish;
5) Changes in the light environment in the form of shading (in the day) or artificial lighting (at night), from overwater structures and associated activities during Project-related construction and operation, leading to effects on individual marine fish performance and behavioural effects;
6) Changes in habitat availability as a result of terminal placement and causeway expansion, leading to the permanent loss of intertidal and subtidal habitat of marine invertebrates and marine fish; and
7) Changes in biotic interactions, namely changes in the abundance of predators relative to their prey, with implications in productivity of marine invertebrates and marine fish at the ecosystem level.

Based on multiple lines of evidence (including empirical studies, consideration of outputs of the Roberts Bank ecosystem model and other models, literature, and professional opinion), prior to implementation of mitigation during Project construction and operation, minor[5] productivity change is assessed for all marine invertebrate and marine fish sub-components,

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[5] A change (increase or decrease) in productivity of marine invertebrates and marine fish is considered negligible between 0% and 5%, minor between 6% and 30%, and moderate between 31% and 60%.

with the exception of orange sea pen (productivity change is assessed as moderate) (EIS Tables 12-12 and 13-12). During Project operation and prior to implementation of mitigation, productivity change of Chinook and chum adult salmon and lingcod is assessed as negligible (EIS Tables 12-12 and 13-12).

Following implementation of mitigation (EIS Sections 12.7 and 13.7), including adherence to fisheries-sensitive timing windows, implementation of environmental management plans during Project construction (i.e., Marine Species Salvage Plan, Underwater Noise Management Plan, Light Management Plan, and Construction Compliance Monitoring Plan; see EIS Section 33.3), and habitat offsetting, a residual adverse effect is identified for bivalve shellfish, Dungeness crab, and orange sea pen, as well as for forage fish and flatfish (EIS Sections 12.8 and 13.8). Potential residual effects are characterised qualitatively by considering magnitude, extent, duration, reversibility, and frequency (as defined in EIS Tables 12-13 and 13-13 for marine invertebrates and marine fish, respectively). Potential residual effects for representative species and sub-components mentioned above (and summarised in **Tables IR4-18-5** and **IR4-18-6**) are assessed as not significant (see EIS Sections 12.9 and 13.9).

In summary, potential Project-related effects on sensitive life periods that may occur outside the fisheries-sensitive windows are considered in the EIS and assessed in EIS Sections 12.0 and 13.0, for marine invertebrates and marine fish, respectively. Adherence to fisheries-sensitive windows will avoid interaction of Project construction activities with marine species' sensitive life periods. Implementation of environmental management plans will further reduce the potential that marine species' sensitive life periods will be affected during Project construction activities that will occur outside the fisheries-sensitive window.

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IR4-19 Marine Invertebrates Marine Fish and Fish Habitat – Intermediate Transfer Pit

Information Source(s)

EIS Volume 3: Section 12; Section 13; Appendix 12-A, Figure 5-1, Figure 6-1

Context

The EIS contains conflicting information for existing habitat conditions within the intermediate transfer pit. In Appendix 12-A, of the EIS, the habitat suitability model suggests that the intermediate transfer pit area is highly suitable habitat for gravid female Dungeness crabs (Figure 5-1), and that it is moderately suitable habitat for Pacific sand lance (Figure 6-1). However, Section 13.6.3.4 of the EIS states that *Beggiatoa* was also found to be present within the intermediate transfer pit, suggesting that the substrate may be anoxic in some areas.

The intermediate transfer pit would alter 33 ha of subtidal habitat for 4 years during Project construction; however, it does not appear to be fully considered in the effects assessments for each valued component or sub-component.

For example:

- the intermediate transfer pit was not identified as a direct source of mortality of infaunal and epifaunal invertebrates;
- the intermediate transfer pit footprint was not considered in the assessment of loss of habitat for Dungeness crabs; and
- the Proponent identified that dredging at the intermediate transfer pit may affect buried Pacific sand lance but also stated that the addition of Fraser River sand to the intermediate transfer pit may be temporarily favourable for Pacific sand lance.

A summary of the existing habitat characteristics within the intermediate transfer pit footprint and the potential effects of the intermediate transfer pit on marine invertebrates and marine fish is required

Information Request

Provide a summary of the habitat characteristics within the proposed footprint of the intermediate transfer pit. Include a description of the current utilization of the intermediate transfer pit area by marine fish and marine invertebrates.

Provide an assessment of the potential effects of Project activities in the intermediate transfer pit on marine fish and marine invertebrate sub-components, with the exception of Dungeness crab (see IR4-~~19~~20[1]).

VFPA Response

The VFPA has revised the Project's construction plan to eliminate temporary storage of Fraser River sand in the intermediate transfer pit (ITP). As such, predicted effects to valued components from this activity will not be realised. For more information concerning the elimination of the ITP from the Project's construction plan, please see *Information Request Package 3 Preamble in Support of Responses to IR3-25 to IR3-40 – General and Disposal at Sea-related Project Construction Update* in Part 2 of CEAR Document #984[2].

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[1] The original information request as posted (CEAR Document #946) referred to IR4-19. This is assumed to be a typographical error, and the correct reference is assumed to be IR4-20.

[2] CEAR Document #894 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document #928).

IR4-20 Marine Invertebrates -Dungeness Crab: Habitat Suitability in ITP

Information Source(s)

EIS Volume 1: Figure 4-9

EIS Volume 3: Section 12; Table 12-9

Context

Table 12-9 of the EIS shows that the Proponent has not included the intermediate transfer pit footprint in its assessment of loss of habitat for Dungeness crab. As this area is scheduled to be used for the storage of sand for the first 4 years of construction, including throughout the brooding seasons for Dungeness crab (Figure 4-9), an assessment of the potential effects of the intermediate transfer pit on Dungeness crabs is required.

Information Request

Provide the footprint area for the intermediate transfer pit and identify areas of overlap with high, moderate, and low suitability habitat for Dungeness crab in all life stages.

Assess the potential effects of the proposed Project activities in the intermediate transfer pit on Dungeness crabs and Dungeness crab productivity.

VFPA Response

The VFPA has revised the Project's construction plan to eliminate temporary storage of Fraser River sand in the intermediate transfer pit (ITP). As such, predicted effects to valued components, including Dungeness crabs, from this activity will not be realised. For more information concerning the elimination of the ITP from the Project's construction plan, please see *Information Request Package 3 Preamble in Support of Responses to IR3-25 to IR3-40 – General and Disposal at Sea-related Project Construction Update* in Part 2 of CEAR Document #984[1].

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[1] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document #928).

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IR4-21 Marine Invertebrates – Clarification: Information Sources

Information Source(s)

EIS Volume 3: Section 12

TDR MF-2 Marine Benthic Subtidal Study

TDR MI-2 Juvenile Dungeness Crabs

TDR MI-4 Dungeness Crab Productivity

Context

According to Fisheries and Oceans Canada, some source materials in Section 12 of the EIS and supporting studies were inaccurate.

For example:

- In the Dungeness Crab Productivity report, August was stated as the peak timing of Dungeness crab megalopae settlement. Dunham et al. 2011 was cited as a source; however, this is not stated in Dunham et al. 2011.
- In EIS Section 12, the Juvenile Dungeness Crabs report was referenced as a source of information on Littleneck clam and Cockle age at sexual maturity; however, this report does not contain information on littleneck clam and cockle.
- EIS Section 12 referenced a document from Waddell purported to have been published in 1984, however the document being referenced was published in 1985 and updated in 1986. The updated version is the only version publicly available at this time. It is unclear if an out of date, draft report was used or if the reference was made in error.

Information Request

Clarify the information source used for the peak timing of crab megalopae settlement and verify that August is the peak timing for settlement.

Clarify what information sources were used for Littleneck clam and Cockle.

Clarify whether the information in the EIS obtained from the cited Waddell reference (1984) is consistent with the updated (1986) version of the document.

VFPA Response

Clarify the information source used for the peak timing of crab megalopae settlement and verify that August is the peak timing for settlement.

The Dungeness Crab Productivity Technical Report (TDR MI-4 in Appendix AIR10-C of Additional Information Request #10[1], page 10) states "settlement occurs progressively later at higher latitudes, except in the Strait of Georgia where, in most years, settlement extends from late June through September, peaking in August" and cites Dunham et al. (2011) as the reference.

This reference is correct for the first half of this sentence (i.e., later at high latitudes); however, DFO correctly points out that Dunham et al. (2011) do not report settlement peaking in August. The "peaking in August" point is substantiated by several sources (which were not cited in the EIS), including the following:

- MacKay and Weymouth (1935) as cited in McMillan et al. (1995), who reported peak settlement in August in Boundary Bay;
- McMillan et al. (1995), who state "peak densities typically occurred in August";
- Fong and Gillespie (2008) who observe "megalops are found primarily in July and August in B.C."; and
- Dinnel et al. (1986), who record "settlement of new recruits started in July, peaked in August, and continued through September".

Clarify what information sources were used for Littleneck clam and Cockle.

The Hemmera 2014e citation to the Juvenile Dungeness Crabs Technical Data Report (TDR MI-2 in Appendix AIR10-C of AIR-12.04.15-10) was an error. The correct citation is Appendix 27-C of the EIS: "Shellfish Harvesting Potential and Contaminant-Related Consumption Risks at Roberts Bank".

As cited in EIS Appendix 27-C, the information source for littleneck clam age/size at maturity (2 to 3 years; 25-35 mm) is Quayle (1943). Information sources for cockle age at maturity (2 years) include Edmondson (1920), Fraser (1931), and Galluci and Galluci (1982).

Clarify whether the information in the EIS obtained from the cited Waddell reference (1984) is consistent with the updated (1986) version of the document.

The citation to Waddell (1984) was an error. The correct citation is the 1986 version of the report (as pointed out by DFO). The information in the EIS obtained from the Waddell reference reflects the 1986 document.

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[1] AIR-12.04.15-10 in CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

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IR4-22 Marine Invertebrates – Clarification: Definition of Recruitment

Information Source(s)

EIS Volume 3: Section 12

TDR MI-2 Juvenile Dungeness Crabs

Context

The term recruitment was used throughout the Juvenile Dungeness Crabs report in reference to recruitment variability; however, the term was not defined. It is unclear whether recruitment variability refers to larval settlement, juvenile densities/abundance, or a stock-recruit relationship in the document.

Information Request

Clarify the definition of recruitment used in the Juvenile Dungeness Crabs report.

Explain whether recruitment variability refers to larval settlement, juvenile densities/abundance, or a stock-recruit relationship.

VFPA Response

Clarify the definition of recruitment used in the Juvenile Dungeness Crabs report.

The term 'recruitment' is used to represent two different concepts within the Dungeness crab assessment (and associated technical data reports; including TDR MI-2 in Appendix AIR10-C of Additional Information Request #10[1]), both of which are widely accepted (e.g., Botsford 2001; Mackenize 2010). To clarify:

- In the Juvenile Dungeness Crabs Technical Data Report (TDR MI-2), the term 'recruitment' was defined in an ecological context as "the addition of individuals to local populations following settlement from the pelagic (planktonic) phase". For this study, it was measured as intertidal density of juvenile[2] crabs; and
- In the Dungeness Crab Productivity Technical Data Report (TDR MI-4 in Appendix AIR10-C of AIR-12.04.15-10[1]), 'recruitment' was defined in a fisheries

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[1] AIR-12.04.15-10 of CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

[2] As outlined in IR4-24 and stated in TDR MI-2 Section 3.3 p. 9 "For this study, juveniles were classified as crabs with carapace widths of <15 mm (including megalopae) to 100 mm (for females) and 120 mm (for males), consistent with the published sizes-at-maturity (Dunham et al. 2011)".

context as the number of crabs entering the smallest size classes of the crab stock each year (i.e., the number of crabs entering a fishable size class).

Both applications of the term were used within EIS Section 12.0, but under different subheadings. Under the 'larvae' subheading of EIS Section 12.5.3.3, recruitment refers to the first, 'ecological' definition of the term while under the 'adults' subheading of EIS Section 12.5.3.3, recruitment refers to the fisheries definition.

Explain whether recruitment variability refers to larval settlement, juvenile densities/abundance, or a stock-recruit relationship.

In the Juvenile Dungeness Crab Technical Data Report (TDR MI-2), 'recruitment variability' refers to a combination of larval settlement and juvenile densities/abundance; it does not refer to a stock recruit relationship. Further information on how the term 'juvenile' is defined is presented to give additional clarity on its influence on how 'recruitment variability' is used and interpreted.

The definition of 'juvenile' is broad (i.e., from megalope through to sub-adults at the cusp of sexual maturity); hence, references to recruitment variability in TDR MI-2 reflect both megalopae (larval settlement) and juvenile densities/abundance. The broad definition of 'juvenile' used in the EIS, and specifically in TDR MI-2, was consistently and intentionally applied in order to be as conservative as possible. This broad definition is considered conservative because it enables the capture of ontogenetic shifts[3] in habitat use, providing not only an understanding of what habitats are preferred by Dungeness crabs to settle and rear, but also ensuring that all potential effects are identified and described, as the potential for interaction with Project components and activities changes as crabs grow and shift to different habitats.

References

Botsford, L. W. 2001. Physical Influences to Recruitment to California Current Invertebrate Populations on Multiple Scales. ICES Journal of Marine Science 58:1081–1091.

Claessen, D. and U. Dieckmann. 2002. Ontogenetic Niche Shifts and Evolutionary Branching in Size-Structured Populations. Evolutionary Ecology Research. 4: 189 – 217.

Dunham, J. S., A. Phillips, J. Morrison, and G. Jorgensen. 2011. A Manual for Dungeness Crab Surveys in British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences 2964.

MacKenzie, C. J. 2010. The Dungeness Crab (Metacarcinus magister) Fishery in Burrard Inlet, BC: Constraints on Abundance-based Management and Improved Access for Recreational Harvesters. MRM project report. Simon Fraser University, Burnaby B.C.

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[3] In size-structured populations, such as Dungeness crabs, it is common for individuals to exploit several niches (including habitats) sequentially in the course of their life history (Werner and Gilliam 1984). The change during life history from one niche (or habitat) to another is referred to as an ontogenetic shift (Claessen and Dieckmann 2002).

Werner, E. E. and J. F. Gilliam. 1984. The Ontogenetic Niche and Species Interactions in Size-structured Populations. Annual Review of Ecology, Evolution, and Systematics. 15: 393–425.

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IR4-23 Marine Invertebrates – Dungeness Crab: Gravid Crab Survey

Information Source(s)

EIS Volume 1: Figure 4-9

EIS Volume 3: Section 12; Appendix 12-A

TDR MF-2 Marine Benthic Subtidal Study

Context

The literature review presented in the Marine Benthic Subtidal Study suggests that Dungeness crab female brooding habitat has specific attributes, such as medium sediment sized sandy substrates, relatively shallow depths, but deep enough to offer temperature and salinity stability, and female crabs often return to the same location for many years. The Marine Benthic Subtidal Study thus suggested that habitats relating to sensitive brooding life history stage should be considered high management and mitigation priorities during anthropogenic development.

The habitat suitability model found that highly to moderately suitable gravid female crab habitat was the most limited habitat type within the local assessment area. Fisheries and Oceans Canada calculated that highly to moderately suitable gravid female crab habitat would decrease by 19% as a result of the Project footprint, not including any potential loss in the intermediate transfer pit footprint.

In Section 12 of the EIS, the Proponent identified limitations to the data collected to support the assessment of Project related effects to gravid female Dungeness crabs and stated that these limitations may have biased the results of the study. For example, SCUBA surveys were conducted at the end of the brooding season, over three days, to maximum depth of 18m, and in poor visibility and strong currents. Additionally, gravid female Dungeness crabs are difficult to detect as they are buried in sand while brooding, with only their eyestalks and mouth at the sand surface.

As noted in the literature review section of the Marine Benthic Subtidal Study, the brooding season for female Dungeness crabs occurs over several months from October to March. The brooding season range is based on literature for the entire Pacific coast, thus the whole time interval may not be applicable to the Strait of Georgia in any particular year. Studies cited in the EIS indicate that earlier male moulting was observed in 2013 in Crab Management Area H, suggesting conditions were different that year, conditions that may have resulted in earlier maturation time for embryos and earlier hatching that specific year. Consequently, the single late January survey conducted in 2013 may have missed the majority of gravid females in the local assessment area.

In addition, the gravid Dungeness crab survey did not include transects within the intermediate transfer pit or the inter-causeway area. The EIS suggested that gravid females have been observed previously in this area and the Proponent's habitat suitability model, described in Appendix 12-A of the EIS, identified this area as highly suitable gravid crab habitat. As this area is scheduled to be utilized for the storage of sand for construction throughout the brooding season for Dungeness crab from years 1-4 in the construction schedule (Figure 4-9), this area should be surveyed for use by gravid female Dungeness crab.

Given the importance of female Dungeness crab brooding sites and the limitations of the current study, an additional field assessment is required to better understand whether, and to what degree, locations within the Project footprint, including the intermediate transfer pit, are utilized by gravid female Dungeness crabs and the potential effects of the Project on gravid female Dungeness crabs and Dungeness crab productivity.

Information Request

Conduct an additional gravid female Dungeness crab field survey. Include, at minimum, areas within the proposed Project and intermediate transfer pit footprints. Transects should be surveyed at multiple times throughout the brooding season, including at the peak, and should range over all depths potentially used by gravid female crabs.

If locations within the Project footprint, including the intermediate transfer pit, are found to be important for the sensitive gravid life history stage of Dungeness crab, provide an assessment of the potential effects of the Project on gravid female Dungeness crab and Dungeness crab productivity within the local assessment area and regional assessment area.

VFPA Response

To clarify, the published brooding window for gravid crabs extends from mid-October to March, such that the timing of EIS field surveys in January occurred in the middle of the season—thereby maximising the potential of detections—not at the end of the season, as stated in the context to this information request.

As stated in the Preamble at the beginning of the responses to Information Request Package 3, through recent changes in dredging equipment options and further engineering analyses, and in consideration of the concerns of Tsawwassen First Nation, and other Aboriginal groups, with the intermediate transfer pit (ITP) and effects on crabs, Project construction no longer requires the ITP as a temporary sand storage location to support construction activities. This change addresses concerns with effects of the ITP on crab habitat and harvesting in particular. Therefore, studies on crab productivity are no longer required for this area.

Because of the limitations of SCUBA based surveys, outlined in TDR MF-2 in Appendix AIR10-C of Additional Information Request #10[1] and EIS Section 12.5.3.3, and noted in the context to this information request, the assessment of potential effects of the Project on gravid female Dungeness crabs did not rely solely on these field studies. Rather, the assessment took a conservative, 'worst-case' approach to predicting crab productivity losses by assuming i) gravid female presence in the terminal and tug basin footprints; ii) that Project activities,

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[1] AIR-12.04.15-10 of CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document # 345) including 22 Technical Data Reports.

particularly dredging, have the potential to cause injury and mortality to this life stage; and iii) that the terminal and tug basin footprints would adversely affect high to moderate suitability gravid crab habitat.

Accordingly, a number of mitigation measures were proposed to avoid, reduce, or offset the potential effects on gravid female crabs. The key mitigation measure proposed for gravid crabs is adherence to DFO’s sensitive timing window that prevents Project construction activities from occurring at depths below -5 m CD (chart datum) from October 15 to March 30, over the brooding season. A crab salvage program is also proposed to minimise potential mortality on crabs, including gravid females. While gravid females tend to fast during the brooding period, Tsawwassen First Nation harvesters report that gravid females are regularly caught in traps in the local assessment area; thus, it is likely that some gravid females can be baited, enabling relocation out of Project footprint areas. In addition, onsite habitat offsetting (e.g., creation of eelgrass as described in EIS Section 12.7.4), while not specific to the gravid life stage, will increase Dungeness crab productivity over the long term. Follow-up monitoring will be undertaken to determine the accuracy of predicted environmental effects on crabs.

Any new SCUBA based field studies for gravid crabs would be subject to the same detection difficulties that impacted earlier surveys (primarily given gravid crabs are often buried in sand) and challenging dive conditions (currents, low visibility), thereby yielding only limited information on the presence of gravid female crabs. Acoustic tagging studies are susceptible to a different suite of limitations, including low sample size (due to high costs), difficulty in tracking/relocating tagged crabs, detection range, and difficulty in obtaining visual confirmation of eggs. Even if these field studies were conducted, outcomes would merely indicate whether gravid crabs are present or not, and this would not change conclusions or proposed mitigation measures, as gravid crab presence in Project areas from October to March has already been assumed in the assessment of potential effects of the Project.

In summary, additional field studies would most likely not be helpful to assess and avoid potential effects of the Project on gravid female crabs for the rationale provided above.

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Preface to IR4-25 to IR4-32: Dungeness Crab Productivity Model

Eight Package 4 information requests are specific to the Dungeness crab productivity model. The nature of these requests, and model, are highly technical, and to facilitate review of the following responses, an overview of the model is provided below. Further details on the Dungeness crab productivity model are found in TDR MI-4 in Appendix AIR10-C of Additional Information Request #10[1].

Dungeness Crab Productivity Model Objectives

There were two primary model objectives:

1. To use available fisheries related catch data, along with fisheries-independent data from DFO research surveys, to develop a scientifically defensible and rigorous Dungeness crab biomass input to the Roberts Bank ecosystem model; and
2. To characterise Dungeness crab existing conditions such that the effects of the Project could be better understood; in particular:
    a. to develop information on population dynamics, estimate annual biomass, recruitment, and production for Dungeness crab stocks; and
    b. determine the relative importance of different areas within the Fraser River estuary.

Prior to development of the Dungeness crab productivity model, there were no quantitative stock assessment studies or data on the size and productivity of the Dungeness crab populations within DFO Pacific Fishery Management Area (PFMA) 29 (which encompasses the regional assessment area (RAA)) and sub-areas 29-6 and 29-7 (which encompass the local assessment area (LAA)).

Study Area

The B.C. commercial Dungeness crab fishery is divided into seven Crab Management Areas (CMAs), which, in turn, are divided into several PFMAs and sub-areas. The Fraser River estuary is located in CMA I (EIS Figure 16-8, reproduced in **Appendix IR4-A**), within PFMA 29 (EIS Figure 16-3, reproduced in **Appendix IR4-A**), which extends roughly from the B.C. Ferries terminal at Roberts Bank north to Sechelt on the Sunshine Coast; the proposed Project footprint straddles sub-areas 29-6 and 29-7.

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[1] AIR-12.04.15-10 of CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

There are gaps in the data at smaller spatial scales (typically a result of privacy concerns); however, where data allowed, focus was placed on assessing sub-areas 29-6 and 29-7, as these are the specific areas that encompass the RBT2 footprint.

Input Data

Model input data included both fishery-dependent and fishery-independent data acquired from the Shellfish Data Unit, Marine Ecosystem and Aquaculture Division, Science Branch, DFO (**Table IR4-1**). All data and results presented in the Dungeness crab productivity model relate only to male crabs because harvest of females is prohibited by regulation.

Table IR4-1 Summary of Data Types and Datasets used to Model Dungeness Crab Productivity

Data Type	Description	Associated DFO Datasets
Fishery-dependent	Data sampled directly from the non-random harvesting process. Samples typically obtained via service providers include fishing activity information such as gear type, total catch, landings, effort, sales, date and place of harvest, etc., but also can include biological attributes of the catch such as size-composition, age structure, and sex ratio.	• Fish Slip Program • Onboard Logbook
Fishery-independent	Data sampled according to a scientific survey design. Samples typically collected by scientists include biological information such as abundance, size composition, moult timing, injury rates, shell condition, and sex ratio.	• Fraser Delta Research Surveys • Vancouver Harbour Research Surveys

Additional information on each data type is provided in TDR MI-4.

How the Dungeness Crab Productivity Model was Used in the Environmental Assessment

Outputs of the Dungeness crab productivity model were used in the assessment of potential effects of the Project as described in the EIS, in several ways. First, the biomass estimates generated by the Dungeness crab productivity model were used as input data into the Roberts Bank ecosystem model. The Dungeness crab productivity model was well suited to provide biomass input parameters for the following reasons:

i) Estimates of biomass were available for the two DFO sub-areas overlapping with the LAA (29-6 and 29-7) as well the PFMA that overlaps with the RAA (Area 29);
ii) The biomass estimates used both fisheries-dependent (i.e., harvest) data and fisheries independent data providing outputs that were buffered against ever-changing fishing patterns; and
iii) Bayesian methods provide more accurate estimates of population parameters because of the ability to include prior biological knowledge.

Second, Dungeness crab productivity model outputs were also used to help characterise existing conditions, providing a quantitative picture of crab production in the Area 29 and its associated sub-areas. Without the Dungeness crab productivity model, this description would be heavily qualitative and largely rooted in fishery landings data which, on their own, are not reliable indices of abundance (see IR4-26). Model outputs confirmed that the Fraser River estuary is a productive area for Dungeness crabs but that productivity fluctuates widely over time, as outlined in EIS Section 12.5.3.

Managing Uncertainty

Overall, based on several diagnostic checks (described below), the Dungeness crab productivity model performs well and meets its objectives to provide rigorous, quantitative estimates of Dungeness crab population parameters in Area 29, where none currently exist. Confidence in its outputs is moderate to high.

Outputs (in the form of posterior distributions) for legal crab biomass before and after fishing suggested that model estimates were precise for Area 29 and sub-area 29-6, as indicated by narrow 95% credible intervals[2]. Estimates are considered less precise for sub-area 29-7, which is largely a result of gaps in the data due to privacy concerns; in other words, the larger confidence intervals at finer spatial scales indicate there were fewer data points with which to generate the estimates.

The Dungeness crab productivity model was tested for its predictive capabilities in several ways. First, model fits to observed data were examined for each input data source (i.e., DFO pre- and post season surveys and fishery dependent surveys). This is standard practice and provides an immediate visual indication of model agreement with each individual survey index or length frequency observation. There are some instances of discrepancy, which are to be expected, showing where the model may have either overestimated or underestimated the proportion of crabs within a size class. However, overall, the model does a reasonable job of matching the overall shape of the observed length distribution.

Second, a residual plot analysis was conducted whereby scatterplots of predicted and observed mean lengths were visually inspected for correlation for each input dataset (see Figure 4-1a to 4-1c in TDR MI-4). Generally, most points fit close to the line and, while there are occasional outliers, these do not drive the results. This indicates the model performs well, on average, across the three datasets (i.e., fishery independent pre- and post- season surveys and fishery dependent surveys).

Third, discrepancy assessment was used in model fitting for each dataset. Discrepancy statistics can be considered the Bayesian counterpart of classical tests for goodness of fit, which judge the fit of a model to the observed data (Gelman et al. 1996). In other words, parameters were combined and adjusted in such a way as to generate a series of plausible

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[2] A credible interval can be thought of as the Bayesian equivalent of a confidence interval around a model parameter or estimate, though their interpretation is slightly different. In Bayesian methods, computed solutions are statements of probability about the parameter value given fixed bounds; it is the equivalent of saying "given our observed data, there is a 95% probability that the true value of the mean falls within the credible range".

models, which were then compared with one another using the discrepancy statistic. Ultimately, the model selected was the one with the lowest D value indicating it is the best of all considered models in matching the observed data as closely as possible. Note that the discrepancy statistics are only comparable within a dataset and provide no additional information to the final model interpretation.

Summary

The Dungeness crab productivity model provides reliable estimates of Dungeness crab biomass, recruitment, and production within PFMA 29, including sub-areas 29-6 and 29-7.

The model was developed by independent fisheries modelling experts, Dr. Sean Cox of Simon Fraser University's Quantitative Fisheries Research Group and Director of the School of Resource and Environmental Management, and Cameron MacKenzie of Atwater Resources Corporation.

The model uses both fishery-dependent and fishery-independent data collected by DFO to estimate the levels of biomass and production needed to support the observed Dungeness crab catch and size-composition over the past two decades using size-structured Bayesian methods[3]. Model performance was assessed using standard approaches, which collectively suggest that the model performs well, though the precision of estimates decreases at finer spatial scales due to fewer data points (driven by privacy concerns). Overall, the model is considered to provide scientifically rigorous quantitative estimates of Dungeness crab population parameters, where none currently exist, that are sufficient to inform the assessment of potential effects of the Project; without the model, the assessment would be predominantly qualitative and based solely on catch data, which may introduce error or uncertainty to predictions.

References

Gelman, A., X. L. Meng, and H. Stern. 1996. Posterior Predictive Assessment of Model Fitness Via Realized Discrepancies. Statistic Sinica. 6: 733-807.

Appendices

Appendix IR4-A	Supporting Figures

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[3] Bayesian methods are standard for invertebrate fishery stock assessments, and are considered most appropriate to meet study objectives because existing knowledge of crab biology can be merged with detailed fishery and survey size composition data.

