IDENTIFICATION OF AREAS FOR MITIGATION OF VESSEL-RELATED THREATS TO SURVIVAL AND RECOVERY FOR SOUTHERN RESIDENT KILLER WHALES

Members of the Southern Resident Killer Whale population near the shipping lanes in the vicinity of Swiftsure Bank, with a container ship in the background. Photo by Katherine Gavrilchuk, DFO.

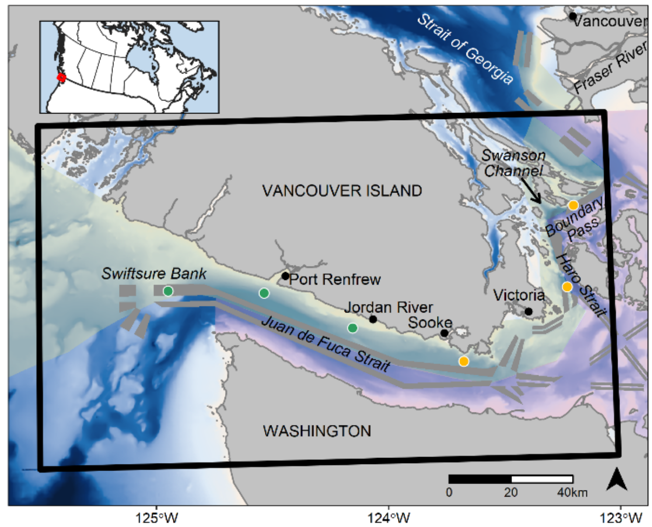

Figure 1. SRKW critical habitat in both Canadian waters (yellow shading) and American waters (pink shading); shipping lanes are shown in grey. Circles denote acoustic recorders used to characterize noise environment (all) and those used for SRKW detections (green circles). Black lines denote the study area.

Context:

The Southern Resident Killer Whale (SRKW) population is listed as Endangered under the Species at Risk Act (SARA). The SRKW population is facing imminent threat to survival and recovery based on their small and declining population size, reproductive biology, population structure, and anthropogenic impacts, which include acoustic and physical disturbance, acoustic masking, contaminants, vessel strike, and reductions in prey availability (primarily Chinook Salmon, Oncorhynchus tshawytscha*).*

Information on SRKW distribution, habitat use, and their intersection with threats can help address impacts to SRKW survival and recovery and support area-based spatial management initiatives. Fisheries and Oceans Canada (DFO) Science advice was requested to identify areas of high co-occurrence of SRKW and vessels for May to October within their critical habitat using sightings data from DFO and other sources, and the best available data on current state of vessel presence, vessel speed, and acoustic environment. This high-resolution analysis of the potential for vessel strike, vessel-related physical disturbance and for noise impacts to the communication and echolocation range of SRKW will inform spatial and temporal advice for SRKW threat mitigation.

This Science Advisory Report is from the February 22-26th, 2021 National Marine Mammal Peer Review on the Identification of Areas to Apply Spatial Management Measures to Protect Southern Resident Killer Whales. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- Southern Resident Killer Whale (SRKW) critical habitat (CH) in Canadian Pacific waters was identified in the Recovery Strategy and includes portions of the Salish Sea and of the continental shelf around Swiftsure Bank. SRKW occurrence and potential vessel-related impacts were examined in these waters.
- Effort-corrected whale watch and Fisheries and Oceans Canada (DFO) sightings data from May to October 2009 to 2020 were evaluated and identified areas of high relative occurrence of SRKW in the Swiftsure Bank Area, Haro Strait, coastal waters near the Fraser River and other locations.
- Occurrence of SRKW varied temporally, with intensity increasing from May to August. In September, the intensity of occurrence was diminished in the Swiftsure Bank area but continued to increase in the Salish Sea. The temporal variation of occurrence aligns with known migratory patterns of SRKW prey (Chinook Salmon (*Oncorhynchus tshawytscha)* returning to the Fraser River from May to August and Coho Salmon (*Oncorhynchus kisutch*) in September).
- Analyses identifying dominant behaviours confirmed Haro Strait as a foraging area. Foraging was also the dominant behaviour in the waters around Swiftsure Bank. The shallows of the Bank, Juan de Fuca Strait, Boundary Pass and Swanson Channel were identified as areas of travel.
- Acoustic detections from recorders deployed at Swiftsure Bank, Port Renfrew, and Jordan River supported the spatial and monthly occurrence results from visual surveys, and the acoustic encounter durations were consistent with outcomes of the behaviour analyses.
- Analysis of Automatic Identification System (AIS) data indicated that Haro Strait experiences a higher vessel presence (AIS Class A and B) per square kilometer when compared to the Swiftsure Bank area. AIS vessel presence at Swiftsure Bank area was dominated by large commercial vessels (Class A), while Haro Strait was primarily dominated by recreational vessels (Class B). Class B vessel presence in both areas increased from May to peak in July and August.
- Noise from AIS Class A vessels, which is comprised of container ships, tankers, vehicle carriers, ferries, tugs, and commercial fishing, naval, government, cargo, and passenger vessels, resulted in a greater decrease in potential communication and echolocation ranges in the Swiftsure Bank area than in Haro Strait for all months. Potential echolocation range also decreased with depth at both locations.
- The eastern slope of Swiftsure Bank (foreslope) was the area most impacted by Class A vessel noise. This area was characterized by high SRKW occurrence, with foraging identified as the dominant behaviour. Other locations in the Swiftsure Bank area exhibited less impacts to the potential echolocation and communication ranges, including the foraging area north of Swiftsure Bank.
- The potential acoustic impact in Haro Strait was lower when compared to the Swiftsure Bank area, despite higher vessel traffic. This is likely the result of differing bathymetry, topography, water properties, and type of vessels.
- Analysis of acoustic recorder data indicated a reduction in the potential echolocation range, especially during daylight hours and on weekends. This reduction is attributed to the presence of recreational vessels.
- There is limited information on the presence