APPENDIX IR4-A
SUPPORTING FIGURES

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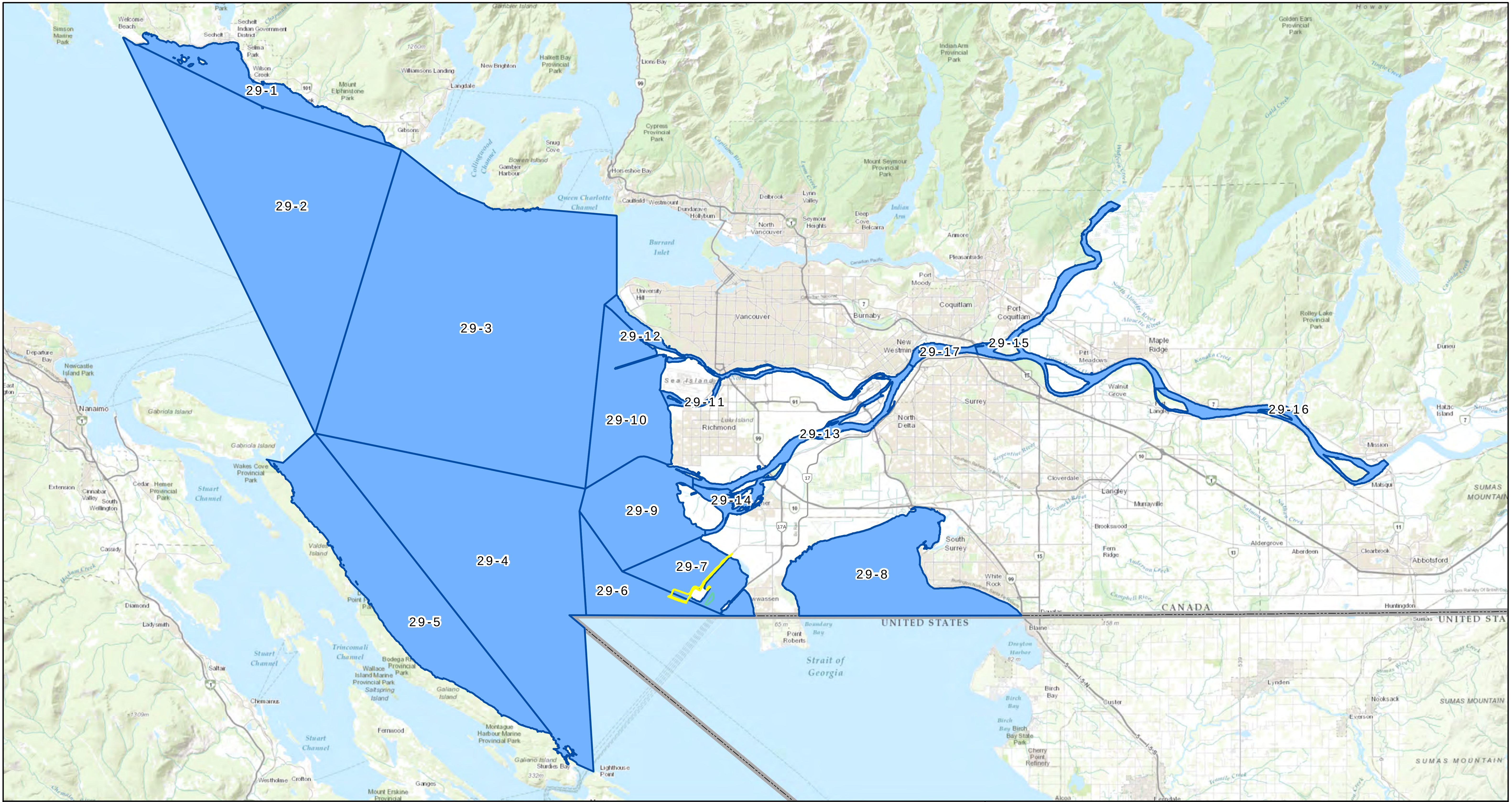

Legend

🟦 DFO PACIFIC FISHERY MANAGEMENT AREA 29 (SUB-AREA 29-X)

🟨 BOUNDARY OF PROJECT AREA

🟩 INTERMEDIATE TRANSFER PIT

-·- U.S.A.-CANADA BORDER

0 10 20
Kilometres
1:330,000
NAD 1983 UTM Zone 10N

N

PORT METRO vancouver

ROBERTS BANK TERMINAL 2

DFO PACIFIC FISHERY MANAGEMENT AREA 29

DATE: 01/19/2015

FIG No. 16-3

Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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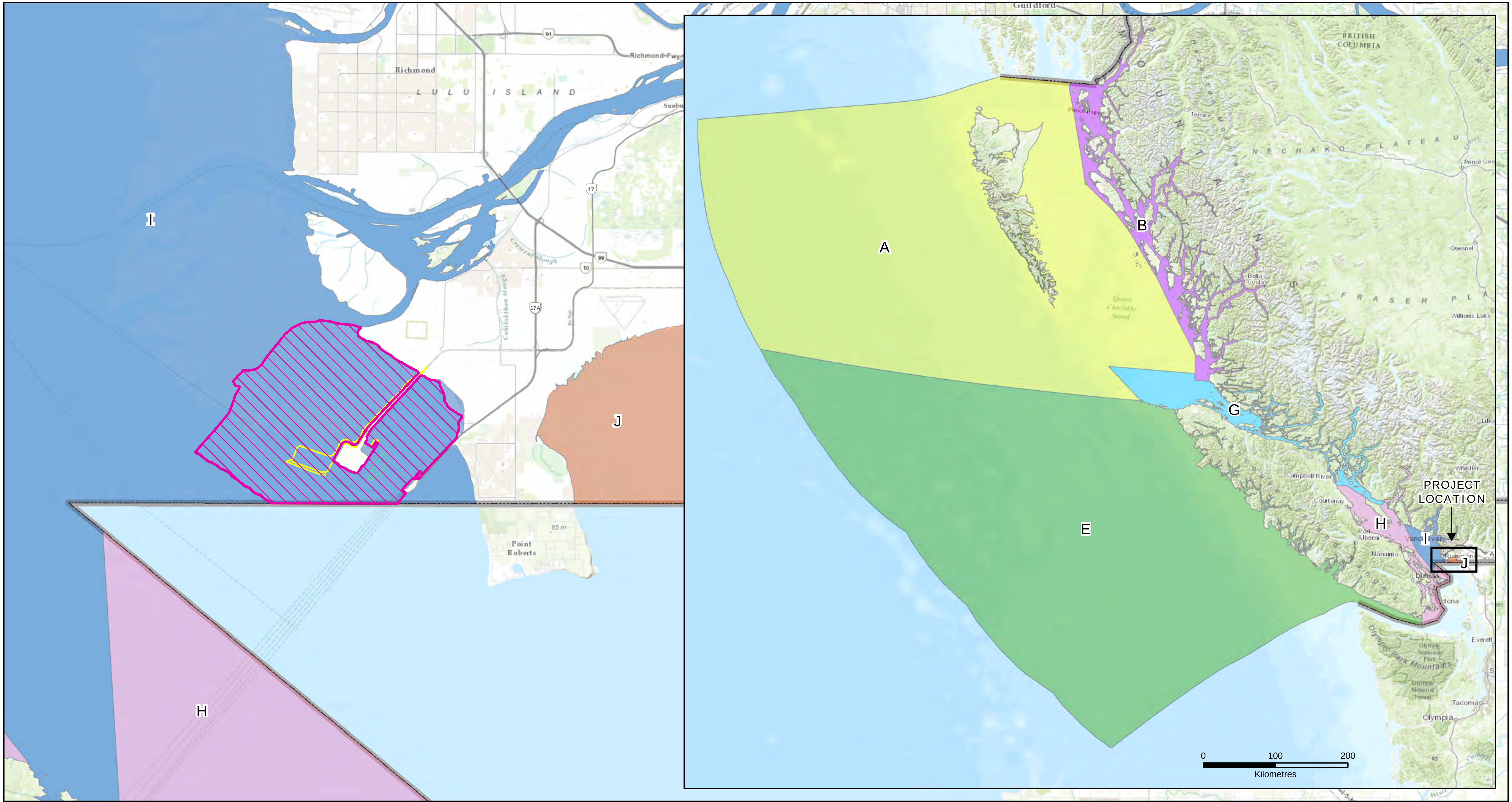

Legend

- ▭ BOUNDARY OF PROJECT AREA
- ▭ INTERMEDIATE TRANSFER PIT
- ▨ COMMERCIAL, RECREATIONAL, AND ABORIGINAL FISHERIES LAA
- ⋯ U.S.A.-CANADA BORDER

CRAB MANAGEMENT AREAS

- 🟨 A
- 🟪 B
- 🟩 E
- 🟦 G
- ▭ H
- 🟦 I
- 🟧 J

0 3 6
Kilometres
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NAD 1983 UTM Zone 10N
N

PORT METRO vancouver

ROBERTS BANK TERMINAL 2

DFO CRAB MANAGEMENT AREAS

DATE: 01/19/2015

FIG No. 16-8

Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

IR4-24 Marine Invertebrates - Dungeness Crab: Life Stage/Age Definition

Information Source(s)

EIS Volume 3: Section 12

TDR MI-2 Juvenile Dungeness Crabs

TDR MI-4 Dungeness Crab Productivity

TDR MF-2 Marine Benthic Subtidal Study

Context

According to Fisheries and Oceans Canada, the definitions used to describe the various Dungeness crab life stages are inconsistent throughout the EIS and TDRs.

For example:

- The description of legal Dungeness crab as males greater than 155 mm carapace width (CW) provided in the Juvenile Dungeness Crabs report is incorrect; regulations require that legal crabs must be at least 165 mm CW (which is equivalent to 154 mm notch-to-notch width). Clarification is required to verify the size used for defining legal sized Dungeness crab.
- The methods section of Juvenile Dungeness Crabs report defines juveniles by a size range, but the results section reports findings for different life stages. It is not clear which life stages are categorized as juvenile and if this category includes instar and sub-adult Dungeness crab. Furthermore, instar refers to a moult stage of which there are many throughout the life of a crab and does not necessarily refer only to juveniles as could be inferred from the results section of Juvenile Dungeness Crabs report.
- In the discussion of key findings in the Juvenile Dungeness Crabs report, conclusions that habitat preferences change as crabs grow, with Ulva preferred by megalopae and first instar crab and Zostera beds preferred by later instars and age 1+ crab (bullet iii); and, that 1+ crabs are largely absent from vegetated intertidal areas at low tide, and prefer tidal channels in the low intertidal to subtidal zones (bullet iv) are not supported by the data. Throughout the discussion, the Proponent refers to age classes, but an age analysis was not conducted. The report's data does not support age-based habitat preference because an age analysis (e.g., length-based) was not conducted. If an aging analysis was conducted, or a length-to-age relationship was analyzed, the methodology, data, and results should be provided. Alternatively, if literature was used to make assumptions about crab ages, this should be specified and sources provided.

Clarification of the various definitions of Dungeness crab life stages and ages is required to assess whether the data supports the conclusions.

Information Request

Provide the definitions of the various life stages/ages of Dungeness crab referred to throughout the EIS and its supporting studies. Clarify which size was used for defining legal sized Dungeness crab.

Provide any sources used in making assumptions about crab ages.

Describe any potential implications of the use of inconsistent definitions in the effects assessment for Dungeness crab.

VFPA Response

Provide the definitions of the various life stages/ages of Dungeness crab referred to throughout the EIS and its supporting studies. Clarify which size was used for defining legal sized Dungeness crab.

Definitions of various life stages/ages of Dungeness crab referred to throughout the EIS and its supporting studies are provided as follows:

- Juveniles are classified broadly as crabs that have not yet reached sexual maturity, ranging from carapace widths of <15 mm (including megalopae) up to 100 mm (for females) and 120 mm (for males), consistent with the published sizes-at-maturity (Dunham et al. 2011), as stated in Section 3.3 p. 9 of TDR MI-2 in Appendix AIR10-C of Additional Information Request #10[1]; therefore, this category includes instars and sub-adults;
- Adults are defined as crabs that have reached sexual maturity, with carapace widths >100 mm for females and >120 mm for males (Dunham et al. 2011); and
- Gravid females are defined as sexually mature adults (i.e., >100 mm) that are egg-bearing.

The 155 mm size carapace width (CW) referred to in TDR MI-2 p. 6 was a typographical error. Throughout the EIS and supporting documents, 165 mm is used as the minimum legal size for Dungeness crab.

Provide any sources used in making assumptions about crab ages.

Information sources pertaining to crab ages are outlined in **Table IR4-24-1**.

To clarify, an age analysis was not conducted because sufficient information on age categories of crabs was available from literature sources (see **Table IR4-24-1** below). Comments on age class were included as supplemental information and were not intended to represent a comprehensive age analysis; integration of age information into TDR MI-2 conclusions has no

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[1] AIR-12.04.15-10 of CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

implication on the analytical findings of the study (i.e., which habitats are preferred by juvenile Dungeness crabs).

Table IR4-24-1 Information Sources Pertaining to Crab Ages

Source	Description	Assumption
Dinnel et al. 1986	The average overwintering size of young-of-year crab was in the range 10 mm to 20 mm	These references were used in conjunction with size data collected in the field to make the assumption in conclusion three of TDR MI-2 (p. 23) that *Ulva* is preferred by megalopae and first instar crab and *Zostera* beds preferred by later instars and age 1+ crab
McMillan et al. 1995	Estuarine 0+ crabs range between 30 mm and 50 mm, and mean CW was about 5 mm during peak settlement in August, increased to approximately 8 mm by late September but was only 12 mm by November; there was little growth between November and early March; after March, mean CW increased markedly from about 13 mm to 30+ mm by mid-June	
Dinnel et al. 1986	Growth during the second year was rapid with crabs reaching 80 mm to 100 mm by winter of the year following settlement	This reference was used in conjunction with size data collected in the field to make the assumption in conclusion four of TDR MI-2 (p. 23) that "1+ crabs are largely absent from vegetated intertidal areas at low tide, and prefer tidal channels in the low intertidal to subtidal zones."
Waddell 1986	Male age class sizes are: 0+ = 0 mm to 30 mm; 1+ = 30 mm to 70 mm; 2+ = 70 mm to 136 mm; 3+ >136 mm; and 4+ appears to begin at 165 mm to 170 mm. Female age class sizes are the same as male age class sizes until they reach approximately 100 mm (the 2+ age group)	This reference was used to further support conclusions three and four in TDR MI-2

Describe any potential implications of the use of inconsistent definitions in the effects assessment for Dungeness crab.

There are no implications to the effects assessment conclusions because consistent definitions of Dungeness crab life stages, as outlined above, were used in the effects assessment of Dungeness crab (see EIS Section 12.5.3).

The broad definition of 'juvenile' used in the EIS, and specifically in TDR MI-2 (see above), was consistently and intentionally applied in order to be as conservative as possible (see IR4-22). An 'encompassing' definition enables the capture of ontogenetic[2] shifts in habitat

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[2] In size-structured populations, such as Dungeness crabs, it is common for individuals to exploit several niches (including habitats) sequentially in the course of their life history (Werner and Gilliam 1984). The change during life history from one niche (or habitat) to another is referred to as an ontogenetic shift (Claessen and Dieckmann 2002).

use, providing not only a more comprehensive understanding of what habitats are preferred by Dungeness crabs to settle and rear, but also ensuring that all potential effects are identified and described, as the potential for interaction with Project components and activities changes as crabs grow and shift to different habitats.

References

Claessen, D. and U. Dieckmann. 2002. Ontogenetic Niche Shifts and Evolutionary Branching in Size-Structured Populations. Evolutionary Ecology Research. 4: 189 – 217.

Dinnel, P. A., D. A. Armstrong, and R. O. McMillan. 1986. Dungeness Crab, Cancer magister, Distribution, Recruitment, Growth and Habitat Use in Lummi Bay, Washington. University of Washington, School of Fisheries Report No. FRI-UW-8612. Seattle, Washington.

Dunham, J. S., A. Phillips, J. Morrison, and G. Jorgensen. 2011. A Manual for Dungeness Crab Surveys in British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2964, Fisheries and Oceans Canada, Ottawa, ON.

McMillan, R. O., D. A. Armstrong, and P. A. Dinnel. 1995. Comparison of Intertidal Habitat Use and Growth Rates of Two Northern Puget Sound Cohorts of 0+ Age Dungeness Crab, Cancer magister. Estuaries 18:390–398.

Waddell, B. J. 1986. Roberts Bank Crab Habitat Loss Response Study: Final Report (1981 to 1984). Prepared for Roberts Bank Environmental Review Committee, Port of Vancouver, and Fisheries and Oceans. 53 pp.

Werner, E. E. and J. F. Gilliam. 1984. The Ontogenetic Niche and Species Interactions in Size-structured Populations. Annual Review of Ecology, Evolution, and Systematics. 15: 393–425.

IR4-25 Marine Invertebrates - Dungeness Crab: Crab Productivity Model Fit

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity

Context

The Dungeness Crab Productivity report stated that model fits to the size composition data for Area 29 crabs were described, followed by posterior distributions for crab recruitment, legal sized crab biomass, and legal sized crab production available to fisheries in each of the areas. Overall, some parameters were well estimated by the model while others could not be improved beyond their prior values. The report also stated that no attempt was made to further improve the fit of predicted length distributions because information on the timing of observer sampling of fishery catches was not available and sampling catches later in the season would have created larger discrepancies between the predicted and observed frequencies because no account of catch prior to sampling was taken.

Fisheries and Oceans Canada stated that it has information regarding the timing of observer sampling that can be made available to the Proponent. However, it is unclear why timing of sampling would be relevant given the method of combining all sampling data from the commercial catches within one year in the model fitting process. The methodology regarding the use of observer sample timing in model validation requires clarification.

Information Request

Provide clarification of the following statement from the Dungeness Crab Productivity report: "No attempt was made to further improve the fit of predicted length distributions because information on the timing of observer sampling of fishery catches was not available and sampling catches later in the season would create larger discrepancies between the predicted and observed frequencies because no account of catch prior to sampling was taken".

Provide a rationale for why timing of observer sampling was not used to improve model fit, given that this data is available.

VFPA Response

Provide clarification of the following statement from the Dungeness Crab Productivity report: "No attempt was made to further improve the fit of predicted length distributions because information on the timing of observer sampling of fishery catches was not available and sampling catches later in the season would create larger discrepancies between the predicted and observed frequencies because no account of catch prior to sampling was taken".

The above statement was offered as one of several possible explanations to account for model results, specifically, the relatively minor discrepancies[1] (e.g., see Figure 4-1a-c in TDR MI-4 in Appendix AIR10-C of Additional Information Request #10[2], for visual representation of such minor discrepancies) between model predictions and observed size composition data. It is therefore not related to the model fitting process itself but, rather, was raised as a possible interpretation of model fitting results.

Additionally, as indicated in the context to this information request, timing of sampling is not relevant given the method of combining all sampling data from the commercial catches within one year in the model fitting process; therefore, inclusion of observer timing data was, and is, not necessary to improve model predictions/results.

Provide a rationale for why timing of observer sampling was not used to improve model fit, given that this data is available.

There are several reasons why timing of observer sampling[3] was not included in the Dungeness crab productivity model:

- Timing of sampling is not relevant given the method of combining all sampling data from the commercial catches within one year in the model fitting process;
- Including observer timing to improve model fit was not considered appropriate because it could lead to model overfitting, whereby the model is made excessively complex simply to provide a better fit to the data. Overfitted models tend to have poor predictive performance (Burnham and Anderson 2002);
- As indicated in the Preface to IR4-25 to IR4-32, the accuracy of model predictions is considered moderate to high (also see Sections 3.4.1 and 4.1 in TDR MI-4), and the comment about observer timing (referenced in this information request) was to offer potential explanations as to why there were minor discrepancies between the predicted and observed results (e.g., see Figure 4-1a-c in TDR MI-4, which visually presents the accuracy of the model results); and

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[1] The VFPA notes that minor discrepancies are inherent to all model predictions and it is uncommon that a model result would not include such discrepancies between predictions and observed data.

[2] AIR-12.04.15-10 in CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

[3] Observer data was not available to the VFPA at the time the model was developed. The VFPA requested available crab fishery dependent and independent data from DFO in December 2012 to inform the Dungeness crab productivity model and observer timing data was not included in the information provided by DFO at that time.

- The model met its objectives (to provide productivity estimates from best available crab fishery data), and inclusion of observer timing data was, and is, not necessary to improve model predictions/results.

References

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. New York: Springer-Verlag. 488 pp.

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IR4-26 Marine Invertebrates – Dungeness Crab: Crab Productivity Catch Per Unit Effort

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity

Context

Catch per unit effort data was not used in the Bayesian size-structured crab population dynamics model, described in the Dungeness Crab Productivity report, which could have implications for the estimation of model parameters and temporal trends.

Catch per unit effort data is available for the fishery-independent crab surveys, and could likely be calculated for the commercial fishery data.

A rationale for why fishery-independent and fishery-dependent catch per unit effort data was not used in the Bayesian size-structured Dungeness crab population dynamics model is required.

Information Request

Provide a rationale for why fishery-independent and fishery-dependent catch per unit effort data was not used in the Bayesian size-structured Dungeness crab population dynamics model.

Explain how catch per unit effort data may have changed model outcomes if it had been used.

VFPA Response

Provide a rationale for why fishery-independent and fishery-dependent catch per unit effort data was not used in the Bayesian size-structured Dungeness crab population dynamics model.

Catch-per-unit effort (CPUE; i.e., the number of crabs caught per unit of time spent fishing) data was not used for abundance estimation within the Bayesian size structured Dungeness crab population dynamics model for the following reasons:

- Including survey CPUE caused unstable model behaviour because it provided contrary indications to the much larger size-composition data sets;
- Survey CPUE for crabs is less valuable in this context because it requires estimating a catchability coefficient that scale the index (e.g., average number of crabs per trap) to the total biomass or numbers of crabs. Estimating catchability requires an informative, low variance data set, which is generally not the case for this fishery; and

- Information derived from the total catch combined with the change in ratio of sub-legal to legal-sized crabs is much more useful in estimating abundance without the need to estimate catchability (Udevitz and Pollock 1992; Chen et al. 1998; Mackenzie 2010). The Bayesian size-structured model is essentially a complex change-in-ratio estimator.

Additional information is provided below.

Fishery CPUE is commonly used as a relative measure of stock abundance where fishery-independent abundance and/or composition data are lacking (i.e., where real data on actual fish abundance and/or composition from one catch is recorded). Its use is considered problematic because catchability in commercial fisheries (i.e., the proportion of stock taken by one unit of fishing effort) is rarely constant across all fishing events (Hilborn and Walters 1992; MacKenzie 2010) and therefore it is not a reliable estimate of the abundance or composition of fish from that particular area. Consequently, use of fishery CPUE can lead to biased estimates of stock size. Even if CPUE is standardised appropriately for factors known to affect fishing power, such as vessel size, power, soak time, etc., the resulting index of relative abundance, in isolation, provides limited information about the effect of fishing (Maunder et al. 2006) because a scalar[1] catchability coefficient needs to be estimated; and, in many cases, the data are not particularly informative about that scalar.

The Dungeness crab productivity model employed 'change-in-ratio' type methods, which are more robust to variable catchability (MacKenzie 2010). Change-in-ratio methods are well known to wildlife scientists seeking to estimate the size of populations, and their utility in the field is widely accepted (Udevitz and Pollock 1992). Change-in-ratio methods provide estimates of population parameters based on changes in proportions of population sub-classes (e.g., legal-sized and sub-legal sized crab) following a known removal (Chen et al. 1998; Smith and Addison 2003; Fong and Gillespie 2008). This class of models does not require constant catchability if only one class is harvested (Chen et al. 1998) and, therefore, is considered more appropriate for estimating Dungeness crab abundance than basing estimates on CPUE data (MacKenzie 2010).

Attempts were made to fit the Dungeness crab productivity model to the fishery-independent CPUE time-series, but these were unsuccessful. Forcing the fit caused the model to destabilise, thereby reducing its predictive ability (and hence its utility); therefore, CPUE data were not used in the final model. The destabilisation resulted from the model's inability to resolve the conflicting signals between the observed declining trend in CPUE and the actual increase in commercial fishery catch and composition of legal-sized crabs. Specifically, CPUE data shows a decline over the period 2006 to 2009, meaning fewer crabs were caught per unit of survey effort (i.e., suggesting fishing became worse); however, fisheries landings increased, while exploitation rates declined during this same time period, suggesting that fishing became better and more crabs were present. When CPUE data is excluded, the model predicts higher than average crab production over this time, thereby explaining the observed increases in

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[1] Scalar refers to any real number, or any quantity, that can be measured using a single real number; it has magnitude but no direction.

commercial catch recorded, as well as the high prevalence of legal-sized crabs in post-season survey size composition data. However, when the model was fitted to survey CPUE data, the abundance trend indicated a declining population and lack of legal-sized crabs, which was inconsistent with other data, especially during the 2006 to 2009 period. Failure to match the CPUE pattern to model-estimated abundance may result from high uncertainty about survey CPUE, which would not be surprising given the small sample sizes, short sampling window, and variable survey timing.

Explain how catch per unit effort data may have changed model outcomes if it had been used.

As stated earlier (and explained in Section 5.0 of TDR MI-4 in Appendix AIR10-C of Additional Information Request #10[2]), survey CPUE data was initially used in the Dungeness crab productivity model but later excluded due to its destabilisation of the model. Its exclusion improved model performance as measured by fits to observed catch and survey size-composition data.

References

Chen, C., J. M. Hoenig, E. G. Dawe, C. Brownie, and K. H. Pollock. 1998. New Developments in Change-in-ratio and Index-removal Methods, with Application to Snow Crab (Chionoecetes opilio). In Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. Edited by G.S. Jamieson and A. Campbell. Can. Spec. Publ. Fish. Aquat. Sci. pp 49-61. Retrieved from http://fluke.vims.edu/hoenig/pdfs/Chen_Hoenig_Dawe_Brownir_Pollock_CIR_%20IR_SnowCrab.pdf.

Fong, K. H. and G. E. Gillespie. 2008. Abundance-based Index Assessment Options for Dungeness Crab (*Cancer magister*) and Spot Prawn (*Pandalus platyceros*). Canadian Science Advisory Secretariat Research Document 2008/049.

Hilborn, R. and C. J. Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics, and Uncertainty. Chapman and Hall, New York.

MacKenzie, C. J. A. 2010. The Dungeness Crab (Metacarcinus magister) Fishery in Burrard Inlet, B.C.: Constraints on Abundance-based Management and Improved Access for Recreational Harvesters (Master's Thesis). Retrieved from http://rem-main.rem.sfu.ca/theses/MackenzieCameron_2010_MRM478.pdf.

Maunder, M. N., J. R. Sibert, A. Fonteneau, J. Hampton, P. Kleiber, and S. J. Harley. 2006. Interpreting Catch Per Unit Effort Data to Assess the Status of Individual Stocks and Communities. ICES Journal of Marine Science. 63: 1373-1385.

Smith, M. T. and J. T. Addison. 2003. Methods for Stock Assessment of Crustacean Fisheries. Fisheries Research. 65: 231-256.

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[2] AIR-12.04.15-10 in CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

Udevitz, M. S. and K. H. Pollock. 1992. Change-in-ratio Methods for Estimating Population Size. In D. R. McCullough and R. H. Barrett (eds), Wildlife 2001: Populations (pp. 90-101). Springer Netherlands.

IR4-27 Marine Invertebrates – Dungeness Crab: Crab Productivity Length Classes

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity Appendix A

Context

In the Dynamic Model Mathematical Specification, described in Appendix A of the Dungeness Crab Productivity report, the Proponent stated that the range of length classes in the proportional size composition was limited to where crabs were actually observed in the fishery and surveys and, because this range varied by year, year specific ranges were used in the sample size and likelihood calculations.

Information about how crabs in the length classes which are larger than the largest length class used in the likelihood calculations were treated in the modelling process is required to assess how the different treatment of these very large crabs could impact biomass and exploitation estimates.

Information Request

Describe how Dungeness crabs in the length classes which are larger than the largest length class used in the likelihood calculations were treated in the Bayesian size-structured crab population dynamics model process.

VFPA Response

Dungeness crabs in the length classes larger than the largest length class, were deliberately excluded from the Bayesian size-structured crab population dynamics model process based on precedent set in Zhang et al. (2002), where immediately after moulting into a size above 210 mm, crabs were assumed to die (i.e., 'senescent mortality'). Like Zhang et al. (2002), there is no indication in the data provided by DFO, on which this model is based, that crabs of this size survive to following years, as evidenced by their rarity in all size composition datasets (refer to the Preface to IR4-25 to IR4-32 for a description of the fishery dependent and independent datasets that underpin the model). For example, the largest length class in the model was 210 mm which, on average, had less than one crab. Additionally, no crabs larger than 210 mm have been observed in scientific surveys of the relatively unfished Vancouver Harbour (Zhang et al. 2002), thereby corroborating this assumption. Because so few crabs survive to a point beyond the largest size class, exclusion of these larger crabs from the model does not have implications for biomass and exploitation estimates.

References

Zhang, Z., H. Hajas, A. Phillips, and J. A. Boutillier. 2002. Evaluation of an Intensive Fishery on Dungeness Crab, *Cancer magister*, in Fraser Delta, British Columbia. Canadian Science Advisory Secretariat Research Document 2002/118. 59 pp.

IR4-28 Marine Invertebrates – Dungeness Crab: Crab Productivity Moulting Pattern

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity

Context

The Dungeness Crab Productivity report assumed that crabs moult once per year, but would never moult twice per year. Fisheries and Oceans Canada stated that this assumption was fine for large males; however, they noted that smaller males (102.5 – 122.5 mm carapace width) may moult twice per year. It is not clear why this moulting pattern for small length classes was excluded. The implications of not including the moulting pattern for smaller males in the Bayesian size-structured crab population dynamics model must be evaluated.

Information Request

Include the moulting pattern in which smaller crabs (102.5 – 122.5 mm carapace width) may moult twice per year, in the Bayesian size-structured Dungeness crab population dynamics model.

If the moulting pattern for smaller crabs cannot be included in the model, provide a rationale for its exclusion and describe the implications.

VFPA Response

Inclusion of the moulting pattern in which small crabs may moult twice per year in the model will not change the trends and patterns of results generated by the model for the reasons provided below.

The use of a single moult per year in the model for crabs >100 mm is consistent with existing studies on the population dynamics of Dungeness crabs within the Fraser River delta; for example, Zhang et al. (2004) assumed that moulting of all size classes occurs at the same time in a single event. While smaller adult crabs have the potential to moult twice per year, the simplifying assumption that adult crabs moult once per year is also consistent with other literature (Dunham et al. 2011; Rasmuson 2013; Zhang and Dunham 2013).

Growth in the model is not deterministic, meaning crabs from a given size class (e.g., 102.5-122.5 mm) grow to a range of post-moult sizes determined by the growth rate and standard deviation parameters. For example, Figure 1 in Appendix A of TDR MI-4 (in Appendix AIR10-C of Additional Information Request #10[1]) shows that crabs from the 102.5 mm class grow to 122.5 mm, 127.5 mm, and 132.5 mm after one moult in the model. Such a range of growth outcomes are expected to capture the cumulative effect of one, two, or three moults during the moulting season without having to specifically model each moult separately.

The model fits the size-composition datasets better in some years than others, and in many cases fits different datasets better in different years. Adding multiple moults per year would complicate the model and may not provide the intended effect of improving fit, particularly since the proportion of crabs moulting multiple times is assumed constant over time. In other words, the model may end up fitting the data better or worse in new places, rather than improving overall fit.

Based on the above, re-running the model to include a twice per year moulting pattern for smaller crabs is not warranted. The implication of exclusion of a twice per year moulting pattern is considered inconsequential: it could add to existing minor discrepancies in model fit to observed data within particular size cohorts and years (as shown in Figure 4-1a-c in Section 4.1 of TDR MI-4, p. 26), potentially causing slight underestimation of smaller crabs in post-season estimates. However, such discrepancies, should they occur, are expected to dampen the subsequent year because the model spreads crabs over different size classes annually as they grow. Overall, including a twice per year moulting pattern for smaller crabs will not change the basic trends and patterns of results nor override model conclusions.

References

Dunham, J. S., A. Phillips, J. Morrison, and G. Jorgensen. 2011. A Manual for Dungeness Crab Surveys in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2964: viii + 68 p.

Rasmuson, L. K. 2013. The Biology, Ecology, and Fishery of the Dungeness Crab, *Cancer magister*. Advances in Marine Biology 65:95–148.

Zhang, Z. and J. S. Dunham. 2013. Construction of Biological Reference Points for Management of the Dungeness Crab, *Cancer magister*, Fishery in the Fraser River Delta, British Columbia, Canada. Fisheries Research. 139: 18-27.

Zhang, Z., W. Hajas, A. Phillips, and J. A. Boutillier. 2004. Use of Length-Based Models to Estimate Biological Parameters and Conduct Yield Analyses for Male Dungeness Crab (*Cancer magister*). Canadian Journal of Fisheries and Aquatic Sciences. 61: 2126-2134.

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[1] AIR-12.04.15-10 in CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

IR4-29 Marine Invertebrates – Dungeness Crab: Crab Productivity Use of Survey Data

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity

Context

The Dungeness Crab Productivity report states that the commercial crab fishery typically begins in mid to late June on an annual basis, and the majority of male legal-sized crabs are captured within 6 weeks. However, for the purposes of the report, surveys that were conducted between April and August were considered preseason surveys. Fisheries and Oceans Canada is of the view that surveys in August seem far too late to be considered part of the pre-season data given the intense fishing pressure within 6 weeks of the start date in June.

A rationale for using July and August surveys in the pre-season data and an explanation for how this may have impacted model and population outcomes is required to ensure data used to estimate crab abundance was modelled appropriately.

Information Request

Provide a rationale for utilizing data from surveys carried out in July and August to represent pre-season data in the Dungeness Crab Productivity report.

Provide an explanation of how survey data obtained in July and August, rather than during the pre-season, may have impacted the results of the model.

VFPA Response

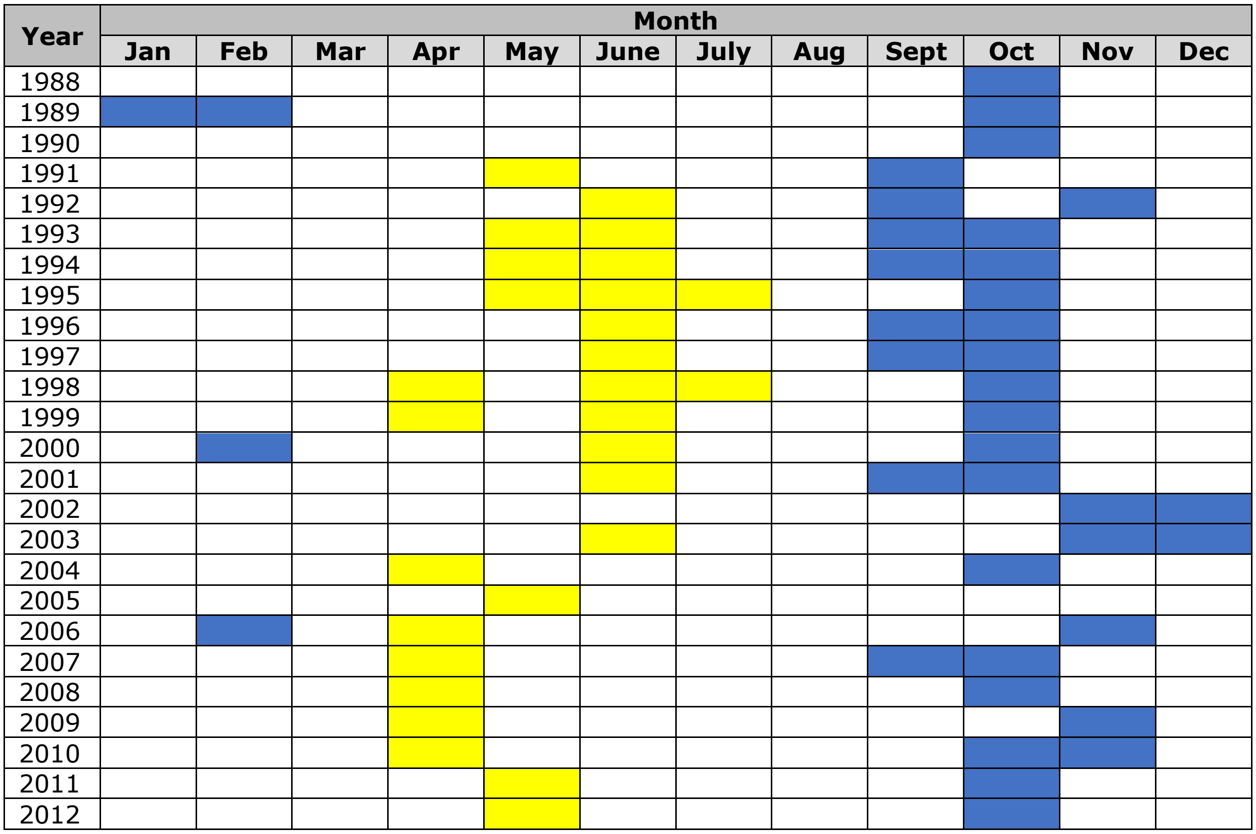
DFO conducts synoptic surveys annually, prior to the scheduled opening of the commercial fishery in June (pre-season), and in late October (post-season) at the end of most commercial activity (Dunham et al. 2011). Ideally, these surveys would occur at the same time each year; however, that is not always the case. **Figure IR4-29-1** shows the synoptic survey dataset by month collected by DFO over a 24 year period. Timing of 'pre-season surveys' was interpreted to range from April to July (see yellow cells in **Figure IR4-29-1** below), while the timing of 'post-season' surveys was interpreted to range from September to February (see blue cells in **Figure IR4-29-1** below). The entire dataset was used in the development of the Dungeness crab productivity model.

The rationale for including July in the pre-season survey range is because, in some years, DFO pre-season surveys were conducted as late as July (see years 1995 and 1998 in

Figure IR4-29-1). The collection of data in July in a limited number of years did not have much influence over model predictions as it only comprises a small fraction of the dataset used. As shown in **Figure IR4-29-1**, the majority of the data was collected in April to June over the time-series of the dataset; there are only 2 instances (1995 and 1998) where data was collected in July in addition to other months. Further, the model fits the pre- and post-season DFO data well over the 1995-1998 period (Figure 4-1a in TDR MI-4), indicating little implication of July data on model results.

Inclusion of August in pre-season surveys in TDR MI-4 in Appendix AIR10-C of Additional Information Request #10[1] was a reporting error; as shown in **Figure IR4-29-1,** no data were collected in August and, hence, no August data were included in the Dungeness crab productivity model.

Figure IR4-29-1 Summary of DFO Survey Sampling in Area 29 by Month



Year	Month											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1988										🟦		
1989	🟦	🟦								🟦		
1990										🟦		
1991					🟨				🟦			
1992						🟨			🟦		🟦	
1993					🟨	🟨			🟦	🟦		
1994					🟨	🟨			🟦	🟦		
1995					🟨	🟨	🟨			🟦		
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2002											🟦	🟦
2003						🟨					🟦	🟦
2004				🟨						🟦		
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2006		🟦		🟨							🟦	
2007				🟨					🟦	🟦		
2008				🟨						🟦		
2009				🟨							🟦	
2010				🟨						🟦	🟦	
2011					🟨					🟦		
2012					🟨					🟦		

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[1] AIR-12.04.15-10 in CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

References

Dunham, J. S., A. Phillips, J. Morrison, and G. Jorgensen. 2011. A Manual for Dungeness Crab Surveys in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2964: viii + 68 p.

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IR4-30 Marine Invertebrates – Dungeness Crab: Crab Productivity External Factors

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity Figure 3-2; Table 3-2

Context

The Dungeness Crab Productivity report found that, according to fishery-dependent landings data, the relative contribution of each Sub-area to overall Area 29 landings appeared to undergo episodic shifts (Figure 3-2 and Table 3-2). Sub-area 29-7 contributed about 5% of total Area 29 crab landings; however, during the 1990s, when total Area 29 landings were lower, Sub-area 29-7 contributed four to five times more crab landings than it does now, which amounted to as much as 18% of Area 29 overall. Conversely, Sub-area 29-6 catches were a very minor portion of Area 29 landings in the 1990s, but have comprised as much as 43% of Area 29 landings in recent years.

It is not clear whether external factors such as fisheries management measures, the implementation of the navigational closure in 2005 (buoy restriction) or 2009 (full closure), and shifts in preferred fishing areas, were considered in order to understand the temporal shifts in the sub-area contributions to the fishery or if these shifts are assumed to be caused by temporal changes to abundance of legal-sized male crab at the sub-area level.

Information Request

Clarify if and how the timing of external factors, such as the existing navigational closure at Roberts Bank for commercial Dungeness crab harvesting, were considered in the methods and conclusions of the Dungeness Crab Productivity report.

Describe the potential for these external factors to affect the Dungeness crab biomass estimate.

VFPA Response

Clarify if and how the timing of external factors, such as the existing navigational closure at Roberts Bank for commercial Dungeness crab harvesting, were considered in the methods and conclusions of the Dungeness Crab Productivity report.

The timing of external factors was not considered in the methods and conclusions of the Dungeness Crab Productivity Technical Data Report (TDR MI-4 in Appendix AIR10-C of Additional Information Request #10[1]) for the following reasons:

i) Quantitative population and fisheries data of sufficient temporal and spatial resolution are required to analyse such factors and, at the time the EIS was being written, and as of July 2017, were not available. The crab fishery in B.C. is passively managed by DFO, meaning that fishery management measures employ the '3-S' strategy, restricting harvest by sex, size, and season, as well as trap limits and gear restrictions (Zhang et al. 2002; MacKenzie 2010); and

ii) The objective of the Dungeness crab productivity model was to generate a biomass estimate for input into the Roberts Bank ecosystem model (see Preface to IR4-25 to IR4-32), rather than to determine the external cause(s) (if any) of the observed historical shifts in landings.

Describe the potential for these external factors to affect the Dungeness crab biomass estimate.

The navigational closure and other external factors such as fishery management measures are unlikely to affect the Dungeness crab biomass estimate for the following reasons[2]:

- The navigational closures at Roberts Bank in 2005 and 2009 were implemented after the observed shifts in landings started to occur. The observed shifts in landings began around 2001 (Table 3-2 and Figure 3-3 in TDR MI-4), though trends of increased landings in sub-area 29-6 and decreased landings in sub-area 29-7 have continued (and differences between the two sub-areas have widened) throughout the closure period;
- Fishery management measures have been applied by DFO consistently across Crab Management Area (CMA) I (including Pacific fishery management area (PFMA) 29) throughout the collection of annual landings data used to develop the model (i.e., 1990 to 2011). Therefore, management measures are not likely to affect observed variations over time in crab landings between sub-areas in PFMA 29;

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[1] AIR-12.04.15-10 in CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document # 345) including 22 Technical Data Reports.

[2] The navigational closure may contribute to the observed trend of relative shifts in landings between sub-areas through the re-location of fishing effort from sub-area 29-7 to 29-6 (i.e., along the western boundary of the navigational closure), as discussed in EIS Section 21.5.1.1 and shown in EIS Figure 21-6.

- Incorporation of DFO's fishery-independent survey data into the Dungeness crab productivity model, based on standardised methods, as well as information on crab biology (termed 'priors') provides more robust and accurate relative indices of abundance than would otherwise be possible if relying on fishery-dependent data alone. Therefore, the biomass estimate is somewhat buffered against external factor variability, including fishing patterns. Further, use of fishery independent data enables the model to capture and account for a larger size range of the population than just the legal-sized males which further strengthens the biomass estimate[3];
- Male crabs are able to move in and out of the closure area, and between sub-areas, both naturally and in response to bait and the area of concentration of commercial crab harvesting effort in the open areas of Roberts Bank can be assumed to reflect areas of positive crab harvest. With the introduction of the 2009 navigational closure, commercial crab harvesting has been concentrated along the western boundary of the closure, as well as the area along the Roberts Bank outer slope, the open area near the eastern boundary of the navigational closure and the area to the west of the navigational closure on the Canadian side of the Canada-U.S.A. border (see EIS Figure 21-6). Thus, most fishable crabs are accounted for in the biomass estimates for sub-area 29-6 and Area 29 overall;
- DFO (2016) identified that landings in all crab areas generally fluctuate with the cyclical nature of crab stocks; and,
- As outlined above and in the Preface to IR4-25 to IR4-32, the objective of the Dungeness crab productivity model was to generate a biomass estimate for input into the Roberts Bank ecosystem model to support the assessment of potential effects of the Project on marine invertebrates. The ecosystem model input biomass estimate was generated by weighting mean biomass estimates for sub-areas 29-6 and 29-7 according to the proportion of spatial overlap between the sub-areas and the Roberts Bank study area. Because this approach combines and weighs mean biomass estimates from the two sub-areas, the relative proportions contributed by each sub-area do not matter (i.e., the total is the same, regardless of how it is divided or why the shifts occurred).

The VFPA also notes that validation studies on the Dungeness crab productivity model indicate that biomass estimates are robust (see TDR MI-4). Further, potential uncertainty in biomass estimates from this model, for input into the Roberts Bank ecosystem model, have also been addressed via use of the pedigree and Monte Carlo sensitivity analyses approach (see EIS Appendix 10-D and responses to Information Request Package 3 (CEAR Document #984[4])).

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[3] In addition, model outputs were validated against all available catch data sources and were determined to be reasonably accurate; the use of multiple different information sources in the model approach increases confidence in the biomass estimate, particularly relative to relying solely on fisheries data, which reports only on legal size males (i.e., a more limited size range) and does not incorporate prior biological information.

[4] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3.

References

Fisheries and Oceans Canada (DFO). 2016. The Economics of British Columbia's Crab Fishery: Socio-economic Profile, Viability, and Market Trends. Available at http://www.dfo-mpo.gc.ca/ea-ae/cat1/no1-4/no1-4-intro-eng.htm#sup3. Accessed July 2017.

MacKenzie, C. J. 2010. The Dungeness Crab (Metacarcinus magister) Fishery in Burrard Inlet, BC: Constraints on Abundance-based Management and Improved Access for Recreational Harvesters. MRM project report. Simon Fraser University, Burnaby, B.C.

Zhang, Z., H. Hajas, A. Phillips, and J. A. Boutillier. 2002. Evaluation of an Intensive Fishery on Dungeness Crab, Cancer magister, in Fraser Delta, British Columbia. Canadian Science Advisory Secretariat Research Document 2002/118. 59 pp.

<u>IR4-31 Marine Invertebrates – Dungeness Crab: Crab Productivity Parameters in the Bayesian Model</u>

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity

Context

In the Dungeness Crab Productivity report, catchability (q), defined as the scaling coefficient for Fisheries and Oceans Canada abundance surveys and tau (τ), defined as the measurement error variances were listed within the parameters for the Bayesian size-structured crab population dynamics model; however, it is not clear if or how these parameters were used in the model specifications.

Information Request

Describe how q and τ were used within the Bayesian size-structured crab population dynamics model.

If these parameters were not used in the Bayesian size-structured crab population dynamics model, update the list of parameters in the document and provide a rationale for their exclusion.

VFPA Response

The catchability coefficient (q) and a measurement error (τ), which correspond to the catch-per-unit-effort (CPUE) DFO dataset, were not used in the final Bayesian size-structured crab population dynamics model (the model). The coefficient 'q' should have not been listed as a parameter in Section 3.3.2 of TDR MI-4 in Appendix AIR 10-C of Additional Information Request #10[1]; the purpose for including it in the parameter list in the EIS was to reflect that the CPUE dataset was initially considered in model specifications, and later excluded for the following reasons:

- Including survey CPUE caused unstable model behaviour because it provided contrary indications to the much larger size-composition datasets;
- Survey CPUE for crabs is less valuable in this context because it requires estimating a catchability coefficient that scale the index (e.g., average number of crabs per trap)

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[1] AIR-12.04.15-10 in CEAR Document #388 From Port Metro Vancouver to the Canadian Environmental Assessment Agency re: Completeness Review - Responses to Additional Information Requirements Follow-Up (See Reference Document #345) including 22 Technical Data Reports.

to the total biomass or numbers of crabs. Estimating catchability requires an informative, low variance dataset, which is generally not the case for this fishery; and

- Information derived from the total catch combined with the change in ratio of sub-legal to legal-sized crabs is much more useful in estimating abundance without the need to estimate catchability (Udevitz and Pollock 1992; Chen et al. 1998; Mackenzie 2010). The Bayesian size-structured model is essentially a complex change-in-ratio estimator.

IR4-26 expands on the above and provides more detailed rationale as to why CPUE data were not included in the model.

Each dataset used in the model has a measurement error (τ)[2] associated with it. While the CPUE dataset, and its associated measurement error, were not included in the final model for the reasons outlined above, both DFO abundance indices and length composition datasets—and corresponding measurement errors $(\tau_{I,g}^2)\ and\ (\tau_{L,g}^2)$, respectively—were included in the model. The measurement errors were included as variables within the likelihood function. Specifically, the multinomial logistic likelihood accounts for the multivariate measurement errors in the size-composition samples. For instance, in multivariate sampling of proportions, overestimates of the proportion for some size classes is correlated with low measurement errors on the proportions in other size classes. A multinomial logistic likelihood was selected over a multinomial likelihood because the former is self-weighting via an estimated sampling variance.

With the removal of 'q' and 'τ' associated with the CPUE dataset, the updated list of parameters used in the model is as follows:

1. $\hat{N}_{1,i}$ (i = 6, 7...22) – male crab abundance in size classes 127.5 mm to 207.5 mm for the first model year t = 1;
2. R_t (t = 1, 2...22) – annual total male crab recruitment to the population;
3. ρ_i (i = 1, 2...5) – proportional allocation of new male recruitment across the five smallest size classes (102.5 mm to 122.5 mm) to represent the size distribution of incoming recruits;
4. P_t^{95}, P_t^{50} – sizes at 95% and 50% annual moulting probability. The time index "t" reflects possible year effects on the size-at-moulting;
5. $\beta_0, \beta_1, \sigma_G$ – linear growth model parameters representing absolute carapace width increment per moult, relative moult increment multiplier, and standard deviation of final sizes around the expected final size per moult;

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[2] Measurement error is the difference between a measured quantity and its true value. In statistics, an error is not a 'mistake'; rather, variability is an inherent part of the results of measurements. Fishery scientists continually encounter the problem of measurement error in the collection and analysis of assessment data because the true abundance of a stock cannot be directly observed; rather, indirect methods are relied on (e.g., research vessel data, commercial catch data), which yield estimates or indices which are related to the true abundance, but there is error in the relationships.

6. M_1 and M_2 – instantaneous annual natural mortality rates for non-moulting and moulting periods, respectively;
7. $S_{g,t}^{50}, S_{g,t}^{95}$ – sizes at 50% and 95% selectivity in the commercial fishery (g = 1), the pre-season survey (g = 2), and the post-season survey (g = 3);
8. $\tau_{I,g}^{2}$ – measurement error variances for DFO abundance indices (g = 2, 3); and
9. $\tau_{L,g}^{2}$ – measurement error variances for length composition (g = 1, 2, 3).

References

Chen, C., J. M. Hoenig, E. G. Dawe, C. Brownie, and K. H. Pollock. 1998. New Developments in Change-in-ratio and Index-removal Methods, with Application to Snow Crab (Chionoecetes opilio). In Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. Edited by G.S. Jamieson and A. Campbell. Can. Spec. Publ. Fish. Aquat. Sci. pp 49-61. Available at http://fluke.vims.edu/hoenig/pdfs/Chen_Hoenig_Dawe_Brownir_Pollock_CIR_%20IR_SnowCrab.pdf. Accessed May 2017.

MacKenzie, C. J. A. 2010. The Dungeness Crab (Metacarcinus magister) Fishery in Burrard Inlet, B.C.: Constraints on Abundance-based Management and Improved Access for Recreational Harvesters (Master’s Thesis). Available at http://rem-main.rem.sfu.ca/theses/MackenzieCameron_2010_MRM478.pdf. Accessed May 2017.

Udevitz, M. S. and K. H. Pollock. 1992. Change-in-ratio Methods for Estimating Population Size. In D. R. McCullough and R. H. Barrett (eds), Wildlife 2001: Populations (pp. 90-101). Springer Netherlands.

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IR4-32 Marine Invertebrates – Dungeness Crab: Crab Productivity Fraction of Released Crab

Information Source(s)

EIS Volume 3: Section 12

TDR MI-4 Dungeness Crab Productivity Appendix A

Context

In Appendix A of the Dungeness Crab Productivity report, a fraction of released crabs (0.1) were assumed to die from handling. Clarification is required to understand how this assumption was made.

Information Request

Provide a rationale, source or citation for why the assumption that a fraction of released crabs (0.1) died from handling is appropriate.

VFPA Response

The assumption of a 0.1 (or 10%) fraction of released crabs dying from handling is based on published ranges of handling mortality rates found in the literature. The primary source is Alverson (1994), cited in Zhang and Dunham (2013), who reported that mortality of soft-shell individuals discarded from traps could be 22% to 25% while the mortality of sub-legal hardshell crab is much lower, at 2% to 4% (this is because soft-shell crabs are more vulnerable to handling mortality than hardshell crabs). Additionally, Zhang et al. (2002) conducted analyses on gain-or-loss in yield based on four different handling rate scenarios, 5%, 10%, 15%, and 20%, while Zheng and Siddeek (2014) used a baseline handling mortality rate of 20% in their stock assessment of red king crab. Hence, available literature would suggest a range of 2% to 25% (of crabs dying from handling) could be possible. The assumption of 10% (0.1) used in the model lies close to the middle of the range of published handling mortality rates and is thus considered reasonable.

Zheng and Siddeek (2014) performed a sensitivity analysis on the handling mortality rate used in their red king crab stock assessment model, where the baseline was set at 20%; the model was re-run under scenarios of a 50% reduction and 100% increase in the handling mortality rate (i.e., 10% or 0.1 and 40% or 0.4, respectively). Overall, a higher handling mortality rate resulted in slightly higher estimates of mature abundance, and a lower rate resulted in a minor reduction of estimated mature abundance, though it is important to note that differences of estimated legal abundance and mature male biomass were small among these various handling mortality rates. In light of these results, the selection of 10% handling mortality rate for the Dungeness Crab Productivity study is considered to be appropriate and shifting its value higher or lower will not materially change model predictions.

Further, as stated in the Preface to IR4-25 to IR4-32, the major objective of the Dungeness crab productivity model was to provide a site-specific biomass estimate for the Roberts Bank ecosystem model (RB model). Had another handling mortality rate been selected in the Dungeness crab productivity model, leading to a slightly higher or lower crab biomass estimate input into the RB model, the biomass estimate would still be considered biologically realistic and robust because i) the model estimates relative changes in productivity with and without the Project and ii) implications of input uncertainty in biomass numbers were tested through rigorous sensitivity analyses. As outlined in question 2.7 of CEAR Document #547[1] and IR3-09 of CEAR Document #984[2], results of sensitivity analyses provide increased confidence that the predicted Project impact for Dungeness crab was robust to uncertainty about input crab biomass.

References

Alverson, D. L., M. H. Freeberg, J. G. Pope, and S. A. Murawski. 1994. A Global Assessment of Fisheries Bycatch and Discards. FAO Fisheries Technical Paper no. 339, Rome, FAO, 233 pp.

Zhang, Z. and J. S. Dunham. 2013. Construction of Biological Reference Points for Management of the Dungeness Crab, *Cancer magister*, Fishery in the Fraser River Delta, British Columbia, Canada. Fisheries Research. 139: 18-27.

Zhang, Z., W. Hajas, A. Phillips, and J. A. Boutillier. 2002. Evaluation of an Intensive Fishery on Dungeness Crab, *Cancer magister*, in Fraser Delta, British Columbia. Fisheries and Oceans Canada, Nanaimo, B.C.

Zheng, J. and M. S. M. Siddeek. 2014. Bristol Bay Red King Crab Stock Assessment in Spring 2014. Available at https://www.npfmc.org/wp-content/PDFdocuments/ membership/ PlanTeam/Crab/September13/BBRKC.pdf. Accessed May 2017.

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[1] CEAR Document #547 From the Vancouver Fraser Port Authority to the Review Panel re: Answers to preliminary technical questions submitted during the completeness phase from Fisheries and Oceans Canada, Natural Resources Canada, and Environment and Climate Change Canada, concerning the ecosystem modelling to support the Roberts Bank Terminal 2 Project environmental review (NOTE: Updated September 28th, 2016).

[2] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document # 928).

IR4-33 Marine Invertebrates: Contaminants in Crab Hepatopancreas

Information Source(s)

EIS Volume 2: Appendix 9.6-B

EIS Volume 3: Figure 12-1

EIS Volume 4: Appendix 27-C

Health Canada Submission CEAR Doc#579

Context

Appendix 27-C described shellfish harvesting potential and contaminant-related consumption risks at Roberts Bank. The Appendix documented that there were no detectable polycyclic aromatic hydrocarbons (PAHs) in samples of leg muscles from Dungeness crabs. In view of this conclusion, the Proponent excluded crab from a subsequent Human Health Risk Assessment similar to that which was conducted for edible bivalve shellfish.

However, according to Health Canada when there is a potential for the consumption of crab hepatopancreas, it should be included as part of the human health risk assessment for traditional foods. Health Canada is of the view that, while consumption of hepatopancreas may be infrequent and low, the tendency for hepatopancreas to accumulate environmental contaminants would result in the potential for this country food to provide a notable contribution to overall dietary exposure.

Although Roberts Bank crab hepatopancreas morphology and sizes are quantified in Table 4-10 of Appendix 27-C, no contaminant concentrations are reported. Crab hepatopancreas tissue is consumed by some individuals, including Indigenous peoples. Therefore, an assessment of current and future hepatopancreas contaminant concentrations, including but not limited to polychlorinated biphenyl (PCBs), PAHs and trace element concentrations in the local assessment area (as denoted by Figure 12-1 of the EIS) is required.

Information Request

Describe the concentration of contaminants of potential concern in crab hepatopancreas throughout the local assessment area, including sites situated within the tug basin and the intermediate transfer pit.

Provide PCB, PAH and trace element concentrations, including the PAH congeners listed in Table 4-13 of Appendix 27-C, the PCB congeners listed in Table 5-2 of Appendix 9.6-B and trace element concentrations in crab hepatopancreas for the list of trace elements shown in Table 4-14 of Appendix 27-C, in crab hepatopancreas tissues for Dungeness crabs located in the local assessment area (as denoted by Figure 12-1 of the EIS).

VFPA Response

1.0 Crab Hepatopancreas Study Overview

A crab hepatopancreas study was conducted at Roberts Bank to determine the concentrations of contaminants of concern in crab hepatopancreas in the local assessment area. In June 2017, Dungeness crab were collected from five traps placed at each of the three study locations (15 traps total). The three sites are shown on Figure IR4-33-A1 in **Appendix IR4-33-A**, and are representative of the local assessment area for human health effects related to marine invertebrates (EIS Figure 27-1). While it was possible to collect crab from the RBT2 terminal footprint location and the Canoe Passage reference site as requested in this information request, access to the tug basin was not feasible or safe because of tug vessel traffic, and because crab harvesting is prohibited in this area. The crab collected from the formerly proposed[1] intermediate transfer pit (ITP) site location are considered representative of the crab that may be harvested in areas near the tug basin. Twelve adult male crabs were harvested from each of the three sites (36 crab total).

Prior to the processing of crab, the weight and carapace width were recorded. The hepatopancreas from each crab was harvested and the weight recorded. Due to the amount of tissue needed for the chemical analysis requested, individual samples of hepatopancreas from each collection site were randomly pooled until there was sufficient tissue. A total of four pooled samples comprising the hepatopancreas from two to four crabs were prepared for each site (4 pooled samples x 3 sites = 12 samples total). Samples were submitted under chain of custody to analytical laboratories accredited by the Canadian Association for Laboratory Accreditation (CALA) for the analysis requested. The analysis was completed in August 2017.

2.0 Study Methodology

2.1 Study Area

The Dungeness crab study area, which is within the RBT2 marine invertebrates local assessment area referenced above, encompasses shallow subtidal areas at Roberts Bank, including the inter-causeway area, within the footprint of the proposed terminal, and a reference location near Canoe Passage approximately 3 km west of the existing terminal (Figure IR4-33-A1 in **Appendix IR4-33-A**).

2.2 Crab Collection

Adult male Dungeness crabs were collected from the three sample locations shown in Figure IR4-33-A1 in **Appendix IR4-33-A** including the proposed RBT2 footprint (RBT2), one location in the inter-causeway area/ITP, and one location selected as a reference location near Canoe Passage (reference), approximately 3 km west of Westshore Terminals. The reference location depth was chosen to be similar to the depth of the RBT2 location. While it was possible

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[1] Use of the ITP is no longer part of the Project Description for RBT2, as described in the *Preamble in Support of Responses to IR3-25 to IR3-40 – General and Disposal at Sea-related Project Construction Update* (CEAR Document #984).

to collect crab from the RBT2 terminal footprint location and the Canoe Passage reference site, access to the tug basin was not feasible or safe because of tug vessel traffic. The crab collected from the ITP site are considered representative of the crab that may be harvested in areas near the tug basin.

A permit for the crab collection was obtained from Fisheries and Oceans Canada (DFO) and collection of Dungeness crab was conducted on June 8, 2017, in accordance with permit requirements. At each sampling location, five commercial traps (placed approximately 20 m apart) were established along a transect line as one set, the start and end of which was marked with a gillnet float anchored by a cannon ball. Traps were baited and soaked overnight (approximately 22 hours) prior to collection. Following trap retrieval, legal-sized male crabs (>165 mm carapace width) were transferred into Rubbermaid containers, and the juveniles and females were released.

2.3 Crab Preparation

Retained specimens were placed in Rubbermaid totes and kept on a bed of ice for approximately three hours until processing. During processing, each individual crab was carefully inspected for external abnormalities and then euthanised. The following observations and measurements were recorded for individuals retained for chemical analysis:

- Species;
- Sex;
- Carapace width (in mm, measured as the widest part of the carapace, from spine to spine);
- Molt stage;
- Visual observations of external abnormalities; and
- Total wet weight (in grams).

The top of the carapace was then carefully removed by cutting the connective tissue between the top and abdomen segments of the carapace and around the legs, and pulling up on the top carapace from the area near the eye stalks. The body cavity, gills, and hepatopancreas were then examined for any abnormalities (e.g., black particulate). The hepatopancreas was removed with a large spoon into a non-contaminating jar and weighted to the nearest 0.1 g. Due to the amount of tissue needed for the chemical analysis, individual hepatopancreases from each collection site were randomly pooled until there was sufficient tissue to form a sample for analysis. A total of four pooled samples, each comprising the hepatopancreases from three crabs, were prepared for each sampling site (4 pooled samples x 3 sites = 12 pooled samples total). Samples were stored at -20^{o}C prior to shipment to the analytical laboratories.

2.4 Chemical Analysis

The frozen hepatopancreas samples were submitted under chain of custody to AXYS Laboratories for analysis of polycyclic aromatic hydrocarbon (PAHs) and polychlorinated biphenals (PCBs), and to ALS Global for analysis of metals and arsenic speciation. Both analytical laboratories are accredited by CALA for the analysis requested. The analysis was completed in August 2017.

2.5 Statistical Analysis

Statistical analysis of the data was conducted to determine whether the average contaminant concentrations in hepatopancreas from crab collected from each of the three sites were statistically different. The statistical analysis was completed for PCB toxic equivalencies (TEQs), major [summed] classes of PAHs, coal element indicator compounds and speciated arsenic compounds as follows:

- If a substance was not detected, it was assumed to be present at a concentration equal to half the reported detection limit (i.e., ND = ½ DL).
- The data was tested for normality using Shapiro-Wilk Test.
- Non-normal data were logarithmically transformed and tested for normality.
- A one-way ANOVA was run and results evaluated to determine if there was a significantly different variance between sites (i.e., $p<0.05$).
- If statistically significant differences were found, box and whisker plots and Tukey HSD (honest significant difference) results were examined to determine site differences relative to each other (using http://vassarstats.net/anova1u.html).

Although some of the data sets were non-normal, the use of a one-way ANOVA is acceptable but can produce Type 1 errors (i.e., report a statistically significant difference when there actually is none). Two of the non-normal data transformations resulted in normal data and two had p-values well above 0.05 and not close to producing Type 1 errors. Therefore, the non-normal data do not alter study conclusions.

3.0 Results

3.1 Crab Measurements and Observations

A total of 36 crabs were collected comprising of 12 individuals from each of the three sites (four composites of three crab). Crab total weight ranged from 583 to 900 grams. Carapace width ranged from 165 mm to 195 mm. Crab hepatopancreas weight ranged from 19 to 69 grams. The crab measurement and observations data are summarised in Table IR4-33-B1 (in **Appendix IR4-33-B**).

3.2 Analytical Results

The detailed analytical results are provided in **Appendix IR4-33-B** and tabulated as follows:

- Table IR4-33-B2 – PCB Concentrations in Crab Hepatopancreas
- Table IR4-33-B3 – PAH Concentrations in Crab Hepatopancreas
- Table IR4-33-B4 – Trace Element and Arsenic Species Concentrations in Crab Hepatopancreas

4.0 Summary and Discussion

4.1 Range and Average Contaminant Levels

The following is a summary of the contaminant levels detected in crab hepatopancreas. The results are presented based on non-detects equal to one half the detection limit (ND = ½ DL).

PCB Concentrations Expressed as TEQs[2] (Table IR4-33-B2):

- Reference Site – concentrations ranged from 0.128 to 0.229 pg/g. The average concentration was 0.177 pg/g.
- RBT2 Site – concentrations ranged from 0.211 to 0.272 pg/g. The average concentration was 0.234 pg/g.
- ITP Site – concentrations ranged from 0.131 – 0.548 pg/g. The average concentration was 0.253 pg/g.

PAH Concentrations for Major Summed Classes (Table IR4-33-B3):

- Reference Site
  - LPAH concentrations ranged from 1.98 to 2.389 ng/g, with an average concentration of 2.113 ng/g.
  - HPAH concentrations ranged from 0.223 to 0.571 ng/g, with an average concentration of 0.379 ng/g.
  - TPAH concentrations ranged from 2.203 to 2.83 ng/g, with an average concentration of 2.492 ng/g.
  - Sum of alkyl PAH concentrations ranged from 3.873 to 7.222 ng/g, with an average concentration of 5.266 ng/g.
  - Total unsubstituted and alkyl PAH concentrations ranged from 6.076 to 9.794 ng/g, with an average concentration of 7.758 ng/g.
- RBT2 Site
  - LPAH concentrations ranged from 1.814 to 2.279 ng/g, with an average concentration of 1.960 ng/g.
  - HPAH concentrations ranged from 0.243 to 0.427 ng/g, with an average concentration of 0.336 ng/g.
  - TPAH concentrations ranged from 2.081 to 2.706 ng/g, with an average concentration of 2.296 ng/g.
  - Sum of alkyl PAH concentrations ranged from 3.495 to 6.235 ng/g, with an average concentration of 4.562 ng/g.
  - Total unsubstituted and alkyl PAH concentrations ranged from 5.731 to 8.394 ng/g, with an average concentration of 6.858 ng/g.
- ITP Site
  - LPAH concentrations ranged from 1.473 to 1.913 ng/g, with an average concentration of 1.687 ng/g.

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[2] Calculated in accordance with WHO (2005) [van den Berg, M; Birnbaum, LS; Denison, M; et al. (2006) The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol Sci 93(2):223−241].

    - HPAH concentrations ranged from 0.213 to 0.946 ng/g, with an average concentration of 0.588 ng/g.
    - TPAH concentrations ranged from 1.554 to 2.859 ng/g, with an average concentration of 2.196 ng/g.
    - Sum of alkyl PAH concentrations ranged from 2.924 to 3.681 ng/g, with an average concentration of 3.315 ng/g.
    - Total unsubstituted and alkyl PAH concentrations ranged from 4.61 to 6.367 ng/g, with an average concentration of 5.511 ng/g.

Coal Indicator Element Concentrations Excluding Arsenic (Table IR4-33-B4):

- Reference Site
    - Bismuth concentrations ranged from 0.0057 to 0.0103 µg/g, with an average concentration of 0.008 µg/g.
    - Cadmium concentrations ranged from 1.04 to 2.60 µg/g, with an average concentration of 1.915 µg/g.
    - Selenium concentrations ranged from 2.90 to 3.64 µg/g, with an average concentration of 3.255 µg/g.
    - Vanadium concentrations ranged from 0.183 to 0.302 µg/g, with an average concentration of 0.247 µg/g.
- RBT2 Site
    - Bismuth concentrations ranged from 0.0054 to 0.011 µg/g, with an average concentration of 0.008 µg/g.
    - Cadmium concentrations ranged from 1.81 to 3.38 µg/g, with an average concentration of 2.723 µg/g.
    - Selenium concentrations ranged from 2.26 to 4.5 µg/g, with an average concentration of 3.045 µg/g.
    - Vanadium concentrations ranged from 0.139 to 0.337 µg/g, with an average concentration of 0.220 µg/g.
- ITP Site
    - Bismuth concentrations ranged from 0.0089 to 0.014 µg/g, with an average concentration of 0.011 µg/g.
    - Cadmium concentrations ranged from 0.415 to 1.26 µg/g, with an average concentration of 0.954 µg/g.
    - Selenium concentrations ranged from 1.60 to 2.78 µg/g, with an average concentration of 2.150 µg/g.
    - Vanadium concentrations ranged from 0.199 to 0.415 µg/g, with an average concentration of 0.308 µg/g.

Arsenic and Inorganic Arsenic Species Concentrations (Table IR4-33-B4):

- Reference Site
    - Total arsenic concentrations ranged from 5.99 to 7.98 µg/g, with an average concentration of 7.085 µg/g.
    - Arsenate was not detected in any sample at a detection limit of 0.10 µg/g.
    - Arsenite concentrations ranged from 0.022 to 0.046 µg/g, with an average concentration of 0.033 µg/g.

- RBT2 Site
    - Total arsenic concentrations ranged from 5.75 to 8.36 µg/g, with an average concentration of 7.355 µg/g.
    - Arsenate was not detected in any sample at a detection limit of 0.10 µg/g.
    - Arsenite concentrations ranged from 0.021 to 0.04 µg/g, with an average concentration of 0.028 µg/g.
- ITP Site
    - Total arsenic concentrations ranged from 6.78 to 12.9 µg/g, with an average concentration of 8.563 µg/g.
    - Arsenate was not detected in any sample at a detection limit of 0.10 µg/g (one sample had a detection limit of <0.25 µg/g).
    - Arsenite concentrations ranged from <0.020 to 0.057 µg/g, with an average concentration of 0.040 µg/g.

4.2 Statistical Comparison Across Sites

The results of the one-way ANOVA test of average contaminant concentrations in crab hepatopancreas across the three study locations are summarised in **Table IR4-33-1** below.

Table IR4-33-1 Summary of Statistical Analysis

Substance	Are the Average Concentrations Statistically Different Across Sites?	Comments
Coal Indicator Element Compounds		
Arsenic	No significant differences	Not applicable (N/A)
Bismuth	No significant differences	N/A
Cadmium	Yes for RBT2 and ITP	RBT2 average concentration is higher than ITP, but not higher than reference site.
Selenium	No significant differences	N/A
Vanadium	No significant differences	N/A
Arsenic Species		
Arsenate Arsenite Arsenobetaine Arsenocholine Dimethylarsinic acid Monomethylarsonic acid	No significant differences	N/A
PAHs (summed major classes)		
HPAH (unsubstituted)	No significant differences	N/A
LPAH (unsubstituted)	Yes for Reference and ITP	Reference site average concentration is higher than RBT2 and ITP.
TPAH (unsubstituted)	No significant differences	N/A

Substance	Are the Average Concentrations Statistically Different Across Sites?	Comments
Sum Alkyl PAH	No significant differences	N/A
Total Unsubstituted and Alkyl PAH	No significant differences	N/A
PCBs, Total Toxic Equivalents (TEQ)		
PCB	No significant differences	N/A

Except for LPAH, there were no significant differences in average contaminant concentrations measured in hepatopancreas from crab collected at the reference site compared with the RBT2 and ITP sites. The average concentration of LPAH at the reference site was significantly higher than that measured at the ITP site. The average concentration of cadmium from the RBT2 site was also higher than that measured at the ITP site.

5.0 Conclusion

In response to IR4-33, additional sampling and analysis of Dungeness crab at Roberts Bank has been completed, to provide concentrations of PCBs, PAHs, and trace elements in crab hepatopancreas. Sampling sites included the location of the proposed RBT2 terminal, a reference site at Canoe Passage, and the area of the formerly proposed ITP, which is considered representative of the tug basin.

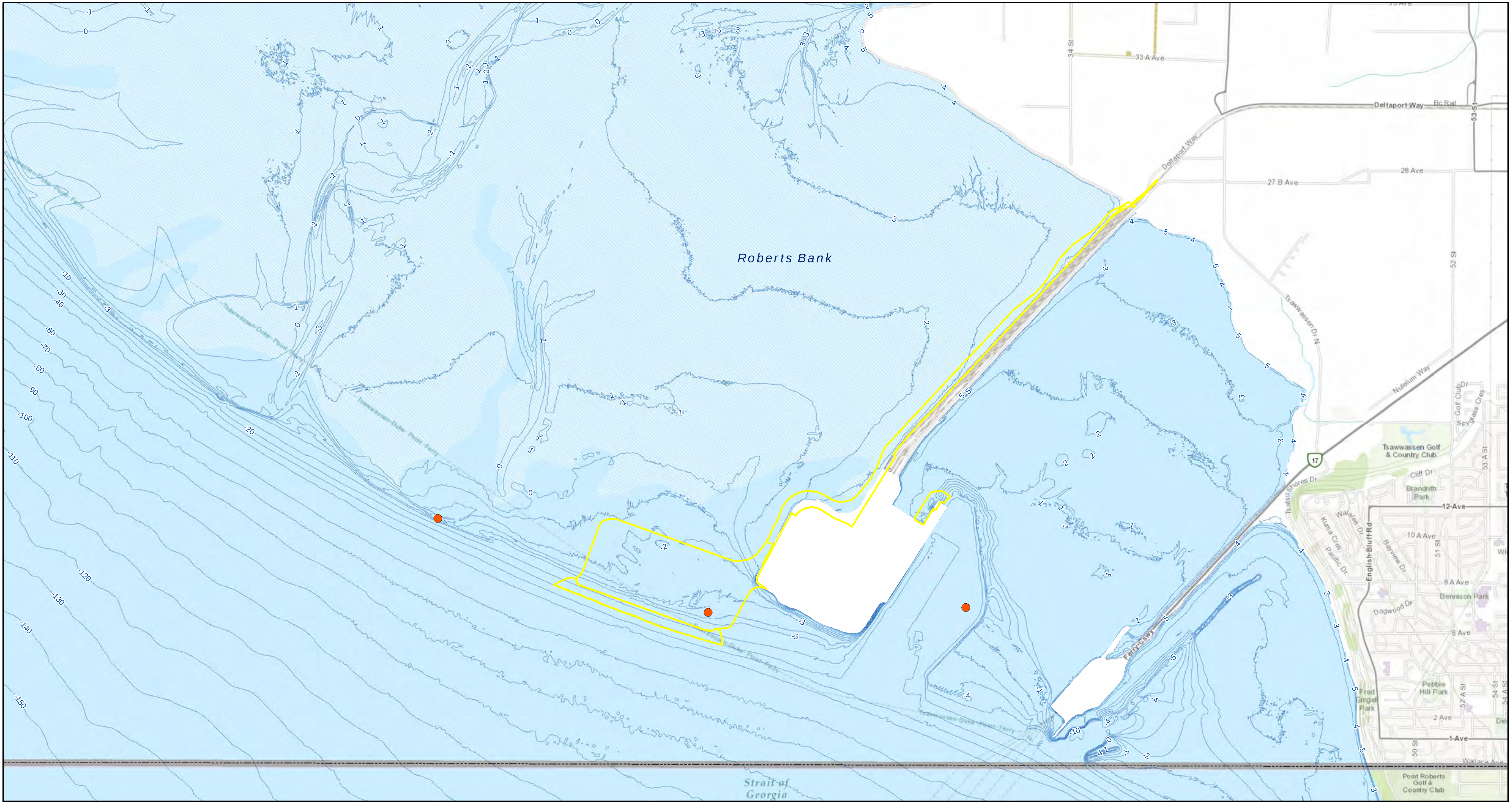
Collectively, the results of a statistical comparison across sites indicate that the average concentrations of PCBs, coal indicator elements, arsenic compounds, and PAHs measured in hepatopancreas from crab collected from the RBT2 and ITP sites are not statistically higher than those measured in crab from the Canoe Passage reference site. This suggests that existing sediment and water quality in and around the existing terminal and proposed RBT2 terminal are not contributing to contaminant concentrations in crab hepatopancreas that are higher than levels found in crab hepatopancreas from the Canoe Passage reference site.

Appendices

Appendix IR4-33-A	Supporting Figure
Appendix IR4-33-B	Supporting Tables

APPENDIX IR4-33-A
SUPPORTING FIGURE

Path: O:\1200-1246\EIS_INFORMATION_REQUESTS\IR4_33\mxd\IR4_33_A1_CrabStudy_SamplingLocations_171019.mxd



Legend

- ● CRAB SAMPLING LOCATION
- ▭ BOUNDARY OF PROJECT AREA
- — BATHYMETRY (METRES, CD)
- ▬ U.S.A.-CANADA BORDER

0 1 2
Kilometres
1:35,000
NAD 1983 UTM Zone 10N
N

PORT of vancouver

ROBERTS BANK TERMINAL 2

RBT2 CRAB HEPATOPANCREAS STUDY - CRAB SAMPLING LOCATIONS

DATE: 10/23/2017
FIG No. IR4-33-A1

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

APPENDIX IR4-33-B
SUPPORTING TABLES

Table IR4-33-B1 Measurements Retained During Crab Processing

Sample ID	Collection Date	Site	Sample number	Pool Number	Sex	Weight (g)	Carapace Width (mm)	Weight hepatopancreas (g)
170608_REF_1	08-06-17	REF	1	1	M	765	175	19
170608_REF_2	08-06-17	REF	2	1	M	892	195	42
170608_REF_3	08-06-17	REF	3	1	M	636	168	34
170608_REF_4	08-06-17	REF	4	2	M	664	170	30
170608_REF_5	08-06-17	REF	5	2	M	679	172	40
170608_REF_6	08-06-17	REF	6	2	M	828	180	49
170608_REF_7	08-06-17	REF	7	3	M	673	170	42
170608_REF_8	08-06-17	REF	8	3	M	583	170	40
170608_REF_9	08-06-17	REF	9	3	M	761	180	46
170608_REF_10	08-06-17	REF	10	4	M	734	175	35
170608_REF_11	08-06-17	REF	11	4	M	641	168	43
170608_REF_12	08-06-17	REF	12	4	M	900	187	50
170608_RBT2_1	08-06-17	RBT2	1	1	M	837	180	57
170608_RBT2_2	08-06-17	RBT2	2	1	M	697	170	54
170608_RBT2_3	08-06-17	RBT2	3	1	M	674	172	39
170608_RBT2_4	08-06-17	RBT2	4	2	M	653	174	37
170608_RBT2_5	08-06-17	RBT2	5	2	M	673	173	43
170608_RBT2_6	08-06-17	RBT2	6	2	M	704	175	43
170608_RBT2_7	08-06-17	RBT2	7	3	M	789	176	41
170608_RBT2_8	08-06-17	RBT2	8	3	M	809	181	56
170608_RBT2_9	08-06-17	RBT2	9	3	M	730	178	30
170608_RBT2_10	08-06-17	RBT2	10	4	M	657	171	39
170608_RBT2_11	08-06-17	RBT2	11	4	M	764	176	56
170608_RBT2_12	08-06-17	RBT2	12	4	M	720	170	50
170608_ITP_1	08-06-17	ITP	1	1	M	732	177	56
170608_ITP_2	08-06-18	ITP	2	1	M	871	190	47
170608_ITP_3	08-06-19	ITP	3	1	M	786	182	46
170608_ITP_4	08-06-20	ITP	4	2	M	716	175	48
170608_ITP_5	08-06-21	ITP	5	2	M	736	184	38
170608_ITP_6	08-06-22	ITP	6	2	M	757	183	47
170608_ITP_7	08-06-23	ITP	7	3	M	720	176	41
170608_ITP_8	08-06-24	ITP	8	3	M	792	182	54
170608_ITP_9	08-06-25	ITP	9	3	M	814	190	69
170608_ITP_10	08-06-26	ITP	10	4	M	707	170	39
170608_ITP_11	08-06-27	ITP	11	4	M	647	165	46
170608_ITP_12	08-06-28	ITP	12	4	M	750	173	61

Table IR4-33-B2 PCB Concentrations in Crab Hepatopancreas (pg/g on a wet weight basis)

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between
Sample ID	RBT2-1	RBT2-2	RBT2-3	RBT2-4	Average	ITP-1	ITP-2	ITP-3	ITP-4	Average	REF-1	REF-2	REF-3	REF-4	Average	101	
% Moisture	9.65	7.67	12.8	7	--	7.61	7.58	7.05	5.72	--	6.36	12.2	12.7	9.11	--	--	--
% Lipid	79	83.5	77.9	80.6	--	81.8	81.8	84	83.2	--	82.5	77.8	78.4	79.8	--	--	--
PCB-1	0.37	0.317	0.658	0.538	--	0.525	0.48	0.605	0.605	--	0.357	0.471	0.429	0.437	--	0.416	--
PCB-2	0.222	0.198	0.31	0.301	--	0.318	0.252	0.302	0.388	--	0.257	0.287	0.222	0.248	--	0.176	--
PCB-3	0.303	0.301	0.464	0.354	--	0.351	0.251	0.348	0.444	--	0.308	0.487	0.29	0.383	--	0.381	--
PCB-4	5.45	3.97	7.09	4.06	--	1.69	2.4	2.74	2.83	--	3.37	6.91	6.08	4.59	--	0.389	--
PCB-5	<0.0776	<0.144	0.095	<0.0687	--	<0.0661	<0.0721	<0.113	<0.0626	--	<0.1	<0.112	<0.101	<0.104	--	<0.137	--
PCB-6	1.3	0.944	1.8	1.08	--	0.535	0.788	0.761	0.673	--	0.777	1.8	1.36	1.24	--	<0.121	--
PCB-7	0.2	0.182	0.233	0.186	--	0.104	0.115	0.141	0.162	--	0.276	1.13	0.214	0.291	--	<0.127	--
PCB-8	5.78	4.35	8.37	4.44	--	1.91	2.73	2.86	2.8	--	3.6	6.91	5.98	5.65	--	0.51	--
PCB-9	0.106	<0.127	0.186	0.109	--	0.073	0.067	<0.102	0.095	--	0.123	0.105	0.134	0.151	--	<0.121	--
PCB-10	0.136	<0.132	0.271	0.12	--	<0.0608	0.073	<0.104	0.124	--	<0.0924	0.188	0.13	0.133	--	<0.126	--
PCB-11	19	16.9	22.6	17.5	--	8.42	8.35	10.5	9.52	--	16.6	25.6	17.8	21.9	--	4.59	--
PCB-12 + 13	0.731	0.516	0.667	0.449	--	0.279	0.282	0.307	0.265	--	0.438	0.849	0.585	0.706	--	<0.129	--
PCB-14	<0.0713	<0.132	<0.0782	<0.0632	--	<0.0608	<0.0663	<0.104	<0.0576	--	<0.0922	<0.103	<0.0924	<0.0954	--	<0.126	--
PCB-15	8.11	7.6	6.9	4.61	--	3.09	8.66	19.9	3.87	--	4	7.8	6.13	6.34	--	0.39	--
PCB-16	13.6	8.46	13	7.79	--	2.77	4.11	4.41	4.58	--	5.3	13.9	12.1	8.75	--	0.179	--
PCB-17	20.6	13.6	21.4	11.8	--	3.77	7.85	8.1	7.22	--	8.36	20.4	18.4	14.9	--	0.174	--
PCB-18 + 30	45.7	29.2	44.1	24.5	--	11.9	20	15.4	16.8	--	16.8	42.8	40.4	33.1	--	0.412	--
PCB-19	0.775	0.616	1.16	0.484	--	0.431	0.445	0.189	0.354	--	0.865	1.49	1.07	0.871	--	0.082	--
PCB-20 + 28	157	189	166	131	--	78.9	296	225	90.7	--	84.4	172	155	142	--	0.662	--
PCB-21 + 33	17.2	11.4	18	10	--	3.87	8.09	6.38	6.51	--	8.69	18.3	15.2	14.7	--	0.368	--
PCB-22	25.1	19	27.1	16.6	--	6.95	22.7	18.3	11	--	12.1	25.8	23.4	21.3	--	0.191	--
PCB-23	<0.158	<0.163	<0.19	<0.108	--	<0.054	<0.0533	<0.0956	<0.0628	--	<0.102	<0.173	<0.0845	<0.151	--	<0.05	--
PCB-24	0.35	0.197	0.37	0.221	--	0.115	0.109	0.151	0.109	--	0.11	0.316	0.353	0.266	--	<0.05	--
PCB-25	5.32	3.26	5.44	3.22	--	1.52	3.39	2.51	2.28	--	2.19	5.02	5.08	4.3	--	<0.05	--
PCB-26 + 29	15.4	10.4	16.8	11.3	--	4.95	11.1	6.85	6.71	--	6.66	14.5	13.9	12.5	--	0.104	--

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**101**	
PCB-27	5.16	4.37	5.09	3	--	1.57	2.94	3.04	2.53	--	2.05	5.19	5.27	3.58	--	<0.05	--
PCB-31	121	109	113	64.7	--	27.8	162	196	51	--	53.6	120	120	87.6	--	0.529	--
PCB-32	12.1	8.81	20.9	8.57	--	4.52	10.5	6.25	9.4	--	5.21	11.3	12.2	10.3	--	0.136	--
PCB-34	0.345	0.234	0.501	0.283	--	0.166	0.232	0.188	0.138	--	0.225	0.498	0.394	0.322	--	0.057	--
PCB-35	1.05	0.519	1.21	0.683	--	0.262	0.188	0.714	0.39	--	0.536	0.876	0.618	0.793	--	0.085	--
PCB-36	0.504	0.563	0.928	0.415	--	0.232	<0.048	0.16	<0.0563	--	0.659	1.02	0.457	0.884	--	<0.05	--
PCB-37	20.6	26.6	15.4	12.2	--	6.42	29.6	18.9	7.92	--	9.22	17.5	14.6	16.9	--	0.273	--
PCB-38	<0.152	<0.157	<0.187	<0.106	--	<0.0531	0.186	<0.0941	<0.0618	--	0.131	0.241	0.254	0.156	--	<0.05	--
PCB-39	1.91	1.71	1.54	0.964	--	0.44	1.08	0.722	0.616	--	0.825	2.13	1.85	1.62	--	<0.05	--
PCB-40 + 41 + 71	93.3	64.1	100	50.3	--	25.2	71.5	45.5	37.8	--	35.5	98.2	92	77.1	--	0.325	--
PCB-42	67.5	45.9	65.5	34.2	--	25	73.3	43.9	23	--	27.5	73	70.2	58.1	--	0.08	--
PCB-43	11.4	13.1	12.4	6.31	--	4.35	15	18.8	4.88	--	5.05	11.3	11.4	9.5	--	<0.0656	--
PCB-44 + 47 + 65	442	362	353	271	--	189	506	292	154	--	166	365	308	324	--	3.08	--
PCB-45 + 51	10.6	6.29	12.1	5.45	--	3	5.98	2.93	3.96	--	4.95	12.6	10.7	8.75	--	0.613	--
PCB-46	2.11	1.25	2.37	0.97	--	0.657	1.09	0.476	0.717	--	1.3	3.99	3.09	1.67	--	<0.0695	--
PCB-48	39.5	33.9	38.6	19.2	--	6.8	16.1	12.8	12.8	--	17.1	42.1	34.6	32.3	--	0.081	--
PCB-49 + 69	274	181	232	134	--	80.1	398	194	104	--	101	236	212	201	--	0.314	--
PCB-50 + 53	10.5	6.67	11.7	4.66	--	4.1	7.81	2.61	3.81	--	4.99	13.2	11.7	8.44	--	0.09	--
PCB-52	797	636	574	407	--	330	1050	606	277	--	288	600	525	530	--	0.585	--
PCB-54	<0.05	<0.0499	<0.0477	<0.0492	--	<0.0497	<0.048	<0.0496	<0.0497	--	<0.0498	<0.0478	<0.05	<0.0501	--	0.112	--
PCB-55	6.1	6.44	6.42	4.62	--	3.45	10.5	3.13	3.21	--	3.33	6.42	5.34	5.65	--	<0.0671	--
PCB-56	59.6	40.5	65	35	--	17.7	53.7	24.3	24.3	--	28.4	58.2	55.5	54	--	0.144	--
PCB-57	0.665	<1.23	1	0.6	--	0.433	<1.03	0.334	0.367	--	<0.615	0.825	0.664	0.676	--	<0.0627	--
PCB-58	1.68	1.5	1.72	1.13	--	0.988	1.73	1.1	0.779	--	0.78	1.79	1.49	1.3	--	<0.066	--
PCB-59 + 62 + 75	30.9	24.5	28.3	17.2	--	10.6	31.1	18.1	13.6	--	11.1	28.1	26.1	21.7	--	<0.05	--
PCB-60	84	103	85.5	68.6	--	48.8	153	44.1	47.9	--	46.5	86.5	72.7	76.1	--	0.109	--
PCB-61 + 70 + 74 + 76	602	596	577	441	--	230	924	329	278	--	285	587	488	486	--	0.743	--
PCB-63	26.6	29.4	24.5	16.4	--	10.1	55.2	20.5	14.2	--	13.3	29.1	23.2	24	--	<0.0641	--

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between
Sample ID	RBT2-1	RBT2-2	RBT2-3	RBT2-4	Average	ITP-1	ITP-2	ITP-3	ITP-4	Average	REF-1	REF-2	REF-3	REF-4	Average	101	
PCB-64	174	139	157	93.8	--	64.3	244	144	66	--	66.8	159	145	135	--	0.191	--
PCB-66	284	358	307	241	--	160	604	165	165	--	154	304	256	285	--	0.404	--
PCB-67	4.95	2.16	5.24	2.99	--	1.45	3.21	1.69	2	--	2.01	5.25	4.77	4.44	--	<0.0547	--
PCB-68	7.31	5.52	8.55	7.08	--	5.24	17.8	5.47	5.12	--	4.2	9.87	7.83	5.64	--	0.566	--
PCB-72	7.7	6.21	8.43	6.05	--	4.78	16.9	6.44	4.6	--	4.21	8.69	7.09	6.23	--	<0.0585	--
PCB-73	10.4	7.99	6.25	4.57	--	4.44	12.3	6.36	3.28	--	3.88	8.14	6.83	7.26	--	<0.05	--
PCB-77	25.9	34	23.3	15.8	--	13.3	50.6	11.4	11.1	--	12.4	21.7	19.8	22.1	--	0.114	--
PCB-78	<0.42	<1.17	<0.326	<0.213	--	<0.147	<1.03	<0.223	<0.329	--	<0.586	<0.358	<0.349	<0.518	--	<0.0598	--
PCB-79	11.7	13.4	9.36	7.88	--	6.83	16.7	5.77	4.9	--	6.41	13.5	12.4	12.5	--	<0.0511	--
PCB-80	<0.404	<1.13	<0.309	0.607	--	<0.139	<0.97	<0.211	<0.311	--	<0.564	<0.345	<0.336	<0.499	--	<0.0575	--
PCB-81	1.68	1.71	1.68	1.07	--	0.796	2.14	0.555	0.604	--	0.746	1.12	1.12	1.13	--	<0.0696	--
PCB-82	54.1	35.9	47.3	25.9	--	23.8	56.4	20.9	18.1	--	20.4	55.1	52.2	46.2	--	<0.0998	--
PCB-83 + 99	2480	1420	1150	1570	--	1200	2500	684	787	--	720	1240	993	1180	--	0.279	--
PCB-84	107	99.5	95.5	52.2	--	47	98.3	44.7	39.8	--	43.7	95.1	94.1	99.1	--	<0.103	--
PCB-85 + 116 + 117	399	319	270	295	--	239	511	154	161	--	155	297	225	294	--	0.083	--
PCB-86 + 87 + 97 + 109 + 119 + 125	615	519	501	363	--	310	896	263	251	--	265	555	465	517	--	0.427	--
PCB-88 + 91	121	108	111	90.3	--	81.4	242	63.9	69.1	--	54	119	105	104	--	<0.0937	--
PCB-89	<0.826	0.545	1.08	0.474	--	<0.523	<0.84	<0.374	0.241	--	0.569	1.42	1.37	1.01	--	<0.0894	--
PCB-90 + 101 + 113	1760	1630	1250	1370	--	1090	3150	835	867	--	766	1320	1090	1310	--	0.458	--
PCB-92	303	292	254	221	--	211	465	174	139	--	134	256	213	249	--	<0.082	--
PCB-93 + 95 + 98 + 100 + 102	603	461	554	331	--	305	861	288	248	--	220	520	417	485	--	4.49	--
PCB-94	2.18	2.18	2.44	1.05	--	1.15	2.56	1.12	1.05	--	1.06	2.77	2.43	1.78	--	<0.0945	--
PCB-96	0.483	0.268	0.731	0.259	--	0.251	0.483	<0.107	0.231	--	0.305	0.738	0.497	0.341	--	<0.0603	--
PCB-103	12.2	12.8	13.8	9.12	--	8.25	26.3	6.61	8.39	--	5.68	12.3	9.52	10.4	--	<0.075	--
PCB-104	0.142	<0.096	0.1	0.074	--	<0.0588	0.148	<0.103	<0.0668	--	0.073	0.29	0.11	0.109	--	<0.0552	--
PCB-105	520	604	405	426	--	372	1010	259	282	--	267	449	336	426	--	0.207	--

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between
Sample ID	RBT2-1	RBT2-2	RBT2-3	RBT2-4	Average	ITP-1	ITP-2	ITP-3	ITP-4	Average	REF-1	REF-2	REF-3	REF-4	Average	101	
PCB-106	<2.57	<1.71	<1.93	<2.26	--	<1.94	<5.34	<1.1	<1.05	--	<1.06	<2.14	<1.67	<1.39	--	<0.074	--
PCB-107	133	139	98.3	84.7	--	81.7	266	76.9	76.7	--	65	125	95.9	112	--	<0.0766	--
PCB-108 + 124	39.1	44.1	31.5	21	--	18.9	61	18.2	14.5	--	18.7	35.9	28.6	34.7	--	<0.08	--
PCB-110 + 115	1190	1140	877	660	--	658	1980	562	532	--	501	1010	872	979	--	0.479	--
PCB-111	3.63	3.41	2.69	3.06	--	2.83	6.75	2.27	2.43	--	2.13	3.73	2.68	2.74	--	<0.0688	--
PCB-112	<0.538	<0.183	<0.353	<0.224	--	<0.315	<0.506	<0.225	<0.124	--	<0.24	<0.174	<0.192	<0.26	--	<0.0582	--
PCB-114	41.3	35.1	27.3	32.8	--	22.3	60	14.4	17	--	18.8	29.7	24	30.3	--	0.087	--
PCB-118	1360	1580	1090	1200	--	991	2780	698	816	--	735	1220	956	1180	--	0.555	--
PCB-120	2.88	1.93	3.47	2.91	--	3.27	7.1	0.917	1.62	--	1.75	4.79	3.01	2.94	--	<0.0627	--
PCB-121	0.682	0.38	0.746	1.08	--	0.643	1.61	<0.263	0.252	--	0.309	1.07	0.845	0.562	--	<0.0621	--
PCB-122	9	8.28	6.87	4.14	--	3.57	8.45	2.14	3.19	--	4.31	7.58	6.69	7.15	--	<0.0887	--
PCB-123	24.6	28.8	21.3	16.1	--	19.3	53.4	11.6	15.7	--	12.6	21.4	16.2	19.7	--	<0.092	--
PCB-126	4.99	5.77	3.56	3.77	--	3.9	10.7	2.43	2.39	--	1.63	5.61	2.71	2.89	--	<0.0933	--
PCB-127	5.53	3.51	2.53	2.97	--	2.55	<5.82	1.31	1.41	--	1.78	<2.15	2.21	2.83	--	<0.0742	--
PCB-128 + 166	495	332	307	382	--	325	657	177	208	--	169	319	253	307	--	<0.105	--
PCB-129 + 138 + 160 + 163	5630	2970	2590	3250	--	3090	5870	1660	1970	--	1640	2730	2160	2610	--	0.558	--
PCB-130	245	145	131	122	--	121	304	83.6	110	--	72.4	137	110	129	--	<0.132	--
PCB-131	10.9	12.3	10.3	6.06	--	5.8	15.4	4.61	4.16	--	5.99	12.8	11.8	11.3	--	<0.155	--
PCB-132	349	266	282	203	--	199	540	149	150	--	157	325	275	290	--	<0.154	--
PCB-133	144	81.4	66.1	82.5	--	78.2	144	43.8	54.6	--	46.3	79.3	59.4	73.6	--	<0.144	--
PCB-134 + 143	60.6	72.7	54.2	30.7	--	37.7	80.8	34.4	27.3	--	30.8	59.9	60.8	56.7	--	<0.157	--
PCB-135 + 151 + 154	797	737	662	530	--	520	1140	387	377	--	379	696	606	673	--	0.212	--
PCB-136	79.8	61	75.6	47.2	--	46.7	84.7	31.8	33.7	--	34.6	74.9	67.1	68.5	--	<0.0646	--
PCB-137	184	96	95.7	120	--	102	181	58	67.7	--	50.9	96.6	66.2	90.6	--	<0.13	--
PCB-139 + 140	44.3	27.5	29.5	23.8	--	22.2	49.8	12.3	19.5	--	15.1	33.9	26.5	28.7	--	<0.138	--
PCB-141	229	210	198	143	--	153	405	124	120	--	105	193	217	191	--	<0.121	--
PCB-142	<4.66	<1.36	<2.51	<0.534	--	<1.41	<0.983	<0.933	<1.35	--	<2.5	<3.83	<1.86	<0.713	--	<0.15	--

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between
Sample ID	RBT2-1	RBT2-2	RBT2-3	RBT2-4	Average	ITP-1	ITP-2	ITP-3	ITP-4	Average	REF-1	REF-2	REF-3	REF-4	Average	101	
PCB-144	58.5	53.2	49.9	39.4	--	36.7	98.1	23.3	29.7	--	24.9	56.4	50.3	49	--	<0.0882	--
PCB-145	<0.0927	<0.139	<0.0884	<0.0735	--	<0.0679	<0.0593	<0.113	<0.0835	--	0.091	0.133	<0.0993	<0.0911	--	<0.07	--
PCB-146	1240	589	591	742	--	661	1280	385	508	--	373	560	412	556	--	0.116	--
PCB-147 + 149	1590	1530	1310	1070	--	947	2590	711	794	--	810	1670	1520	1450	--	0.372	--
PCB-148	7.17	6.16	7.16	5.1	--	6.1	14.7	3.56	4.98	--	3.65	8.42	6.52	7.22	--	<0.0903	--
PCB-150	3.74	3.56	3.91	2.67	--	3.02	8.15	1.71	2.78	--	2.14	4.16	3.41	3.47	--	<0.066	--
PCB-152	0.433	0.441	0.485	0.29	--	0.281	0.521	0.196	0.205	--	0.284	0.7	0.574	0.42	--	<0.0622	--
PCB-153 + 168	7350	3120	2840	3640	--	3570	6180	1800	2360	--	1980	3160	2450	2890	--	0.66	--
PCB-155	7	4.85	6.38	6.2	--	3.95	8.62	2.55	3.73	--	2.9	6.6	5.35	4.71	--	0.053	--
PCB-156 + 157	301	244	168	217	--	175	414	113	128	--	115	179	148	185	--	<0.105	--
PCB-158	220	159	154	155	--	133	314	82.4	104	--	75.7	147	127	148	--	<0.0805	--
PCB-159	<2.77	<0.807	11.5	7.81	--	8.78	20.9	5.43	5.91	--	<1.48	<2.27	<1.11	<0.423	--	<0.089	--
PCB-161	<2.83	<.827	<1.72	<0.365	--	<0.966	<0.673	<0.639	<0.925	--	<1.52	<2.33	<1.13	<0.433	--	<0.0912	--
PCB-162	8.81	10	7.39	6.73	--	7.55	18.7	6.3	7.06	--	5.46	9.92	7.7	9.54	--	<0.0883	--
PCB-164	92.1	100	94	68.9	--	77.3	207	55.4	61.2	--	50.6	98.3	92.7	90	--	<0.0868	--
PCB-165	13	6.25	5.82	7.96	--	7.45	12.7	3.42	4.9	--	3.62	6.41	5	6.42	--	<0.114	--
PCB-167	89.5	104	77.9	67.4	--	64.6	184	49.7	59.9	--	51.8	80.9	67.6	81.7	--	<0.0892	--
PCB-169	<2.75	<1.78	<2.48	<2.02	--	<1.94	<4.1	<1.79	<1.24	--	<1.55	<2.4	<2.26	<1.73	--	<0.0895	--
PCB-170	748	321	304	348	--	360	587	184	216	--	183	309	346	294	--	<0.0793	--
PCB-171 + 173	197	124	104	110	--	107	201	55.9	63.4	--	61.4	118	143	116	--	<0.0803	--
PCB-172	172	79.4	78.6	90.8	--	84.9	147	48.9	62	--	46.1	71.7	87.2	75.8	--	<0.0779	--
PCB-174	263	201	217	153	--	172	368	109	107	--	107	216	387	224	--	<0.0751	--
PCB-175	23	17.9	18	16	--	15.9	34.3	9.63	12.5	--	8.88	19.2	22	18.6	--	<0.0795	--
PCB-176	33.1	28.3	31.1	22.6	--	19.8	55.7	14.6	15	--	15.9	34.7	45.8	31.7	--	<0.0666	--
PCB-177	433	275	221	222	--	222	496	138	165	--	149	237	325	268	--	<0.0725	--
PCB-178	372	201	184	230	--	214	390	119	143	--	109	189	209	194	--	<0.0855	--
PCB-179	168	164	145	114	--	113	211	80.5	69.1	--	80.1	169	226	161	--	<0.0707	--
PCB-180 + 193	2510	1130	1030	1270	--	1240	1980	644	797	--	618	1010	1280	1000	--	0.225	--

Location ID	**RBT2**					**ITP**					**Reference**					**Lab Blank**	**One-way ANOVA Averages Significantly Different between**
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**101**	
PCB-181	7.35	4.19	3.3	4.24	--	3.68	6.09	2.08	2.4	--	2.06	3.24	3.46	3.74	--	<0.077	--
PCB-182	<0.134	--	<0.131	<0.116	--	<0.114	<0.18	<0.122	<0.0766	--	<0.0521	<0.159	<0.121	<0.131	--	<0.0686	--
PCB-183 + 185	643	304	305	338	--	341	567	154	218	--	156	291	363	299	--	<0.0738	--
PCB-184	11.8	7.87	8.46	7.72	--	5.57	11.5	3.66	5.3	--	4.22	9.77	8.47	8.39	--	<0.0626	--
PCB-186	<0.132	<0.157	<0.111	<0.0983	--	<0.0965	<0.153	<0.103	<0.065	--	<0.0513	<0.157	<0.119	<0.129	--	<0.0676	--
PCB-187	2150	1090	1080	1390	--	1230	2230	684	838	--	603	1030	1120	1090	--	0.2	--
PCB-188	4.01	3.49	4.03	3.79	--	4.2	8.06	2.53	3.3	--	2.29	4.25	3.43	3.77	--	<0.0634	--
PCB-189	22.2	16.1	15.2	17.3	--	15.5	31.6	10.5	11.6	--	9.1	14.4	15.5	14.6	--	<0.0879	--
PCB-190	175	88.5	67.5	87.3	--	70.8	150	46.4	47.5	--	46.8	73.9	102	71.6	--	<0.0635	--
PCB-191	38.5	18.7	14.4	17.5	--	15.4	27.8	9.17	10.2	--	9.02	15.1	19.9	16.2	--	<0.0631	--
PCB-192	<0.126	<0.149	<0.115	<0.102	--	<0.1	<0.158	<0.107	<0.0674	--	<0.0498	<0.149	<0.113	<0.123	--	<0.0643	--
PCB-194	356	155	185	175	--	207	276	103	128	--	92.8	160	228	150	--	<0.0739	--
PCB-195	113	43.5	61	52.8	--	60.5	92.2	31.1	37	--	31.8	55.9	72.1	50.9	--	<0.0789	--
PCB-196	211	86.9	107	109	--	88.6	156	51.1	68.5	--	52.3	105	158	94.8	--	<0.077	--
PCB-197 + 200	32.3	19.1	30.7	25.5	--	22	43.5	14.8	15.6	--	14.9	27.3	34.9	24.7	--	<0.05	--
PCB-198 + 199	520	201	235	211	--	209	367	131	163	--	123	258	345	217	--	<0.0796	--
PCB-201	35.1	27.2	31.4	28.1	--	26.9	52.8	16.1	20.1	--	15.1	33.3	40.2	30.4	--	<0.0517	--
PCB-202	184	86.1	93.4	126	--	111	167	57.3	64.7	--	54.3	100	106	91.4	--	<0.0597	--
PCB-203	324	124	152	160	--	137	240	80.7	96.1	--	81.9	148	194	140	--	0.075	--
PCB-204	0.704	0.427	0.505	0.617	--	0.5	0.6	0.23	0.375	--	0.262	0.543	0.374	0.555	--	<0.0521	--
PCB-205	15.7	6.87	8	7.32	--	8.7	12.3	4.36	4.91	--	4.25	7.72	10.3	7.42	--	<0.0634	--
PCB-206	132	54.8	68.9	57.3	--	70.5	88.8	37.3	48.2	--	34.5	67.9	70	65.5	--	<1.09	--
PCB-207	13.5	6.28	9.28	8.67	--	8.7	11.6	4.7	6.25	--	4.29	9.4	9.09	7.82	--	<0.78	--
PCB-208	47.2	19.5	26.9	24.4	--	27.6	36	14.2	20.4	--	13.6	28.3	25.7	25.9	--	<0.86	--
PCB-209	44.3	16.6	27.4	21.4	--	24.9	28.7	14.7	19.4	--	12.4	26.9	20.9	23	--	0.196	--

Location ID	**RBT2**					**ITP**					**Reference**					**Lab Blank**	**One-way ANOVA Averages Significantly Different between**
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**101**	
Total Monochloro Biphenyls	0.895	0.816	1.43	1.19	--	1.19	0.983	1.26	1.44	--	0.922	1.25	0.941	1.07	--	0.797	--
Total Dichloro Biphenyls	40.6	33.9	48.2	32.6	--	16.1	23.3	37.2	20.2	--	28.7	51.1	37.8	40.9	--	5.88	--
Total Trichloro Biphenyls	464	436	472	308	--	157	580	513	218	--	218	473	441	375	--	2.72	--
Total Tetrachloro Biphenyls	3090	2720	2720	1900	--	1250	4340	2010	1270	--	1290	2780	2410	2400	--	5.66	--
Total Pentachloro Biphenyls	9780	8490	6820	6780	--	5690	15000	4180	4350	--	4010	7380	6010	7090	--	5.47	--
Total Hexachloro Biphenyls	19200	10900	9730	11000	--	10400	20800	6010	7220	--	6210	10700	8810	10000	--	1.14	--
Total Heptachloro Biphenyls	7970	4070	3830	4440	--	4230	7500	2320	2790	--	2210	3820	4710	3890	--	0.225	--
Total Octachloro Biphenyls	1790	750	904	895	--	871	1410	490	598	--	471	896	1190	807	--	--	--
Total Nonachloro Biphenyls	193	80.6	105	90.4	--	107	136	56.2	74.9	--	52.4	106	105	99.2	--	--	--
Decachloro Biphenyl	44.3	16.6	27.4	21.4	--	24.9	28.7	14.7	19.4	--	12.4	26.9	20.9	23	--	--	--
TOTAL PCBs	42600	27500	24700	25500	--	22800	49900	15600	16600	--	14500	26300	23700	24700	--	21.9	--
TOTAL TEQs(1)	**0.470**	**0.341**	**0.378**	**0.408**	**0.399**	**0.352**	**0.955**	**0.227**	**0.220**	**0.439**	**0.219**	**0.395**	**0.316**	**0.271**	**0.300**	--	Yes for ITP and REF

(1) Calculated in accordance with WHO (2005) [van den Berg, M; Birnbaum, LS; Denison, M; et al. (2006) The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol Sci 93(2):223−241]. If not detected ("<'), a substance was assumed to be present at a concentration equal to the method detection limit (i.e., "<" = MDL).

Table IR4-33-B3 PAH Concentrations in Crab Hepatopancreas (ng/g on a wet weight basis)

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**101**	
% Moisture	9.65	7.67	12.8	7	--	7.61	7.58	7.05	5.72	--	6.36	12.2	12.7	9.11	--	--	--
% Lipid	79	83.5	77.9	80.6	--	81.8	81.8	84	83.2	--	82.5	77.8	78.4	79.8	--	--	--
Unsubstituted PAHs																	
Naphthalene	1.03	1.08	1.18	0.93	--	0.953	0.77	0.869	0.762	--	1.01	1.14	1.09	1.01	--	0.601	--
Acenaphthylene	0.09	0.076	0.116	0.078	--	0.077	0.101	0.056	0.059	--	0.089	0.116	0.094	0.101	--	0.014	--
Acenaphthene	0.36	0.372	0.555	0.4	--	0.286	0.331	0.267	0.352	--	0.372	0.575	0.451	0.476	--	0.028	--
Fluorene	0.078	0.118	0.093	0.105	--	0.059	0.082	0.076	0.083	--	0.138	0.146	0.096	0.159	--	0.066	--
Phenanthrene	0.194	0.218	0.241	0.265	--	0.419	0.35	0.183	0.255	--	0.316	0.321	0.176	0.273	--	0.285	--
Anthracene	0.062	0.052	0.094	0.051	--	0.119	0.172	0.022	0.043	--	0.076	0.091	0.073	0.062	--	0.017	--
Fluoranthene	0.088	0.095	0.156	0.163	--	0.356	0.346	0.077	0.099	--	0.227	0.155	0.084	0.107	--	0.074	--
Pyrene	0.096	0.09	0.112	0.092	--	0.13	0.136	0.08	0.073	--	0.205	0.129	0.076	0.092	--	0.063	--
Benz[a]anthracene	0.022	0.014	0.029	0.025	--	0.087	0.088	0.015	0.035	--	0.021	0.026	0.013	0.014	--	0.005	--
Chrysene	0.061	0.044	0.094	0.079	--	0.223	0.236	0.041	0.106	--	0.082	0.099	0.034	0.042	--	0.014	--
Benzo[b]fluoranthene	<0.0126	<0.0242	0.01	0.012	--	0.043	0.016	<0.0053	<0.0114	--	<0.0015	0.012	<0.0048	<0.0066	--	<0.0093	--
Benzo[j,k]fluoranthene	<0.0131	<0.0245	0.026	0.012	--	0.064	0.058	<0.0053	<0.0117	--	<0.0017	0.02	<0.0048	0.008	--	<0.0094	--
Benzo[e]pyrene	<0.0152	<0.0346	<0.01	0.011	--	0.014	<0.0204	<0.0071	<0.0159	--	<0.0152	<0.011	0.009	0.01	--	<0.0142	--
Benzo[a]pyrene	<0.0152	<0.0342	<0.0099	<0.0099	--	0.018	<0.0202	<0.007	<0.0157	--	<0.015	<0.0109	<0.0062	<0.009	--	<0.014	--
Dibenz[a,h]anthracene	<0.0152	<0.025	<0.0106	<0.0072	--	<0.0107	<0.0165	<0.0073	<0.0085	--	0.022	<0.0137	<0.0098	<0.0085	--	<0.0103	--
Indeno[1,2,3-cd]pyrene	<0.0152	<0.0178	<0.0075	<0.0059	--	<0.0116	<0.015	<0.0067	<0.0099	--	<0.0089	<0.013	<0.0069	<0.0063	--	<0.0069	--
Benzo[ghi]perylene	<0.0152	<0.0192	<0.0068	0.013	--	0.011	<0.0136	<0.0062	<0.009	--	0.014	<0.0118	0.007	0.009	--	<0.0062	--
LPAH (unsubst.)	**1.814**	**1.916**	**2.279**	**1.829**	**1.960**	**1.913**	**1.806**	**1.473**	**1.554**	**1.687**	**2.001**	**2.389**	**1.98**	**2.081**	**2.113**	**1.011**	**Yes for ITP and REF**
HPAH (unsubst.)	**0.267**	**0.243**	**0.427**	**0.407**	**0.336**	**0.946**	**0.88**	**0.213**	**0.313**	**0.588**	**0.571**	**0.441**	**0.223**	**0.282**	**0.379**	**0.156**	**Yes for ITP and RBT2**
TPAH (unsubst.)	**2.081**	**2.159**	**2.706**	**2.236**	**2.296**	**2.859**	**2.686**	**1.686**	**1.554**	**2.196**	**2.572**	**2.83**	**2.203**	**2.363**	**2.492**	**1.167**	**Yes for ITP and REF**

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between Sites?
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**101**	
Perylene	<0.0152	0.07	<0.0108	0.034	--	0.035	<0.0219	<0.0076	0.025	--	0.065	0.056	<0.0065	0.025	--	<0.0149	--
Biphenyl	0.224	0.238	0.268	0.223	--	0.185	0.17	0.212	0.195	--	0.208	0.239	0.221	0.253	--	0.099	--
Dibenzothiophene	0.03	0.031	0.033	0.039	--	0.027	0.036	0.027	0.025	--	0.037	0.046	0.026	0.043	--	0.058	--
Retene	0.148	0.166	0.126	0.096	--	0.073	0.181	0.102	0.065	--	0.501	0.424	0.138	0.522	--	0.042	--
Alkyl-substituted PAHs																	
1-Methylnaphthalene	0.494	0.546	0.601	0.476	--	0.392	0.321	0.406	0.388	--	0.505	0.58	0.54	0.509	--	0.248	--
2-Methylnaphthalene	0.75	0.876	0.822	0.774	--	0.722	0.592	0.72	0.646	--	0.855	0.839	0.813	0.823	--	0.534	--
1,2-Dimethylnaphthalene	0.044	0.048	0.051	0.051	--	0.056	0.041	0.037	0.041	--	0.048	0.053	0.047	0.053	--	0.034	--
2,6-Dimethylnaphthalene	0.307	0.696	0.253	0.258	--	0.214	0.179	0.202	0.225	--	0.495	0.239	0.223	0.294	--	0.155	--
2,3,6-Trimethylnaphthalene	0.111	0.106	0.097	0.11	--	0.096	0.068	0.078	0.075	--	0.12	0.108	0.078	0.121	--	0.06	--
2,3,5-Trimethylnaphthalene	0.089	0.073	0.074	0.07	--	0.073	0.068	0.06	0.059	--	0.087	0.082	0.061	0.089	--	0.065	--
1,4,6,7-Tetramethylnaphthalene	<0.0152	<0.0192	0.022	<0.0208	--	<0.0226	<0.0197	<0.0107	0.016	--	0.037	0.032	0.017	0.023	--	<0.0104	--
1-Methylphenanthrene	0.035	0.035	0.034	0.028	--	0.037	0.044	0.024	0.022	--	0.053	0.035	0.02	0.035	--	0.042	--
2-Methylphenanthrene	0.059	0.109	0.05	0.052	--	0.06	0.08	0.039	0.066	--	0.115	0.069	0.04	0.078	--	0.076	--
3-Methylphenanthrene	0.035	0.061	0.033	0.041	--	0.053	0.073	0.027	0.058	--	0.075	0.033	0.023	0.03	--	0.053	--
2-Methylanthracene	<0.0151	<0.0108	0.022	<0.0095	--	0.022	0.034	0.01	0.02	--	<0.015	0.02	0.013	0.017	--	<0.0128	--
9/4-Methylphenanthrene	0.135	0.123	0.054	0.044	--	0.05	0.076	0.029	0.043	--	0.094	0.085	0.026	0.043	--	0.03	--
3,6-Dimethylphenanthrene	<0.014	0.018	<0.0135	<0.0155	--	0.018	0.032	0.01	0.018	--	<0.0218	<0.0151	<0.0084	<0.0129	--	0.015	--
2,6-Dimethylphenanthrene	<0.0139	<0.0169	<0.0135	<0.0154	--	<0.0116	0.019	<0.0064	<0.0106	--	<0.0217	<0.015	<0.0083	<0.0128	--	0.012	--
1,7-Dimethylphenanthrene	0.018	0.019	0.016	0.019	--	0.012	0.03	0.013	0.013	--	0.031	0.019	0.013	0.02	--	0.021	--
1,8-Dimethylphenanthrene	<0.0152	<0.0169	<0.0135	<0.0154	--	<0.0116	<0.0166	<0.0064	<0.0106	--	<0.0217	<0.015	0.024	<0.0128	--	<0.0085	--
1,2,6-Trimethylphenanthrene	<0.0152	<0.0187	<0.0162	<0.014	--	<0.014	<0.0297	<0.0115	<0.0192	--	<0.0299	<0.0258	<0.0212	<0.0202	--	<0.0068	--
Homolog Sums – AlkylPAH																	
C1-Naphthalenes	1.24	1.42	1.42	1.25	--	1.11	0.913	1.13	1.03	--	1.36	1.42	1.35	1.33	--	0.782	--
C2-Naphthalenes	0.995	1.57	0.952	0.882	--	0.828	0.693	0.718	0.752	--	1.31	0.946	1.03	1.01	--	0.62	--
C3-Naphthalenes	0.778	0.569	0.592	0.518	--	0.576	0.411	0.369	0.436	--	1.23	1.1	0.532	0.579	--	0.283	--
C4-Naphthalenes	0.286	0.259	0.243	0.174	--	0.171	0.101	0.146	0.123	--	0.397	0.375	0.214	0.287	--	0.085	--
C1 Phenanthrenes/ Anthracenes	0.07	<0.0102	0.067	0.113	--	0.185	0.149	0.08	0.123	--	0.21	0.088	0.042	0.035	--	0.201	--
C2 Phenanthrenes/ Anthracenes	0.118	0.097	0.12	0.11	--	0.118	0.23	0.077	0.144	--	0.19	0.138	0.104	0.146	--	0.125	--

Location ID	RBT2					ITP					Reference					Lab Blank	One-way ANOVA Averages Significantly Different between Sites?
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**101**	
C3-Phenanthrenes/ Anthracenes	0.451	1.06	0.258	0.155	--	0.122	0.506	0.176	0.22	--	0.455	0.362	0.25	0.307	--	0.141	--
C4-Phenanthrenes/ Anthracenes	0.584	1.26	0.345	0.293	--	0.348	0.678	0.228	0.367	--	2.07	0.93	0.351	0.914	--	0.139	--
Sum Alky PAH	**4.522**	**6.235**	**3.997**	**3.495**	**4.562**	**3.458**	**3.681**	**2.924**	**3.195**	**3.315**	**7.222**	**5.359**	**3.873**	**4.608**	**5.266**	**2.376**	**Yes for ITP and REF**
Total Unsubstituted and Alkyl-PAH	**6.603**	**8.394**	**6.703**	**5.731**	**6.858**	**6.317**	**6.367**	**4.61**	**4.749**	**5.511**	**9.794**	**8.189**	**6.076**	**6.971**	**7.758**	**3.543**	**Yes for ITP and REF**

Table IR4-33-B4 Trace Element and Arsenic Species Concentrations in Crab Hepatopancreas (µg/g on a wet weight basis)

Sample Location	RBT2					ITP					Reference					
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**One-way ANOVA Averages Significantly Different between Sites?**
% Moisture	79.0	83.5	77.9	80.6	--	81.8	81.8	84.0	83.2	--	82.5	77.8	78.4	79.8	--	--
Coal Indicator Elements																
Arsenic	7.36	5.75	8.36	7.95	7.355	6.94	12.9	7.63	6.78	8.5625	7.98	7.71	5.99	6.66	7.085	No
Bismuth	0.0058	0.0054	0.0094	0.0107	0.007825	0.0089	0.014	0.0118	0.0094	0.011025	0.0103	0.0057	0.0081	0.0063	0.0076	No
Cadmium	3.38	2.93	2.77	1.81	2.7225	1.26	1.18	0.961	0.415	0.954	1.04	2.6	1.68	2.34	1.915	Yes for ITP and RBT2
Selenium	4.5	2.26	2.69	2.73	3.045	2.23	2.78	1.99	1.6	2.15	3.24	2.9	3.64	3.24	3.255	Yes for ITP and RBT2
Vanadium	0.181	0.139	0.224	0.337	0.22025	0.405	0.415	0.214	0.199	0.30825	0.302	0.295	0.207	0.183	0.24675	Yes for ITP and RBT2
Other Elements																
Aluminum	1.06	2.03	0.69	2.66	--	1.06	1.08	1.24	1.21	--	2.18	1.52	1.1	1.94	--	--
Antimony	0.0079	0.0064	0.01	0.0127	--	0.02	0.0225	0.0207	0.0168	--	0.0262	0.0092	0.0129	0.009	--	--
Barium	0.158	0.129	0.182	0.131	--	0.222	0.223	0.136	0.191	--	0.571	0.303	0.272	0.197	--	--
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	--	<0.0020	<0.0020	<0.0020	<0.0020	--	<0.0020	<0.0020	<0.0020	<0.0020	--	--
Boron	0.88	0.99	1.28	1.23	--	1.25	1.36	1.7	1.93	--	1.62	0.82	0.9	0.91	--	--
Calcium	322	410	357	524	--	538	409	350	376	--	328	386	298	452	--	--
Cesium	0.0076	0.0064	0.0101	0.0092	--	0.0074	0.0093	0.0079	0.0079	--	0.0067	0.0082	0.0075	0.0074	--	--
Chromium	0.06	0.039	0.074	0.107	--	0.076	0.104	0.069	0.054	--	0.081	0.053	0.041	0.056	--	--
Cobalt	0.853	0.652	0.812	0.709	--	0.644	0.798	0.452	0.349	--	0.772	0.958	0.774	0.915	--	--
Copper	102	70.1	66.6	54	--	24.5	43.1	48	20.6	--	92.4	104	82.6	92.2	--	--
Iron	54.3	81.6	118	110	--	63.2	94.2	69.3	80	--	97.8	124	115	46.1	--	--
Lead	0.0212	0.0352	0.0432	0.03	--	0.0525	0.089	0.0328	0.041	--	0.0361	0.0412	0.0228	0.0161	--	--
Lithium	0.1	0.11	<0.10	<0.10	--	0.13	0.1	0.11	0.12	--	0.12	<0.10	<0.10	0.13	--	--
Magnesium	438	527	410	523	--	499	457	578	489	--	342	419	378	411	--	--
Manganese	1.54	1.28	1.64	1.42	--	1.48	1.58	0.981	1.15	--	1.57	1.66	1.4	1.3	--	--
Molybdenum	0.295	0.2	0.298	0.337	--	0.421	0.404	0.311	0.313	--	0.343	0.295	0.308	0.307	--	--

Sample Location	**RBT2**					**ITP**					**Reference**					
Sample ID	**RBT2-1**	**RBT2-2**	**RBT2-3**	**RBT2-4**	**Average**	**ITP-1**	**ITP-2**	**ITP-3**	**ITP-4**	**Average**	**REF-1**	**REF-2**	**REF-3**	**REF-4**	**Average**	**One-way ANOVA Averages Significantly Different between Sites?**
Nickel	0.56	0.411	0.795	0.838	--	1.69	1.43	0.521	0.482	--	0.751	0.892	0.595	0.579	--	--
Phosphorus	1580	1500	2040	2110	--	1850	1860	1490	1520	--	1980	1850	1850	1930	--	--
Potassium	2520	2250	2850	2740	--	2540	2750	2470	2420	--	2650	2700	2670	2670	--	--
Rubidium	1.63	1.25	1.85	1.7	--	1.62	2.01	1.61	1.78	--	1.59	1.61	1.57	1.55	--	--
Sodium	3900	4880	3430	3680	--	4330	3310	4390	4400	--	3850	3930	3430	3860	--	--
Strontium	7.5	8.72	9.2	10.7	--	12.3	11.8	10.3	10.4	--	9.74	9.7	7.33	9.97	--	--
Tellurium	<0.0040	<0.0040	<0.0040	<0.0040	--	<0.0040	0.0054	<0.0040	<0.0040	--	<0.0040	<0.0040	<0.0040	<0.0040	--	--
Thallium	0.0008	0.00043	0.00065	0.00076	--	0.00062	0.00085	0.00066	0.00055	--	0.00063	0.00072	0.00072	0.00069	--	--
Tin	0.05	0.046	0.042	0.044	--	0.074	0.045	0.048	0.048	--	0.048	0.041	0.046	0.053	--	--
Uranium	0.0257	0.0208	0.0259	0.0324	--	0.0692	0.048	0.036	0.0262	--	0.0233	0.0181	0.0281	0.0163	--	--
Zinc	18.4	13.3	18.4	19.7	--	21.1	19.2	16.1	17	--	20.6	20	18.5	18.7	--	--
Zirconium	<0.040	<0.040	<0.040	<0.040	--	<0.040	<0.040	<0.040	<0.040	--	<0.040	<0.040	<0.040	<0.040	--	--
Speciated Arsenic																
Arsenate (As V)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.25	<0.10	<0.10	<0.1375	<0.10	<0.10	<0.10	<0.10	<0.10	--
Arsenite (As III)	0.04	0.021	0.023	0.028	0.028	0.053	0.057	<0.020	0.041	0.0428	0.046	0.032	0.031	0.022	0.0328	--
Dimethylarsinic Acid (DMA, as As)	<0.020	<0.020	0.021	<0.020	<0.0203	<0.020	<0.050	<0.020	0.026	<0.029	<0.020	0.02	<0.020	<0.020	<0.020	--
Monomethylarsonic Acid (MMA, as As)	0.108	0.026	0.087	0.023	0.061	0.096	0.116	0.031	0.066	0.0773	0.043	0.035	0.067	0.021	0.0415	--
Arsenobetaine (AsB, as As)	4.66	3.6	5.02	4.73	4.5025	3.53	8.1	4.87	3.97	5.1175	4.32	3.89	3.24	3.95	3.85	--
Arsenocholine (AsC, as As)	0.055	0.035	0.06	0.066	0.054	0.077	0.063	0.049	0.033	0.0555	0.044	0.054	0.049	0.031	0.0445	--

IR4-34 Marine Invertebrates: Blackened Crab Study

Information Source(s)

EIS Volume 4: Appendix 27-C

Context

Appendix 27-C indicated that the Proponent was currently working with Indigenous groups to further investigate blackened crab observations in the Roberts Bank area and that crab harvesters from several Indigenous groups had provided crabs to the Proponent with abnormal appearance such as the blackening of the exoskeleton. Tissues from the collected crabs were to be analyzed for fungal disease, trace elements and PAHs, and the results shared with Indigenous groups.

Information Request

Provide the results of the follow-up investigation regarding blackened crab observations in the Roberts Bank area, including those related to crab fungal disease, trace elements and PAHs. Discuss any comments that the Indigenous groups have provided on the study or the study results.

VFPA Response

Overview

During consultation on the development of the EIS, concerns were raised by Aboriginal groups about blackened shell and tissue found in some Dungeness crab harvested from the Fraser River estuary. The comments indicated a perception that the tissue from crabs with blackened shell could pose a risk to human health if consumed, and that the observed blackening may be related to contamination from coal.

The VFPA considered comments received on blackened crab relative to the Project description, and broader biophysical context, including the following:

- RBT2, as a new container terminal, will not be handling coal and therefore will not result in releases of coal to the environment (EIS Section 4.0); and
- Blackened crab has been identified as a broader issue of concern beyond the Roberts Bank area, as discussed in the Study Results section below.

In response to concerns raised by Aboriginal groups, the VFPA conducted two studies to investigate Dungeness crab tissue quality. These included the following:

- Study 1: Dungeness Crab Health Study, as included in the EIS (EIS Appendix 27-C); and
- Study 2: Aboriginal Dungeness Crab Health Follow-Up Study.

The summary of the Aboriginal Dungeness Crab Health Follow-Up Study (the Crab Health Study 2) is included as **Appendix IR4-34-A**. The Crab Health Study 2 was initiated in the summer of 2014 with crab collection by Aboriginal harvesters, and was completed in spring of 2015, after the submission of the EIS. The Crab Health Study 2 was conducted in collaboration with local Aboriginal groups to address the overall implications that perceived shellfish contamination could have on harvesting practices and human health (as described in the EIS Sections 27.5.7 and 27.5.5).

The Crab Health Study 2 applied the same methods and analysis used to conduct the first study presented in the EIS, including the same sampling locations, as shown in Figure 1 of **Appendix IR4-34-A**. In addition, it included participation from Aboriginal crab harvesters in retaining trapped specimens of Dungeness crab displaying evidence of blackening for analysis. A total of 15 collection kits and handling instructions were provided to crab harvesters from Tsawwassen First Nation (TFN), Musqueam First Nation, Penelakut Tribes, and Hwlitsum operating under licences in DFO Fisheries Management Area 28 and 29.

Study Results

The key findings of the Crab Health Study 2 are summarised below.

Black lesions were observed on four of the five crabs collected by Aboriginal harvesters. The black lesions were concluded to be consistent with chitinolytic shell disease, generically referred to as “shell disease”, a condition common to crab and other crustaceans (Bower 1996, Bower et al. 1994, Wang 2011, DFO 2014). This disease is caused by a bacterial or fungal infection of an area where the outer layer of the shell has been previously damaged. Shell disease has not been linked to contamination. The disease is not specific to the Roberts Bank area and is present across the Pacific Northwest, including Alaska and British Columbia (Bower et al. 1994) and in Atlantic Canada (Smolowitz et al. 2014).

As stated in **Appendix IR4-34-A**, contaminant levels, including polycyclic aromatic hydrocarbons (PAHs) and trace elements, in the tissue from crabs sampled for the Crab Health Study 2 were generally similar to or lower than those found in crab analysed in Study 1 included in EIS Appendix 27-C. The supporting data is provided in **Tables IR4-34-1**, **IR4-34-2**, and **IR4-34-3** below.

The trace elements that are typically associated with coal deposits include arsenic, bismuth, cadmium, selenium, and vanadium, as shown in **Table IR4-34-1**. Concentrations of each of these in the blackened shell crab samples collected for Crab Health Study 2 were either similar to or lower than the levels evaluated in the human health assessment in the EIS. The assessment in the EIS concluded negligible health risks related to trace elements. Therefore, health risks associated with consumption of crab with blackened shells, sampled in this study, are similarly negligible.

Concentrations of PAHs in the tissue samples collected were generally either not detected, or were detected at levels lower than those found in the laboratory blanks (as shown in **Table IR4-34-3**). These results indicate that the blackened crab are not accumulating PAHs at measurable concentrations, which is consistent with the information presented in the EIS.

The Crab Health Study 2 concluded there was not a human health risk from the consumption of the sampled Dungeness crab tissue, as the PAH and trace element levels were similar to or lower than the concentrations evaluated in the human health assessment for the EIS. Therefore, the conclusions of both Study 1 and Study 2 are consistent in stating that the PAHs and trace elements measured in Roberts Bank Dungeness crab muscle would not result in unacceptable risks to human health upon consumption (EIS Section 27.6.1.4).

Table IR4-34-1 Contaminant Levels in Crab – Metals (Trace Elements Related to Coal) (mg/kg wet weight basis)

	Crab Sample ID					**Average**[a]			**Lab Blank**[b]
	G1	**G2**	**G3**	**G4**	**G5**	**Crab Health Study (Study 2)**	**EIS (Study 1)**	**Study 2 vs. Study 1 Average Levels**	
Physical Tests									
% Moisture	83.6	81.9	83.2	80.2	82	--			0.25
Coal Elements									
Arsenic (As)-Total	4.83	9.69	13.3	10.3	7.51	9.126	9.82	Lower	0.004
Bismuth (Bi)-Total	0.0059	0.012	0.0152	0.0106	0.007	0.01014	0.009	Similiar[c]	0.002
Cadmium (Cd)-Total	0.0066	0.0129	0.013	0.0075	0.0096	0.00992	0.082	Lower	0.001
Selenium (Se)-Total	0.376	0.521	0.513	0.512	0.597	0.5038	0.531	Lower	0.01
Vanadium (V)-Total[d]	<0.020	<0.020	0.022	<0.020	<0.020	0.0044	<0.02	Lower	0.02

Notes:

mg/kg = milligrams per kilogram

a. Average concentration of the five coal element samples. Values were estimated based on the total amount detected in each sample and were not blank corrected. Non-detects were assumed to equal the detection limit (EIS Appendix 27-C: Table 4-14).

b. A laboratory blank is a control sample used to determine the amount of contamination contributed to the samples due to laboratory preparation and analysis.

c. The concentrations are essentially the same when rounded to two decimal points. The difference between .009 and 0.01 is within the range of normal analytical variability.

d. This is an example of a sample that is below the laboratory blank concentrations (<0.020) indicating the samples do not contain quantifiable contaminant concentrations, which is the same in Study 1 and Study 2.

Table IR4-34-2 Contaminant Levels in Crab – Metals (Other Trace Elements) (mg/kg wet weight basis)

	Crab Sample ID					Average[a]	Lab Blank[b]
	G1	G2	G3	G4	G5		
Aluminum (Al)-Total	1.04	0.82	0.72	0.84	1.93	1.07	0.4
Antimony (Sb)-Total	<0.0020	0.0029	0.0028	0.0025	0.0032	0.00228	0.002
Barium (Ba)-Total	0.212	0.174	0.106	0.057	0.484	0.2066	0.01
Beryllium (Be)-Total[c]	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.002
Boron (B)-Total	3.02	4.89	6.14	4.44	4.44	4.586	0.2
Calcium (Ca)-Total	4420	2260	1740	1200	6490	3222	4
Cesium (Cs)-Total	0.0031	0.0036	0.0037	0.0036	0.0032	0.00344	0.001
Chromium (Cr)-Total	0.037	0.175	0.089	0.207	0.071	0.1158	0.01
Cobalt (Co)-Total	0.0439	0.0472	0.0307	0.0663	0.0542	0.04846	0.004
Copper (Cu)-Total	4.77	6.48	4.42	6.8	4.56	5.406	0.02
Iron (Fe)-Total	4.84	6.85	6.23	8.48	8.54	6.988	0.6
Lead (Pb)-Total	<0.0040	<0.0040	<0.0040	<0.0040	0.009	0.0018	0.004
Lithium (Li)-Total	0.12	0.12	0.1	<0.10	0.15	0.098	0.1
Magnesium (Mg)-Total	976	775	982	718	857	861.6	0.4
Manganese (Mn)-Total	0.291	0.284	0.651	0.194	1.05	0.494	0.01
Molybdenum (Mo)-Total	0.013	0.0131	0.0151	0.013	0.0093	0.0127	0.004
Nickel (Ni)-Total[c]	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.04
Phosphorus (P)-Total	1520	1460	1460	1240	1730	1482	2
Potassium (K)-Total	2900	3250	2510	3330	2990	2996	4
Rubidium (Rb)-Total	0.847	0.854	0.788	0.901	0.774	0.8328	0.01
Selenium (se) Total	0.376	0.521	0.513	0.597	0.512	0.5038	0.01
Sodium (Na)-Total	5900	5170	5370	4090	4450	4996	4
Strontium (Sr)-Total	67	41.9	32.4	19.6	95.6	51.3	0.01
Tellurium (Te)-Total	<0.0040	<0.0040	<0.0040	<0.0040	0.0043	0.00086	0.004
Thallium (Tl)-Total[c]	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	0.0004
Tin (Sn)-Total[c]	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.02
Uranium (U)-Total	<0.00040	0.0011	0.00113	0.00056	0.00148	0.000854	0.0004
Zinc (Zn)-Total	32.2	48.6	43.4	46.2	45.1	43.1	0.1
Zirconium (Zr)-Total[c]	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.04

Notes:

a. Average concentration of the five coal element samples. Values were estimated based on the total amount detected in each sample and were not blank corrected. Non-detects were assumed to equal the detection limit (EIS Appendix 27-C: Table 4-14).

b. A laboratory blank is a control sample used to determine the amount of contamination contributed to the samples due to laboratory preparation and analysis.

c. This is an example of a sample that is below the laboratory blank concentrations indicating the samples do not contain quantifiable contaminant concentrations.

Table IR4-34-3 Contaminant Levels in Crab – Polycyclic Aromatic Hydrocarbons (ng/g on a wet weight basis)

	Crab Sample ID					Average[a]			Lab Blank[b]
	G1	G2	G3	G4	G5	Crab Health (Study 2)	EIS (Study 1)	Study 2 vs. Study 1 Average levels	
Physical Tests									
% Moisture	84.5	80.8	81.6	81.5	83.2	--		--	--
% Lipid	0.7	0.7	0.48	0.51	0.51	--		--	--
Unsubstituted PAH									
Naphthalene	0.565	0.487	0.599	0.531	0.532	0.5428	1.35	Lower	0.581
Acenaphthylene	0.029	0.039	0.037	0.045	0.032	0.0364	0.07302	Lower	0.033
Acenaphthene	0.109	0.334	0.093	0.512	0.032	0.216	0.0766	Higher - see Note[c]	<0.0207
Fluorene	0.077	0.128	0.079	0.18	0.068	0.1064	0.0656	Higher - see Note[c]	0.055
Phenanthrene	0.233	0.236	0.201	0.344	0.172	0.2372	0.369	Lower	0.248
Anthracene	0.024	0.033	0.024	0.041	0.014	0.0272	0.0374	Lower	0.02
Fluoranthene	0.113	0.085	0.119	0.16	0.086	0.1126	0.4988	Lower	0.161
Pyrene	0.074	0.058	0.105	0.122	0.064	0.0846	1.9422	Lower	0.182
Benz[a]anthracene	0.013	0.008	0.033	0.021	0.01	0.017	0.01636	Similar	0.1
Chrysene	0.031	0.023	0.065	0.05	0.03	0.0398	0.0322	Similar	0.158
Benzo[b]fluoranthene	<0.015	<0.011	0.03	<0.0144	<0.0125	0.006	0.02504	Lower	0.168
Benzo[j,k]fluoranthenes	<0.0159	<0.0116	0.029	<0.0151	0.014	0.0086	0.01716	Lower	0.112
Benzo[e]pyrene	<0.0217	<0.0164	<0.034	<0.0197	<0.0191	<0.022	0.06744	Lower	0.143
Benzo[a]pyrene	<0.0218	<0.0165	<0.0342	<0.0198	<0.0192	<0.022	0.05176	Lower	0.136
Dibenz[a,h]anthracene	<0.0089	<0.0103	<0.0183	<0.0129	<0.0125	<0.013	0.0227	Lower	0.04
Indeno[1,2,3-cd]pyrene	0.014	0.014	0.034	<0.0154	0.014	0.0152	0.03912	Lower	0.123
Benzo[ghi]perylene	0.017	0.014	0.04	0.017	<0.0097	0.0176	0.2746	Lower	0.137
LPAH (unsubst.)	1.037	1.257	1.033	1.653	0.85	1.166	1.954	Lower	0.937
HPAH (unsubst.)	0.262	0.202	0.455	0.37	0.218	0.3014	(2.882	Lower	1.46
TPAH (unsubst.)	1.299	1.459	1.488	2.023	1.068	1.4674	4.848	Lower	2.397
Perylene	<0.0228	<0.0156	<0.0329	<0.0199	<0.0178	<0.022	0.02422	Similar[d]	0.046

	Crab Sample ID					Average[a]			Lab Blank[b]
	G1	G2	G3	G4	G5	Crab Health (Study 2)	EIS (Study 1)	Study 2 vs. Study 1 Average levels	
Biphenyl	0.28	0.285	0.232	0.264	0.2	0.2522	0.231	Higher – See note[c]	0.189
Dibenzothiophene	0.018	0.032	0.02	0.041	0.016	0.0254	0.0606	Lower	0.045
Retene	<0.0516	0.045	0.044	0.057	0.047	0.0386	0.1518	Lower	0.03
Alkyl-substituted PAHs									
1-Methylnaphthalene	0.141	0.151	0.112	0.192	0.103	0.1398	0.241	Lower	0.111
2-Methylnaphthalene	0.243	0.261	0.229	0.332	0.191	0.2512	0.4346	Lower	0.203
1,2-Dimethylnaphthalene	<0.0631	<0.0467	<0.0865	<0.0271	<0.0707	<0.059	0.05788	Similar[d]	<0.049
2,6-Dimethylnaphthalene	0.124	0.15	0.089	0.138	0.072	0.1146	0.1644	Lower	0.076
2,3,6-Trimethylnaphthalene	0.059	0.06	0.046	0.056	0.044	0.053	0.1038	Lower	0.041
2,3,5-Trimethylnaphthalene	0.043	0.079	0.041	<0.0413	0.038	0.0402	0.07344	Lower	0.087
1,4,6,7-Tetramethylnaphthalene	<0.0354	<0.0397	<0.0294	0.0262	<0.0196	0.00524	0.0365	Lower	<0.0232
1-Methylphenanthrene	0.025	0.013	0.033	0.031	0.02	0.0244	0.033	Lower	0.029
2-Methylphenanthrene	0.043	0.042	0.049	0.071	0.035	0.048	0.064	Lower	0.043
3-Methylphenanthrene	0.03	0.029	0.028	0.036	0.024	0.0294	0.0342	Lower	0.037
2-Methylanthracene	<0.0103	<0.0105	<0.0148	0.018	<0.0111	0.0036	0.01842	Lower	<0.0129
9/4-Methylphenanthrene	0.034	0.219	0.029	0.057	0.024	0.0726	0.044	Lower	0.022
3,6-Dimethylphenanthrene	0.008	<0.0251	<0.0176	0.011	<0.0092	0.0038	0.02018	Lower	0.01
2,6-Dimethylphenanthrene	0.01	<0.0246	<0.0173	0.011	0.012	0.0066	0.01712	Lower	0.012
1,7-Dimethylphenanthrene	0.013	<0.0241	0.019	0.018	0.015	0.013	0.025745	Lower	0.019
1,8-Dimethylphenanthrene	<0.0078	<0.0246	<0.0173	<0.0089	<0.009	<0.014	0.01538	Lower	<0.009
1,2,6-Trimethylphenanthrene	<0.0138	<0.0177	<0.0199	<0.0189	<0.0145	<0.017	0.0149	Similar[d]	<0.0126
Homolog Sums – AlkylPAH									
C1-Naphthalenes	0.384	0.412	0.341	0.523	0.293	0.3906	0.6746	Lower	0.314
C2-Naphthalenes	0.401	0.461	0.296	0.376	0.295	0.3658	1.033	Lower	0.248
C3-Naphthalenes	0.216	0.281	0.14	0.153	0.074	0.1728	0.6866	Lower	0.137
C4-Naphthalenes	0.051	0.163	<0.0294	0.069	<0.0196	0.0566	0.812	Lower	<0.0232
C1-Phenanthrenes/Anthracenes	0.108	0.071	0.11	0.085	0.06	0.0868	0.1874	Lower	0.132

	Crab Sample ID					Average[a]			Lab Blank[b]
	G1	G2	G3	G4	G5	Crab Health (Study 2)	EIS (Study 1)	Study 2 vs. Study 1 Average levels	
C2 Phenanthrenes/Anthracenes	0.059	0.072	0.071	0.106	0.063	0.0742	0.2604	Lower	0.095
C3-Phenanthrenes/Anthracenes	0.039	0.174	0.074	0.118	<0.0145	0.081	0.2912	Lower	0.036
C4-Phenanthrenes/Anthracenes	0.47	1.72	0.264	1.24	0.069	0.7526	0.7724	Lower	0.077
Sum Alky PAH	1.728	3.354	1.296	2.67	0.854	1.9804	4.7176	Lower	1.039
Total Unsubstituted and Alkyl-PAH	3.027	4.813	2.784	4.693	1.922	3.4478	9.5564	Lower	3.436

Notes:

ng/g = nanograms per gram

a. Average concentration of samples. Values were estimated based on the total amount detected in each sample and were not blank corrected. Non-detects were assumed to equal the detection limit (EIS Appendix 27-C: Table 4-13).
b. A laboratory blank is a control sample used to determine the amount of contamination contributed to the samples due to laboratory preparation and analysis.
c. Individual PAH level is higher than in EIS analysis, but the sum of the total PAH mixture, which is of relevance to human health risk, is lower than the sum of the PAH mixture in the EIS.
d. The concentrations are essentially the same when rounded to two decimal points, therefore is within the range of normal analytical variability.

Comments from Aboriginal Groups

On July 9, 2015 a summary of the Crab Health Study 2, *Summary Report – Roberts Bank Dungeness Crab Health Studies* (**Appendix IR3-34-A**) and a cover letter (**Appendix IR3-34-B**) were shared with the following Aboriginal groups engaged in consultation regarding the Project:

- Tsawwassen First Nation
- Stz'uminus First Nation
- Semiahmoo First Nation
- Penelakut Tribe
- Métis Nation British Columbia
- Lyackson First Nation
- Musqueam Indian Band
- Hwlitsum
- Cowichan Tribes
- Halalt First Nation
- Tsleil-Waututh Nation
- Lake Cowichan First Nation
- Katzie First Nation
- Kwikwetlem First Nation

The VFPA did not receive any comments from Aboriginal groups engaged in consultation regarding the Project on the *Summary Report – Roberts Bank Dungeness Crab Health Studies*. Concerns related to crab harvesting and the perception of contamination regarding blackened crab shell and tissue are topics of continued discussion with Aboriginal groups identified for consultation regarding the Project.

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Appendices

Appendix IR4-34-A	Summary Report – Roberts Bank Dungeness Crab Health Studies
Appendix IR4-34-B	Cover Letter to ‘Summary Report – Roberts Bank Dungeness Crab Health Studies’

APPENDIX IR4-34-A

SUMMARY REPORT – ROBERTS BANK DUNGENESS CRAB HEALTH STUDIES

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MEMORANDUM

Date:	June 5, 2015
To:	Kyle Robertson, Manager, Environmental Assessment & Permitting; Port Metro Vancouver
From:	Doug Bright, PhD, R.P.Bio., Hemmera
File:	302-042.08
Re:	Summary Report – Roberts Bank Dungeness Crab Health Studies

1.0 PROJECT BACKGROUND

The Roberts Bank Terminal 2 Project (RBT2 or Project) is a proposed new, three-berth marine terminal at Roberts Bank in Delta, B.C. that could provide 2.4 million TEUs (twenty-foot equivalent unit containers) of additional container capacity annually. The Project is part of Port Metro Vancouver's (PMV) Container Capacity Improvement Program, a long-term strategy to deliver projects to meet anticipated growth in demand for container capacity to 2030.

Port Metro Vancouver has filed an Environmental Impact Statement (EIS) for the proposed RBT2 Project with the Canadian Environmental Assessment Agency. The filing of the EIS initiates a thorough review, including multiple opportunities for public comment.

To read the EIS, visit the Canadian Environmental Assessment Agency website (registry reference number 80054).

2.0 PURPOSE AND OBJECTIVES OF ROBERTS BANK DUNGENESS CRAB HEALTH STUDIES

Hemmera, on behalf of PMV, has undertaken two studies that investigate Dungeness crab (*Metacarcinus magister*) tissue quality in response to concerns raised by members of the public and local Aboriginal groups regarding external black lesions and internal deposits of black material, observed in some Dungeness crabs harvested from the Fraser River estuary. The studies include:

- **Study 1**: Dungeness Crab Health Study for the RBT2 Environmental Assessment (Hemmera 2014); and
- **Study 2**: Aboriginal Dungeness Crab Health Follow-up Study.

The first study involved contaminant analysis of crab tissue and the completion of a human health risk assessment to support the development of the RBT2 environmental assessment (EA). The second study paralleled the first study in terms of methods and analysis, but involved collaboration with Aboriginal groups to provide samples of crabs as well microscopic examination of the tissue structures (i.e., histologic) of blackened areas.

The overall purpose of these studies was threefold: (i) to quantify contaminant concentrations in Dungeness crabs at Roberts Bank; (ii) to determine whether the crabs if consumed would pose a risk to human health; and (iii) determine the cause – if possible - of observed blackening of some crabs (for example, whether the observed blackening is a result of coal contamination or some other mechanism).

Both studies involved the following steps:

- Collection of Dungeness crabs within sub-tidal areas at Roberts Bank;
- Evaluation of visible abnormalities (e.g., blackening of the shell, tumours, deformities etc.); and
- Analysis of tissue chemistry of soft tissue (leg muscle) to:
    - Quantify concentrations of contaminants that are often derived from coal such as polycyclic aromatic hydrocarbons (PAHs), metals (e.g., cadmium), and other trace elements (e.g., arsenic, selenium); and
    - Calculate exposure potential and risk to humans through consumption of crabs.

The second study also included collaboration with local Aboriginal groups to obtain crab samples that display external black lesions or internal deposits of a black material. A qualified invertebrate pathologist assisted with the microscopic examination of the tissue structure of blackened areas to attempt to diagnose the cause of blackening.

3.0 METHODS

3.1 DUNGENESS CRAB HEALTH STUDY FOR RBT2 ENVIRONMENTAL ASSESSMENT

Dungeness crab sampling and lab analysis were conducted as part of the RBT2 EA for marine invertebrates. Details of the methods and results of this study can be found in Hemmera 2014.

The study took place in shallow subtidal areas surrounding the existing Roberts Bank terminals and extended north towards Canoe Passages (**Figure 1**). Three sample locations were selected within this area: (i) a reference location north of the existing terminals, near Canoe Passage; (ii) at the proposed RBT2 site; and (iii) in the inter-causeway area (i.e., between Roberts Bank and B.C. Ferries causeways) at the location of the proposed intermediate transfer pit (ITP). The latter two of these areas were selected based on the known accumulations of coal particulates within local seabed sediments.

In April 2014, five baited traps were deployed at each sampling location, and allowed to soak overnight. Following trap retrieval, biologists examined all trapped crabs for external abnormalities, including evidence of discoloration or erosion of the exoskeleton (i.e., outer shell), discoloration of the gills, and parasites.

For internal observations and laboratory tissue analyses, five individuals were collected at each sampling location, with efforts made to collect legal-sized males (>165mm carapace width), since these are retained for commercial, recreational, and Aboriginal fisheries. Internal surfaces including the body cavity, gills, and hepatopancreas were visually inspected for any abnormalities, particularly the presence of black material. Following visual inspection, biologists harvested the leg muscle tissue. This tissue was analyzed by AXYS Laboratories for substances associated with coal particulates (i.e., PAHs) using sensitive analytical techniques designed to achieve very low sample detection limits. Samples were also sent to ALS Laboratories for analysis of metals and trace elements.

3.2 ABORIGINAL DUNGENESS CRAB HEALTH FOLLOW-UP STUDY

Tsawwassen First Nation (TFN), Musqueam First Nation, Penelakut Tribes, and Hwlitsum crab harvesters operating under licenses in DFO Fisheries Management Areas 28 and 29 were asked to retain trapped specimens of Dungeness crab displaying evidence of blackening. Collection kits, including instructions for handling, were provided to crab harvesters participating in the study. A total of 15 kits were distributed.

Five legal-sized male crabs were collected from DFO Fisheries Management Area 29-7 at Roberts Bank in August 2014 by a participating TFN crab harvester. All collected crabs were examined by a biologist for external abnormalities, including evidence of discoloration or erosion of the exoskeleton, discoloration of the gills, and parasites. No internal dissections were conducted on these crabs so that the integrity of the internal tissues was preserved for subsequent histologic examination.

Similar to the methods outlined in **Section 3.1** above, following visual inspection, leg muscle tissue was sent for laboratory analysis of PAHs, metals, and other trace elements. The remainder of the specimens (including legs and body) were sent to a pathologist at The Atlantic Veterinary College at the University of Prince Edward Island for histologic analysis in order to attempt to diagnose the cause of the blackening.

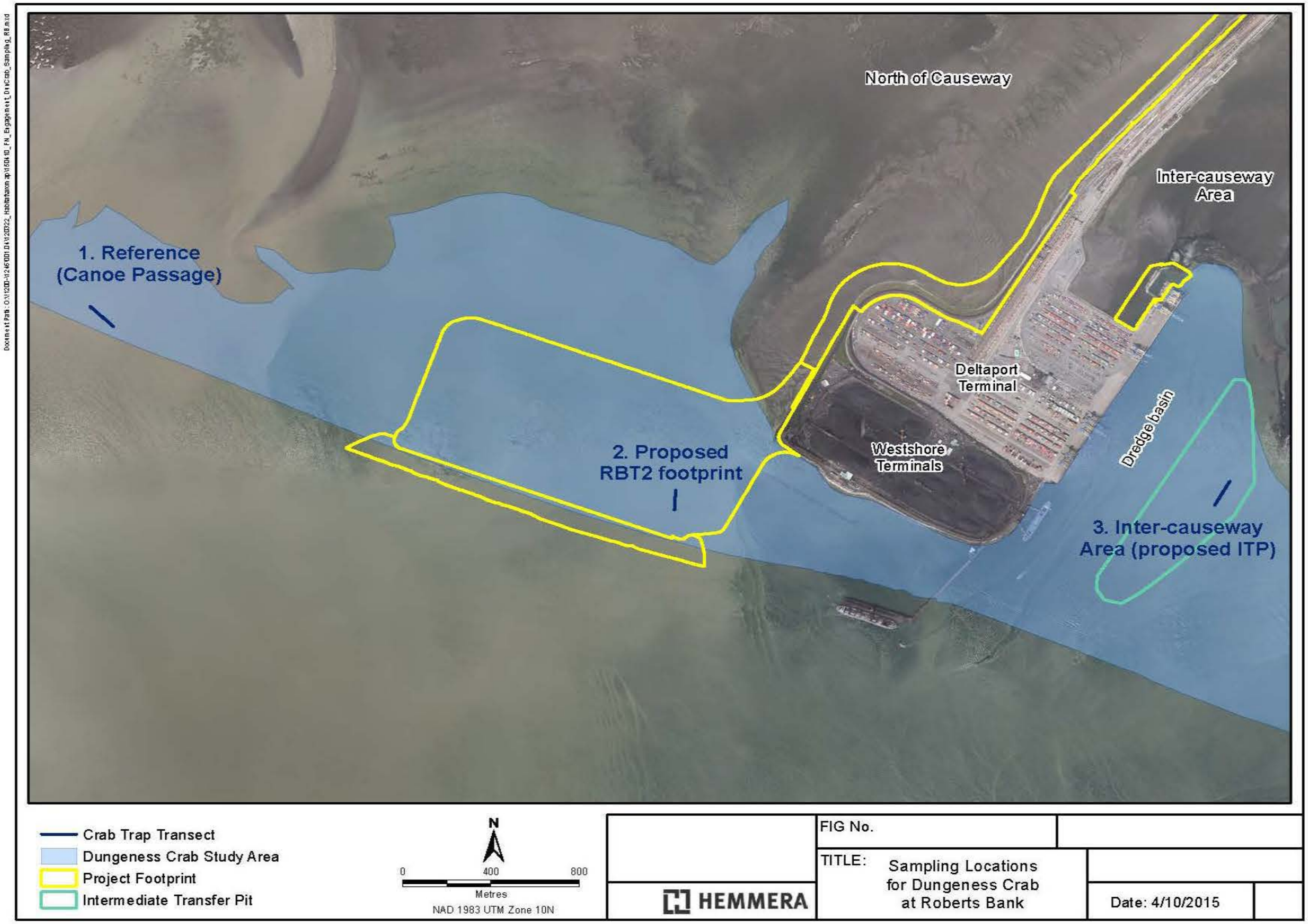

Figure 1 Sampling Locations for Dungeness Crab at Roberts Bank

4.0 RESULTS AND DISCUSSION

4.1 DUNGENESS CRAB HEALTH STUDY FOR RBT2 ENVIRONMENTAL ASSESSMENT

Examination of both external and internal surfaces of Dungeness crabs collected at Roberts Bank did not yield evidence of coal particulate accumulation, though twelve crabs displayed external black lesions on the outer shell.

The leg muscle tissue did not contain detectable PAH concentrations, in spite of the use of sensitive laboratory analytical methods. Only one contaminant of potential concern, arsenic, was observed in Dungeness crab muscle tissue at a concentration that was statistically and significantly different from the reference site on the northern edge of Roberts Bank (see Hemmera 2014 for details). Based on these results, arsenic contaminant concentrations were carried forward to estimate the risks to human health associated with the consumption of Dungeness crabs. In marine crustaceans and bivalves, toxic forms of arsenic typically only occur in very small portions (Borak and Hosgood 2007) while non-toxic forms make up the major portion of measurable arsenic in edible muscle tissues (Cullen and Riemer 1989, Edmonds and Francesconi 1993).

A quantitative human health risk assessment for arsenic concluded that health risks from the consumption of Dungeness crab tissue are acceptably low. Refer to Hemmera 2014 for more information on consumption risks associated with Dungeness crab.

It was hypothesised that shell disease, resulting from the activities of either bacteria or fungi, was likely responsible for the blackening. This hypothesis was tested in the second study, where crabs caught by Aboriginal harvesters were sent to an expert pathologist for examination and diagnosis. The results are summarised in **Section 4.2** below.

4.2 ABORIGINAL DUNGENESS CRAB HEALTH FOLLOW-UP STUDY

Four of the five crabs that were collected from Roberts Bank by a TFN crab harvester in August 2014 had small black lesions (**Photos 1** and **2**). The fifth crab showed no signs of black lesions or discolouration during initial examination.

Results of follow-up tissue analysis are virtually identical to those outlined in **Section 4.1** above and presented in Hemmera 2014: PAHs (indicative of coal contamination) were not found at detectable concentrations and only arsenic showed slightly elevated levels compared to the reference site. Again, the measured level of arsenic is not considered to pose a risk to human health.

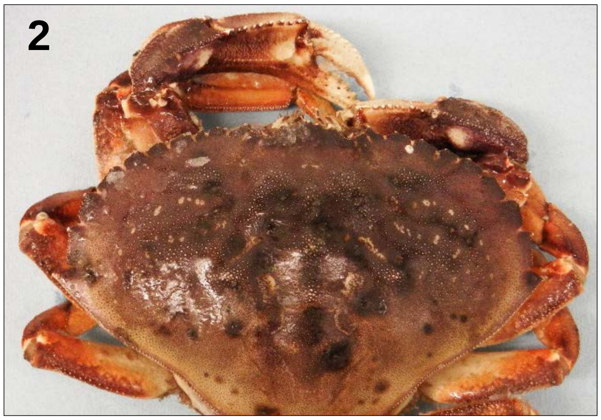

Photo 1 **Small black lesion on abdomen and cheliped of Dungeness crab #G1 from Roberts Bank**

Photo 2 **Black lesions on carapace of Dungeness crab #G3 from Roberts Bank**

Results from the histologic analysis indicate that the lesions observed on the crab shells are areas of shell damage, erosion and ulceration that are colonised by mixed bacteria. No evidence of a fungal infection was found. These results are characteristic of "shell disease" and this diagnosis is consistent with conclusions drawn by DFO in an independent study of Dungeness crab health in the Fraser River delta (DFO 2014).

Shell disease often presents as pitting, erosion and melanisation (i.e., dark brown to black pigmentation) of the crab's shell. It is a common response to physical damage to the outermost layer of the shell (called the exocuticle) which leaves the crab susceptible to secondary infection by microorganisms such as bacteria and fungi (Bower 1996). Shell disease is usually not lethal, although in advanced cases underlying tissues may be colonised by opportunistic pathogens which can lead to the death of internal tissues (i.e., necrosis) and possibly death of the crab itself (Bower 1996). The extent of shell disease is also related to the amount of time elapsed since the crab last molted: newly molted crabs have a much lower tendency to have blackened areas of their carapace or legs. Shell disease is widespread and has been reported in a variety of crustacean species, for example, lobsters in Atlantic Canada (Smolowitz et al. 2014); however, there is no known shell disease trend data.

5.0 CONCLUSIONS

Both studies investigating Dungeness crab health at Roberts Bank led to the same conclusions:

- There is no evidence of crab contamination related to coal dust, based on the results of sensitive tissue chemistry analysis testing for PAHs, metals, and trace elements;
- Despite slightly elevated arsenic concentrations, consumption risks are acceptably low and pose no risk to human health; and
- Results of microscopic examination point to localised physical damage of the exoskeleton and the bacterial shell disease as the underlying cause of blackening.

Results from these two studies are corroborated by an independent DFO investigation into the occurrence and cause of blackened Dungeness crabs from the Vancouver and Fraser River Delta areas (DFO 2014). This report investigated varying levels of erosion and blackening of the exoskeleton and also identified bacterial shell disease as the likely mechanism. Similarly no fungal infections were detected, nor were any other pathogens of concern.

6.0 REFERENCES

Borak, J. and H. D. Hosgood. 2006. Seafood arsenic: Implications for human health risk assessment. Regulatory Toxicology and Pharmacology 47:204-212.

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APPENDIX IR4-34-B

COVER LETTER TO ‘SUMMARY REPORT – ROBERTS BANK DUNGENESS CRAB HEALTH STUDIES’

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PORT METRO
vancouver

VIA COURIER AND EMAIL

July 15, 2015

Address Removed

Dear __________:

Re: Memorandum – Roberts Bank Dungeness Crab Health Studies

In response to reports from Aboriginal groups regarding blackening of Dungeness crab and concerns related to potential contamination, Port Metro Vancouver (PMV) arranged for Hemmera to undertake testing of Dungeness crab tissue. PMV also provided Aboriginal groups with crab sampling kits in an effort to obtain sample crab for testing.

In follow up to our previous communication and the provision of sample crabs by Aboriginal groups, please find attached, for your information, a memorandum on the work undertaken by Hemmera. Please share the information with others in your community as appropriate. A summary of key information contained in the memorandum is provided on the following page.

Should you have any questions regarding the memorandum attached, please contact Laura Strand, Manager, Aboriginal Affairs via email <email address removed> or phone<contact information removed>

Yours truly,

PORT METRO VANCOUVER

Jemma Scoble
Aboriginal Consultation & Engagement
Infrastructure Sustainability

Encl. (1)

Summary of Key Information:

PMV has conducted two studies on Dungeness crab tissue:

- The first study involved collection of crabs and analysis of tissue for contaminants. This study informed the human health risk assessment in the Roberts Bank Terminal 2 (RBT2) Environmental Impact Statement (EIS).
- The second study followed the same methods and analysis of the first study, but involved collaboration with Aboriginal groups to provide samples of crabs.

Both studies were conducted to:

- Determine levels of certain contaminants (related to coal) in Dungeness crab at Roberts Bank; and
- Determine whether these levels of contamination pose a risk to human health if the crabs are consumed.

In addition, the second study sought to determine the source of black spots that have been seen on the shells of some crabs.

The results of both studies were the same:

- There is no evidence of coal contamination, based on the results of sensitive tissue chemistry analysis testing for PAHs, metals, and trace elements;
- Consumption risks are acceptably low and pose no risk to human health; and
- The underlying cause of the blackened shells is determined to be shell disease (a common condition due to bacterial infection of existing lesions/damage in the crab shells).

IR4-35 Staging of Construction Materials

Information Source(s)

EIS Volume 1: Section 4.4.1.11; Section 4.4.1.13; Appendix 4-B; Appendix 4-E

Context

The Proponent, in Appendix 4-B, in Preliminary design 60287593-MA-221 (Causeway preload) and 602875-MA-214 and 211 (Containment dyke) identified a temporary site for the stockpile of salvaged riprap along the widened causeway (dyke CD1), on top of preload.

In Appendix 4-E, the Proponent identified that granular base material would be imported for use as preload in the Apron (Terminal Area Preload Stage 9). Preload 9 would utilize stockpiled Terminal granular base. The Proponent, in Section 4.4.1.11, stated that the western apron area will be preloaded using stockpiled terminal granular base, or reclaimed sand from the intermediate transfer pit.

The Proponent, in Section 4.4.1.13 of the EIS, further identified that temporary lay down areas on either the widened causeway or the terminal's west basin would be used for building materials such as steel, concrete, asphalt, rebar and piping. These materials would be delivered via road transport. Railway materials such as ties, rail, switches and ballast would be delivered initially by barges and trucks, and subsequently by trains once the causeway rail infrastructure is operational to the terminal while major equipment for the terminal, such as the ship-to-shore gantry cranes, automated stacking cranes, and rail mounted gantry cranes, would be delivered pre-assembled via special ocean-going vessels for immediate use.

A summary confirming the laydown and stockpile areas information is required.

Information Request

Provide a location map and table summarizing all lay down areas and stockpile areas to be used to stage materials for Project construction including the ones identified in the Preliminary design 60287593-MA-221 (Causeway preload) and 602875-MA- 214 and 211 (Containment dyke).

VFPA Response

Specific staging areas and stockpile laydown areas will be determined by the Infrastructure Developer during detail design and construction planning phases for the Project. All staging and laydown areas can be accommodated within the Project footprint. Depending on the sequencing or phasing of construction activities undertaken by the Infrastructure Developer, several areas of the Project footprint will be available for temporary staging or stockpiling of construction materials; therefore, staging or storage areas outside the Project footprint to support construction activities are not required.

Table IR4-35-1 outlines the handling activities, anticipated staging areas, and timing for the various material types that will be delivered to site for terminal, road, RBT2 overpass, rail, and building infrastructure. Figure IR4-35-A1 in **Appendix IR4-35-A** illustrates the location of anticipated staging areas listed in **Table IR4-35-1**.

Table IR4-35-1 Handling, Staging, and Timing of Construction Materials

Type of Material	Handling Activities	Anticipated Staging Areas*	Construction Timing (Years)
A. Terminal			
Core rock, rip-rap, misc. rock	Deliver/Place	N/A	Years 1-4
Dredged material (from dredge basin, tug basin, and Fraser River maintenance dredging activities)	Deliver/Place	N/A	Years 1-3
Fill and preload materials (i.e., Fraser River dredgeate and existing quarry sources)	Deliver/Place	N/A	Years 3-5
B. Causeway			
Core rock, rip-rap, misc. rock	Deliver/Place	N/A	Years 1-4
Fill and preload materials (i.e., Fraser River dredgeate and existing quarry sources)	Deliver/Place	N/A	Years 2-5
C. Roads			
Expanded Polystyrene (EPS) blocks, sub-base course, and fill materials	Deliver/Stockpile/Place	S-Bend	Years 3-4
Bedding sand, import backfill, base course	Delivery/Stockpile/Place	S-Bend	Years 3-5
Raw materials for onsite asphalt batch plant	Deliver/Stockpile/Prepare/Place	East Terminal	Years 3-5
Watermain/sewer pipe, PVC drainage pipe	Deliver/Stockpile/Install	West/East Causeway	Years 3-4
Catch basins and manholes	Deliver/Stockpile/Install	West/East Causeway	Years 3-5
Raw materials for onsite concrete batch plant	Deliver/Stockpile/Use	East Terminal	Years 4-5
Pre-cast reinforced concrete barriers, street lights and signs, fence	Deliver/Stockpile/Install	West/East Causeway	Years 4-5
D. RBT2 Overpass			
Reinforced concrete deck, piers/bents, jump spans	Deliver/Place	N/A	Years 3-5
Steel beams, pre-cast concrete box girder, galvanized BC	Deliver/Stockpile/Install	S-Bend	Years 3-5

Type of Material	Handling Activities	Anticipated Staging Areas*	Construction Timing (Years)
MOTI steel fence, pre-cast traffic barrier, elastomeric bearing pads, expansion joints, pre-cast concrete retaining wall panels			
E. Rail			
Track, ties, fasteners, turnouts (switches)	Deliver/Stockpile/Install	West/East Causeway and East/West Terminal	Years 2-5
Ballast	Deliver/Stockpile/Place	West/East Causeway and East/West Terminal	Years 2-5
Pre-cast concrete retaining walls	Deliver/Stockpile/Install	West/East Causeway	Years 2-5
F. Buildings			
Mechanical/Electrical/Building Materials	Deliver/Stockpile/Install	East Terminal	Years 3-5

Note: *For staging area locations, refer to Figure IR4-35-A1 in **Appendix IR4-35-A**.

Appendices

Appendix IR4-35-A Staging of Construction Materials Conceptual Layout (Figure IR4-35-A1)

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APPENDIX IR4-35-A

STAGING OF CONSTRUCTION MATERIALS CONCEPTUAL LAYOUT

(FIGURE IR4-35-A1)

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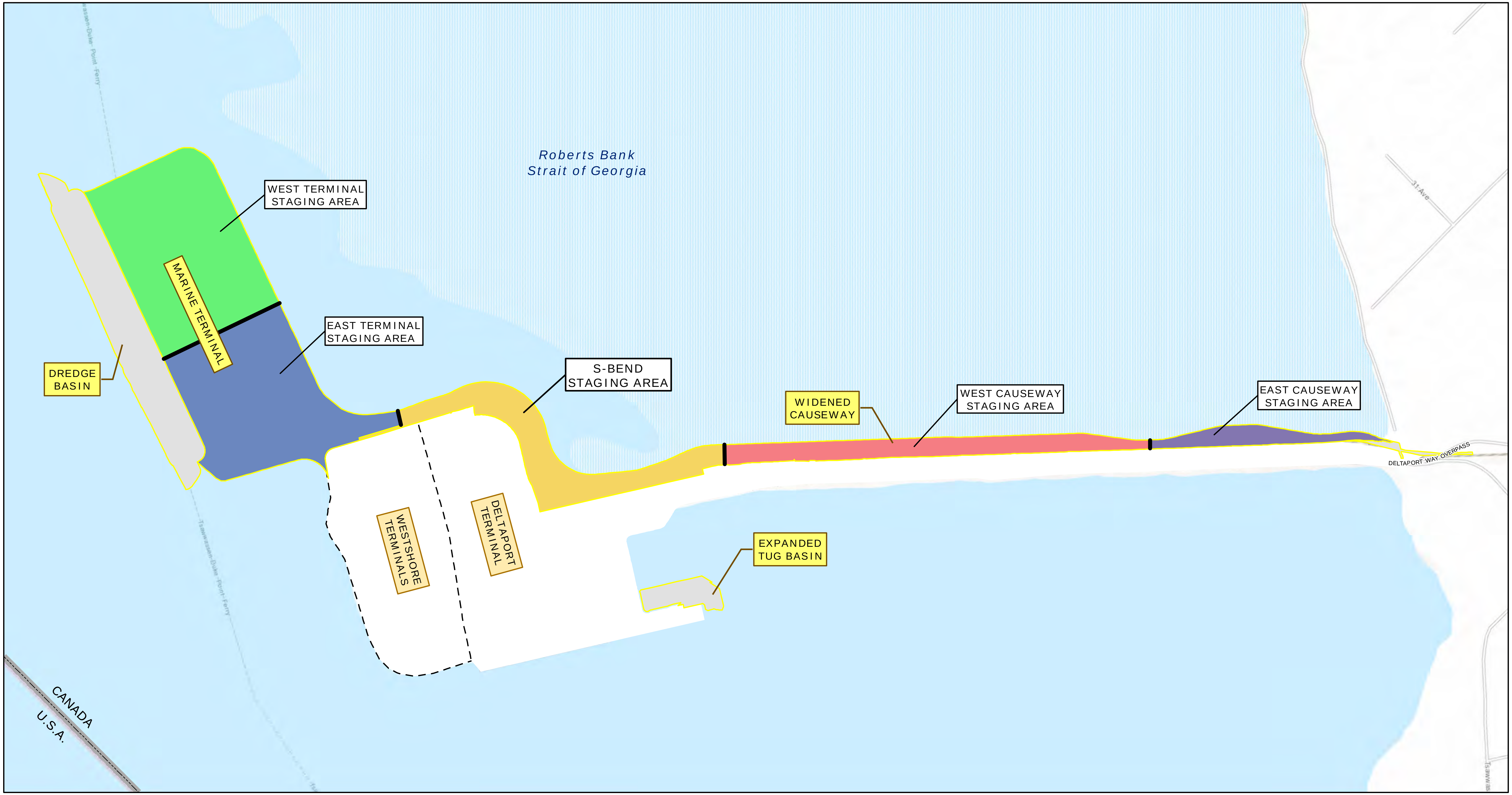

Legend

☐ BOUNDARY OF PROJECT AREA

0 175 350 700
Meters

1:17,500

NAD 1983 UTM Zone 10N

N

PORT of vancouver

ROBERTS BANK TERMINAL 2

IR4-35-A1
STAGING OF CONSTRUCTION MATERIALS CONCEPTUAL LAYOUT

DATE: 07/12/2017

FIG No. IR4-35-A1 Staging of Construction Materials

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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IR4-36 Storm Water Runoff – Widened Causeway

Information Source(s)

EIS Volume 1: Section 4.4.2.3**,** Appendix 4-A**,** Appendix 4-B

EIS Volume 2: Section 9.6.8.1

Proponent Response to IR1-15 (CEAR Doc#897)

EIS Volume 5: Section 31.2.1.1

Context

The Proponent, in Section 9.6.8.1, reported that during construction storm water discharge from existing and newly created terminal and causeway areas disturbed by construction activities have potential to lead to changes in sediment dispersion and increase in sediment deposition. The Proponent also stated in Section 31.2.1.1, that during Project construction, heavy rainfall may result in the erosion of granular surfaces or preload areas within the containment dykes at the terminal and along the widened causeway. Sediments carried into the marine environment via surface runoff and deposited in intertidal or subtidal areas may adversely affect marine habitat and water quality. Proposed mitigation would be that construction activities would be conducted in accordance with the Construction Environmental Management Plan to minimize changes to marine water quality from stormwater runoff.

The Proponent also reported that during operations, stormwater would be collected from the 108 hectare terminal site and discharged at outfalls along the Terminal 2 berth face. Collected drainage water at the terminal, would be passed through oil-water separators to collect surface oil and grit. Each stormwater outfall would be fitted with a shutoff valve to allow termination of flows in the event of a hazardous material spill, and effluent velocities would be controlled to minimize scouring within the berth pocket. Conceptual design plans for stormwater management within the following proposed areas were identified in Appendix 4-B (Diagrams CI 260-26). The Proponent, in its response to IR1-15 (CEAR Doc#897), predicted that there would be an annual stormwater discharge volume of 1,080,000 m3/year from the 108 hectare terminal area.

The area for the proposed 108 hectare terminal does not include the 42.4 hectares for the proposed 5.2 km widened causeway. The Proponent, in Appendix 4-A, proposed that the basis of design for roads on the causeway would be graded for stormwater to drain into and infiltrate through the gravel shoulder. The designs of the paved road, Roberts Bank Terminal 2 overpass, and rail infrastructure would also promote drainage and prevent ponding.

According to the Proponent, in Section 4.4.2.3, inbound and outbound trains would likely not be RBT2 pure trains. Trains would require sorting or reassembly at other terminal yards or repositioning to the mainline tracks between the T-Yard and the DPU/Bad Order Setout Yard.

Information about the management and effects of storm water runoff (during construction and operation of the proposed Project) from the 42.4 hectare (5.2 km) widened causeway (causeway rail addition and improvement, causeway road addition and improvement, and causeway utility corridor) is required.

Information Request

Provide a detailed description of how storm water will be managed within the widened causeway area, including the paved road, overpass and rail infrastructure during construction and operation of the proposed Project.

Describe the proposed mitigation measures to address the environmental effects from storm water runoff from the widened causeway, including the effects from coal dust, surface oil and grit from the paved road, overpass and rail infrastructure.

VFPA Response

During the construction phase, stormwater along the widened causeway will be managed using conventional techniques such as silt fences, straw bales, and diversion structures to contain any water within the causeway footprint, where it will either infiltrate into the subgrade below, or be managed within the larger fill areas.

Specific requirement for stormwater management during the construction phase will be detailed in the Sediment and Erosion Control Plan (as part of the Construction Environmental Management Plans), as described in Section 33.3.11 of the EIS. The Sediment and Erosion Control Plan will be developed during the detail design and construction planning phase by the Infrastructure Developer in consultation with regulators.

The effectiveness of stormwater management techniques will be monitored as per the Construction Compliance Monitoring Plan (see EIS Section 33.3.2). Specifically, routine water quality monitoring of select parameters (e.g., total suspended solids) will be undertaken at locations, frequencies, and durations to be determined in consultation with regulators as the Construction Compliance Monitoring Plan is developed.

During the operation phase, stormwater along the widened causeway will be managed according to standard management practices in B.C. that will be described in environmental management plans (see IR4-37 for more information). The implementation of such practices is expected to be adequate to achieve acceptable water quality for release to the environment, as the anticipated quantities of coal dust, oil, and grit generated during operation of the Project are expected to be minimal. Stormwater management details will be finalised during the detail design phase by the Infrastructure Developer.

The following concepts are provided as examples of stormwater design and control measures that may be implemented along the various sections of the widened causeway. Performance of the stormwater management system will be monitored as per the Operation Compliance Monitoring Plan (see EIS Section 33.4.1)

Causeway Road Addition and Improvement at S-Bend of Widened Causeway

For the main access road infrastructure on the widened causeway, including the RBT2 overpass, stormwater could be directed along the roadway to catchments leading to one or more oil/water separators (specific location to be determined during detail design) prior to discharging into an interceptor sewer located along the east side of the terminal. The interceptor sewer could be equipped with an oil/water separator (see Figure IR4-36-A1 in **Appendix IR4-36-A**) to further condition stormwater prior to discharging into the Strait of Georgia. Refer to drawing numbers 60287593-CI-264, 265, 266, and 267 in EIS Appendix 4-B.

Causeway Rail Addition and Improvement, Including Associated Service Roads

Within the main rail yard (T-Yard) and associated service roads, stormwater could be managed through a combination of natural and assisted ground infiltration. In this area, the surfaces would be finished with a coarse-sized permeable surface of ballast (rail) or gravel (road). Rainwater would percolate through these layers into the subgrade below. To further assist this process, underground perforated pipes wrapped in filter cloth connecting to 'open bottom' manholes could also be used along the various service roads (see Figure IR4-36-A1 in **Appendix IR4-36-A**). These systems would help reduce ponding of water during storm events, by acting as temporary water storage areas. Collected water would infiltrate into the subgrade via the bottom of the manholes.

Within the DPU/Bad Order Setout Yard and associated service roads, stormwater could be managed through assisted ground infiltration, as the area will largely be covered by impermeable surfaces. The rail tracks within this yard could be covered with drip pans to collect any grease or oil that may drip from the various rail equipment. These drip pans would be connected to a series of oil/water separators before connecting to open bottom manholes where the water will percolate into the subgrade. The associated rail service roads would likely be paved. Should the service roads be paved, they would be equipped with slotted trench drains along their length (see Figure IR4-36-A1 in **Appendix IR4-36-A**). These drains would also connect to a series of oil/water separators before connecting to open bottom manholes where the water would percolate into the subgrade.

Causeway Utility Corridor and Emergency Access Road

Along the utility corridor and emergency access road, stormwater could be managed with natural ground infiltration. These areas would be finished with a gravel surface. Rainwater would percolate through this layer into the subgrade below, and suspended sediment (i.e., grit and coal dust) would be captured in pore spaces of the gravel layer. Surface oil is not anticipated along the utility corridor or emergency access road.

Appendices

Appendix IR4-36-A	Supporting Figure (Figure IR4-36-A1)

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APPENDIX IR4-36-A
SUPPORTING FIGURE
(FIGURE IR4-36-A1)

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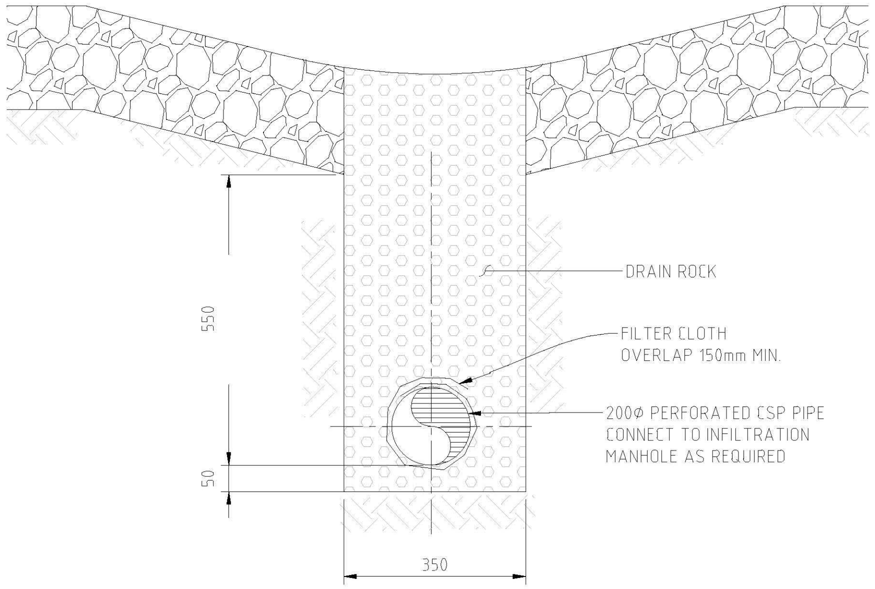
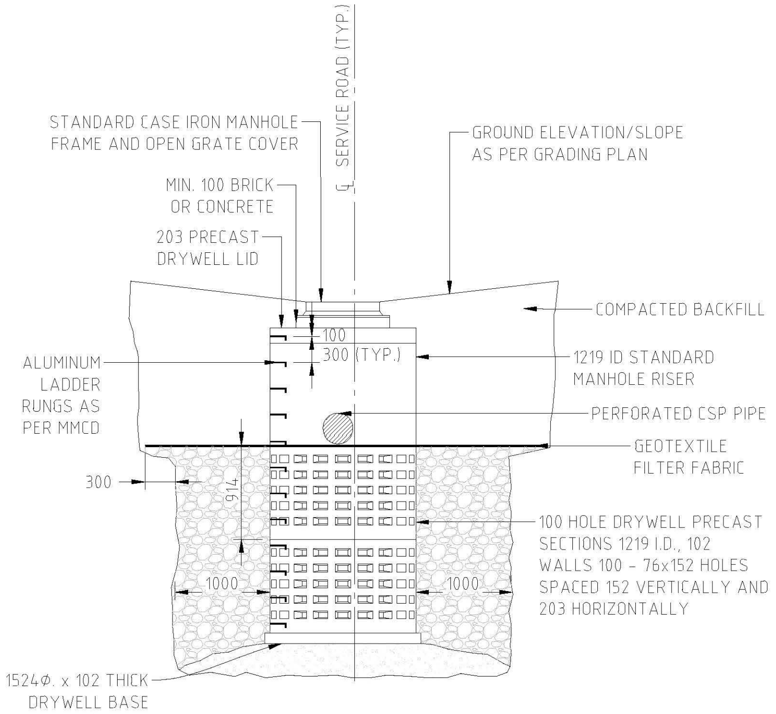
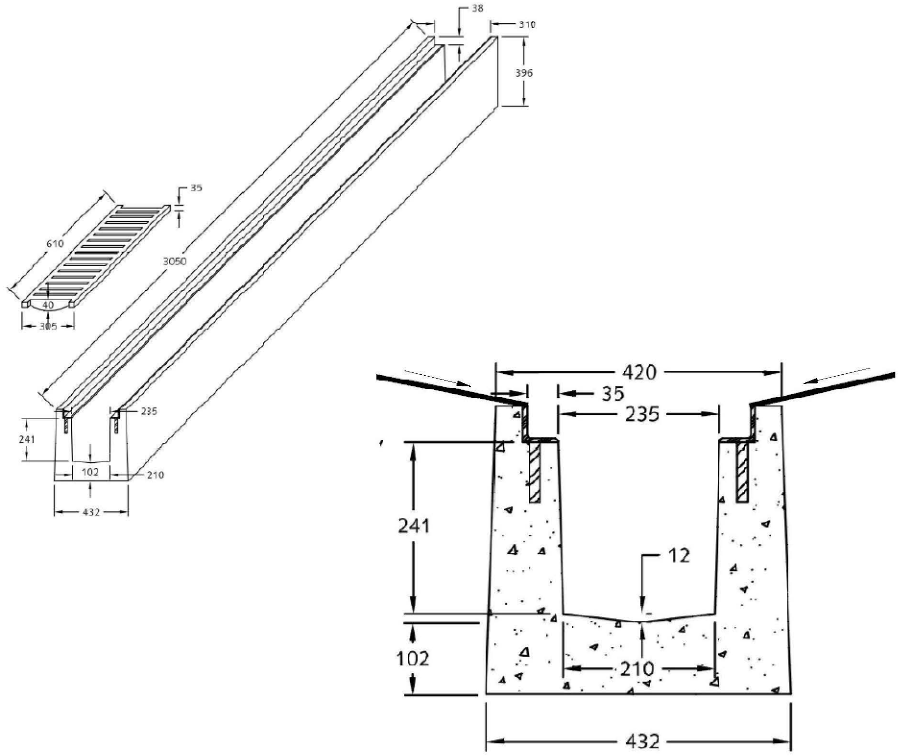


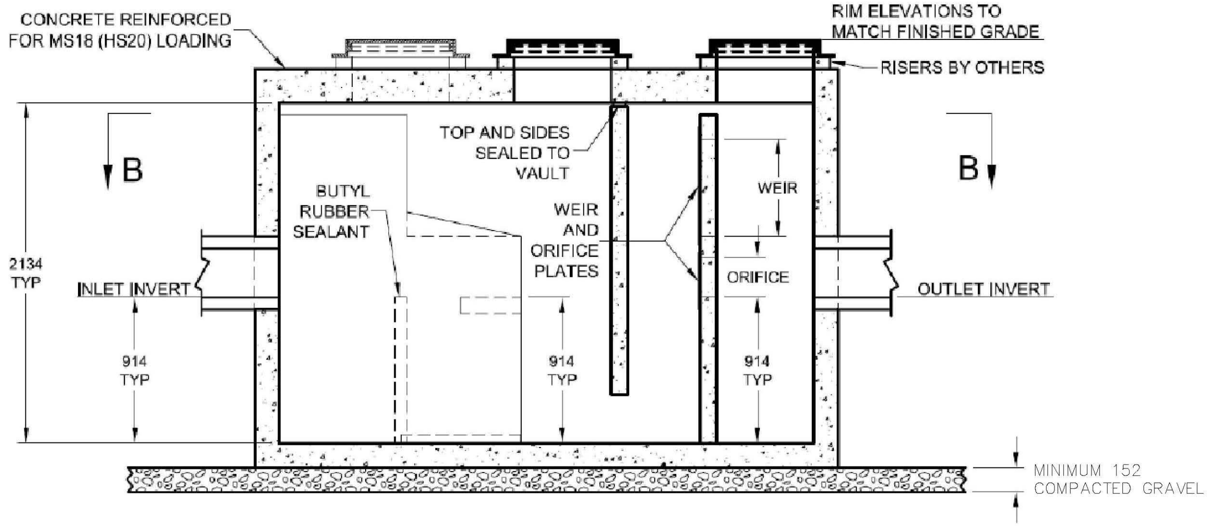
BELOW GRADE PERFORATED PIPE INFILTRATION CONCEPT
(UNPAVED SURFACE)



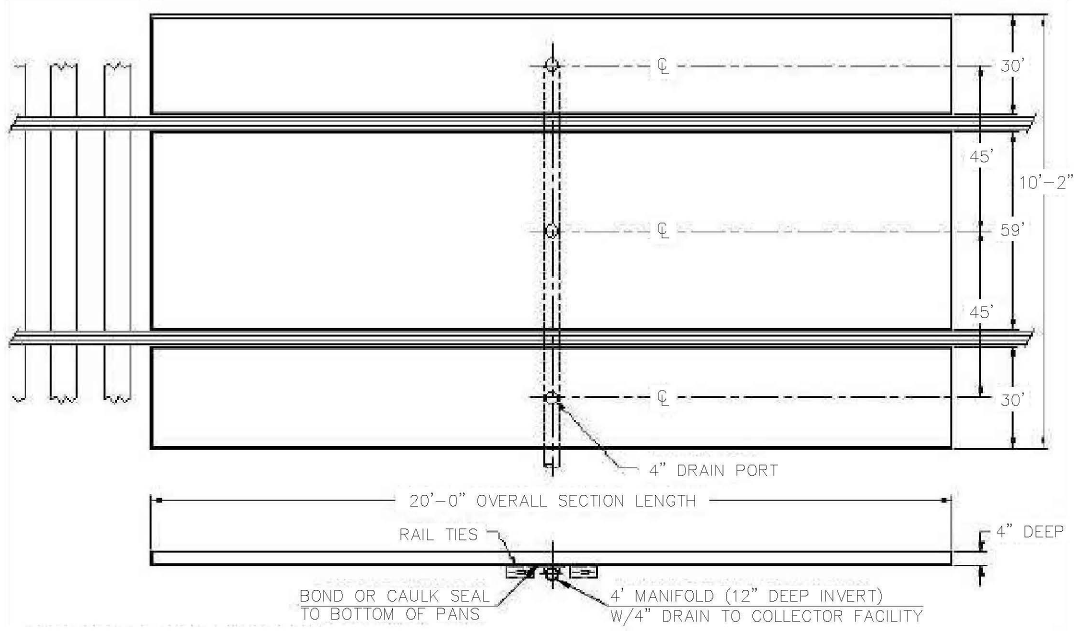
INFILTRATION MANHOLE CONCEPT



SLOTTED TRENCH DRAIN COLLECTION CONCEPT



OIL WATER SEPARATOR CONCEPT



STAR TRACK CONTAINMENT SYSTEM

MATERIAL: FIBERGLASS RESIN & GLASS MAT
HEAVY DUTY COMPOSITE WALLS & DECK
WALL THICKNESS 1/4"

NOTE: PLUMBING MUST TRAVEL BENEATH TRACKS AS SHOWN

RAIL CAR COLLECTOR PAN CONCEPT

NOTES:

1. DIMENSIONS IN METRES UNLESS STATED OTHERWISE

PRELIMINARY
DO NOT USE FOR CONSTRUCTION
Last Saved: Jul. 20/17 10:51am

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Ref.No. | REFERENCE

moffatt & nichol

IN ASSOCIATION WITH:

Stantec

No.	Date	REVISION	Dr'n	Ch'd
A	JUL13/17	PROGRESS SET #1 – ISSUED FOR DISCUSSION	SF	KS

PORT of vancouver
VANCOUVER FRASER PORT AUTHORITY
ENGINEERING DEPARTMENT

DESIGN BY B.NIEHAUS
DRAWN BY S.FOURNIER
APPROVED K. SKABAR
DATE JUL13/17
SCALE NTS
PMV SITE

ROBERTS BANK TERMINAL 2
DRAINAGE CONCEPT TYPICAL DETAILS

SIZE B
DWG. IR4-36-A1
SHEET 1 of 1
REV. A

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IR4-37 Marine Water Quality – Extreme Weather Event

Information Source(s)

EIS Volume 2: Section 9.7.8.2; Section 9.7.10

EIS Volume 5: Section 31.2.1.1

Context

The Proponent, in Section 9.7.8.2 of the EIS, indicated that storm water collected across the terminal area would be passed through oil interceptors, while storm water collected in fuelling areas and oil-filled electrical transformer areas would pass through oil-water separators prior to discharge from the terminal. Storm-water discharge will be managed according to standard management practices and in accordance with regulations, and are not expected to result in measurable changes in water quality.

The Proponent, in Section 31.2.1.1, further identified that the storm drainage system would be able to accommodate flows generated during a 1 in 10-year rain storm, with a 15-minute time of concentration.

During Project construction, heavy rainfall may result in the erosion of granular surfaces or preload areas within the containment dykes at the terminal and along the widened causeway. Sediments carried into the marine environment via surface runoff and deposited in intertidal or subtidal areas may adversely affect marine habitat and water quality. While during Project operation, prolonged heavy rain or the accumulation of snow, followed by rapid melt during a heavy rainfall, may result in a pulse of increased surface runoff from paved areas in the terminal, which may temporarily exceed the capacity of the storm water system. An increase in storm water discharge would have a negligible effect on the subtidal environment to which it discharges (based on volume of the receiving environment).

The Tsawwassen First Nation has indicated that it is possible that community members utilize the beach area near the BC Ferry Terminals on a routine basis. As well, the local assessment area has been identified as an area for recreational use and traditional harvesting.

Additional information about storm water and contaminants released from the storm water facilities, tug basin area and from the widened causeway area into the marine environment in periods of heavy rainfall is required.

Information Request

Assess the effects from a pulse of increased surface runoff not captured by the storm water system at the terminal or by the widened causeway area, including sources from the tug Basin and the widened causeway area. Include the considerations of the effects from all contaminants from the Project site on human health, biophysical environment, and the proposed onsite habitat compensation features.

Provide a description and justification of the techniques and assessments that would be used for detecting and addressing any storm water pollution, particularly as it relates to post-storm marine contamination or human health.

Provide a comparison of these results to applicable water quality standards.

VFPA Response

Assess the effects from a pulse of increased surface runoff not captured by the storm water system at the terminal or by the widened causeway area. Include the considerations of the effects from all contaminates from the Project site on human health, biophysical environment, and the proposed onsite habitat compensation features.

A pulse rain event exceeding a 1 in 10-year event will typically be high intensity and short-lived, and changes in water quality, if any, will not be prolonged based on volume of the receiving environment. A pulse of increased surface runoff not captured by the stormwater collection systems or infrastructure installed at the terminal or widened causeway could include small amounts of petroleum hydrocarbons (oil and grease), polycyclic aromatic hydrocarbons (PAHs), or suspended sediment (from coal dust or dust). The effects from a pulse of increased surface runoff not captured by the stormwater collection infrastructure at the terminal and along the widened causeway are anticipated to be negligible for the following reasons:

- Pulse events are not expected to contain high concentrations of these substances due to the types of activities that occur at a container terminal (i.e., as compared to a bulk terminal);
- Environmental management and monitoring plans will be implemented during both the construction and operation phases to ensure that potential risks on the site are managed; and
- Surface runoff will be collected and conditioned by the stormwater systems routinely during events that are more frequent (i.e., less than a 1 in 10-year event).

Managing risks and monitoring for compliance will occur during both the construction and operation phases. Effects to the marine environment, including the biophysical environment and proposed onsite habitat compensation features, from surface runoff that bypasses stormwater system infrastructure during a pulse event are expected to be negligible, but will ultimately depend upon factors such as the volume and properties of suspended contaminants in the runoff that is not captured, as well as the pathway and proximity to environmentally sensitive areas.

In addition, human health effects of a pulse event are not anticipated, based on the low frequency of such events (i.e., expected to occur less than once every ten years). Contaminants of concern in runoff from a pulse storm event will be quickly diluted and are not anticipated to bioaccumulate in tissues of edible marine resources, and therefore, would not pose a risk to human health upon consumption. Human health effects via other effect pathways, such as inhalation or dermal contact, are also not anticipated.

Further details on measures planned for stormwater management are outlined below.

As previously identified in the responses to IR1-15[1] and IR4-36, stormwater will be managed to meet regulatory and industry standards according to measures determined and implemented by the Infrastructure Developer. The VFPA will ensure that the proposed stormwater system can achieve the applicable standards (as determined through the relevant acts, regulations, and guidance documents) through Infrastructure Developer contractual obligations (see IR4-38 for more information). The stormwater collection systems at the marine terminal and S-bend area will be sized according to industry standard practice, which is currently a 1 in 10-year design rain storm event, with a 15-minute time of concentration.

IR4-36 provides examples of stormwater design and control measures that may be used or implemented along the various sections of the widened causeway. Drawing numbers 60287593-CI-260 to 267 in EIS Appendix 4-B illustrate conceptual designs for storm drain catchment areas and collection infrastructure for the terminal and S-bend area of the widened causeway. Since the tug basin will be expanded as an open water area and the only components with the potential to be exposed to rain events and surface runoff will be a floating dock for boat access and associated gangways, a stormwater collection system is not required.

As explained in EIS Section 4.2.1.5, stormwater will be collected by a stormwater system that includes oil interceptors to trap surface oil and grit that reaches the drainage collection system. The conceptual design for the terminal stormwater system has five outfalls located at the wharf face with the top of the outfall pipes being at elevation –5.0 m chart datum (CD) as per regulatory guidelines. Each outfall will be fitted with shutoff valves to prevent discharge if required in the event of an on-terminal spill. In addition, independent oil containment systems will be provided at the fuelling facilities, electrical transformer yards, reefer wash station, and the equipment washing station. Collected drainage water from these areas will be passed through coalescing plate oil-water separators sized for a minimum hydraulic flow rate of a 10-year return, 1-hour storm event. These oil-water separators will be equipped with gravity oil stop valves.

Provide a description and justification of the techniques and assessments that would be used for detecting and addressing any storm water pollution, particularly as it relates to post-storm marine contamination or human health.

The priority for stormwater management within VFPA jurisdiction is property-scaled adoption of stormwater source control measures and stormwater best management practices (see PMV 2015). The risk of pollution from stormwater runoff at RBT2 will be reduced with the implementation and monitoring of requirements described in environmental management plans, including Stormwater Pollution Prevention Plans (SPPPs) and Spill Preparedness and Response Plans (described in EIS Sections 33.3.15 and 33.4.7). These plans, prepared by the

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[1] CEAR Document #897 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 1 (See Reference Document #559).

Infrastructure Developer for the construction phase and the Terminal Operator for the operation phase, will outline the specific methods that will be used for detecting and addressing any stormwater pollution risks, including risks to the marine environment and human health.

Stormwater pollution prevention plans for both the construction and operation phases will be prepared by the Infrastructure Developer as per the requirements outlined in *Port Metro Vancouver Project and Environmental Review Guidelines – Developing Your Stormwater Pollution Prevention Plan, July 2015.* Each SPPP will be prepared by a qualified environmental professional with expertise in stormwater management and water quality issues. The SPPPs will provide a site inventory in which physical properties of the site, the stormwater infrastructure, primary and secondary activities to be carried out on the site, the materials present, the location of all activities and materials, and the hydrologic parameters. Based on the site characterisation, issues and stormwater pollution risks will be identified and analysed, including the following:

- Applicable standards, acts and regulations;
- Potential pollutant sources;
- Potential sensitive receptors, including environmental (terrestrial, marine, freshwater), public (municipal, community, stakeholders), Aboriginal (First Nations and Métis), and potential pollutant pathways; and
- A risk analysis that considers the probability of each type of pollutant being released and the consequences of a release.

Following the risk analysis, a plan to mitigate any risks will be developed. Mitigation measures can include prevention, containment/reduction, and treatment. Once the stormwater pollution prevention plan has been implemented, the quality of stormwater will be monitored to track effectiveness of mitigation measures, and the site managed to enable continuous improvement (i.e., implementation of adaptive management measures as required) based on the monitoring outcome of a water quality event[2].

The SPPP will be updated as necessary during the construction phase to reflect current and anticipated site-specific issues or pollution risks to stormwater, and appropriate mitigation measures to be implemented to prevent, contain, reduce, and/or treat stormwater runoff. For each Project phase, the Spill Preparedness and Response Plan will outline fuel handling, storage, and spill prevention and containment measures, and will include contingency and response plans that detail measures to be followed during spill containment and cleanup.

Monitoring to verify compliance with applicable standards and terms and conditions of Project approval, including SPPP and Spill Preparedness and Response Plan requirements, will be conducted at locations, frequencies, and durations to be determined in consultation with regulators, as outlined in the Construction Compliance Monitoring Plan and the Operation Compliance Monitoring Plan (see EIS Sections 33.3.1 and 33.4.1, respectively). These plans

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[2] A water quality event is a time period over which water with anomalous characteristics is detected through monitoring.

will define response and adaptive actions in the event of a failure in the implementation of the plans or of a recommended mitigation measure.

Provide a comparison of these results to applicable water quality standards.

As outlined above for SPPP development requirements, applicable standards, acts, and regulations will be reviewed to determine applicable water quality standards for the stormwater pollution risk identified from the issues identification and the risk analysis. At a minimum, monitoring results will be compared to the relevant water quality standards outlined in the Canadian Water Quality Guidelines for the Protection of Aquatic Life developed through the Canadian Council of Ministers of Environment (CCME 1999).

References

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Factsheets. Available at http://ceqg-rcqe.ccme.ca/en/index.html#void. Accessed July 2017.

Port Metro Vancouver. 2015. Project and Environmental Review Guidelines – Developing Your Stormwater Pollution Prevention Plan, July 2015. Available at https://www.portvancouver.com/wp-content/uploads/2015/05/PER-Stormwater-Pollution-Prevention-Plan-Guidelines-Final-2015-07-09.pdf. Accessed July 2017.

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IR4-38 Wastewater System

Information Source(s)

Proponent Response to IR1-16 (CEAR Doc#897)

Context

The Proponent’s response to Review Panel information request IR1-16 identified that the sewage treatment facility will be designed to treat a volume of 60 cubic meters (m^3) of effluent per day and the specific processes (means and methods) for sewage treatment will be determined at a later stage by the Infrastructure Developer in the Project planning.

It was further identified that for the Infrastructure Developer contract, the Proponent will utilize a Design Build Finance Maintain (DBFM) procurement process which places the responsibility for the meeting of the detailed design specification and performance on the Infrastructure Developer. The Proponent’s role is to monitor the Infrastructure Developer for compliance with its contract.

As part of the response to IR1-16, the Proponent also identified that it will ensure that the proposed wastewater system is capable of achieving the applicable effluent standards under the federal *Fisheries Act* and *Wastewater Systems Effluent Regulations*.

Additional information about the DBFM procurement process is required.

Information Request

Provide an explanation of the Design Build Finance Maintain (DBFM) procurement process, and how the DBFM procurement process will ensure that the sewage treatment system, as determined by the Infrastructure Developer, will meet the standards set out under federal legislation.

VFPA Response

As discussed further below, a Design Build Finance Maintain (DBFM) contract structure uses performance-based technical specifications in conjunction with the ‘Payment Mechanism’ to drive contractor performance.

However, it is important to note that the standards set out under federal legislation—including the federal *Fisheries Act* and *Wastewater Systems Effluent Regulations*—are binding in their own right and such legislated requirements must be complied with regardless of the procurement process used. The performance-based technical specifications and the ‘Payment Mechanism’ employed in a DBFM contract structure are intended only as mechanisms to create incentives for the Infrastructure Developer and to drive contractor performance. A DBFM contract structure is simply one form (among many) of construction contract and, in such a construction contract, the contractor is responsible for complying with applicable legislation.

However, it is the binding force of the federal legislation—not the DBFM procurement process (or any other alternative procurement process)—that will ensure that the sewage treatment system, as determined by the Infrastructure Developer, will meet the standards set out under that legislation.

In the case of the sewage treatment facility, the technical specifications will state the volume of effluent the facility must be able to treat each day, and the applicable effluent discharge standards to be met, as per the relevant federal legislation. Treatment performance of the sewage treatment system will be monitored as per the Operation Compliance Monitoring Plan (see EIS Section 33.4.1).

The Infrastructure Developer, through its design, will ensure that the facility meets the technical specification requirements (including the relevant legislative requirements). Once in operation, compliance with the performance-based technical specifications is enforced through the Payment Mechanism. The Payment Mechanism defines the rules under which the Infrastructure Developer is paid. Generally, in a DBFM contract, the Infrastructure Developer is paid out for the construction, operation, and maintenance of the asset over the life of the contract. For example, in a case such as RBT2, this could be approximately 30 years. To receive the payment related to the sewage treatment facility, the Infrastructure Developer must achieve the required performance levels of the treatment facility during each pay period. If the required performance levels are not met, they will lose that payment, which is non-recoverable. A lost payment will be a significant issue for the Infrastructure Developer, as the payment will be used to provide equity investors a return on their capital outlay and fulfill debt obligations. As a result, the Infrastructure Developer is incentivised to ensure all the required performance criteria are met continually for each pay period over the life of the contract. In addition, the Infrastructure Developer is incentivised to rectify any issues to ensure technical compliance or risk another non-payment.

IR4-39 Dredging – FRPD 309

Information Source(s)

EIS Volume 1: Appendix 4-E

EIS Volume 2: Appendix 9.6-C

Proponent Response to IR1-11 (CEAR Doc#897), Table IR1-11-1

Context

The Proponent, in response to Review Panel information request IR1-11, identified that FRPD309 - with its pump ashore capability, large hopper size, and acceptable dredging depth capability - would be an alternative second dredge during sand reclamation from the intermediate transfer pit. In the IR response, the Proponent provided a brief comparison of the potential changes to air and noise and the effects of those changes on human health, marine fish, marine mammals and coastal birds.

As set out in Appendix 9.6-C of the EIS, an unnamed second dredge would be used to unload the intermediate transfer pit into the Roberts Bank Terminal 2 footprint from October 1 to March 31, 2020 and that suspended material would be added to the water column via both the Columbia at the dredge basin and the Unnamed Second Dredge at the intermediate transfer pit. The overlap in operations in both dredge basin and intermediate transfer pit suspended sediment could result in interactions of sediment re-suspension plumes from the two Project areas, and elevated total suspended solids concentrations in the vicinity of the Project site.

Additional Information about the environmental effects of using FRPD 309 is required.

Information Request

Update the alternatives analysis in Table IR1-11-1 of the Proponent’s response to Review Panel information request IR1-11. Include the consideration of effects on water quality (total suspended solids) and sediment deposition in the evaluation of potential environmental effects for each vessel, and if necessary, update the alternative means analysis conclusions.

VFPA Clarification

To clarify statements provided in the context of this information request, the overlap in dredging operations in both the dredge basin using the *Columbia* and intermediate transfer pit (ITP) using the *Titan* and an unnamed second dredge was modelled over a 12-month dredging period when all three dredge vessels are anticipated to be operating simultaneously. Total suspended solids (TSS) concentrations were presented in EIS Section 9.7.8.1, EIS

Figure 9.7-8[1] (corresponding figure in EIS Appendix 9.6-C is Figure 5.2.30), and sediment deposition was presented in EIS Section 9.6.8.1 and EIS Figures 9.6-8 and 9.6-9 (corresponding figures in EIS Appendix 9.6-C are Figures 5.2.32 and 5.2.33). An interaction of sediment re-suspension plumes from dredge basin dredging, loading of the ITP via barge dumping, and dredging of the ITP is not expected (see EIS Figure 9.7-8).

VFPA Response

As described in the Preamble at the beginning of the responses to Information Request Package 3 (CEAR Document #984[2]), the VFPA no longer requires the ITP to construct the Project, thus eliminating any potential overlap in operations. Based on the updated construction activities, therefore, an alternative means analysis for reclaim dredging of the ITP, including an assessment of changes to water quality (total suspended solids) and sediment deposition, is unnecessary.

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[1] Note that EIS Figure 9.7-8 presents peak TSS levels over the 12-month duration of dredging to give a conservative representation of the TSS concentration in the water column, even though the reported maximum TSS would not occur at the same time within the water column or across the spatial extent of the plume.

[2] CEAR Document #984 From the Vancouver Fraser Port Authority to the Review Panel re: Responses to Information Request Package 3 (See Reference Document #928).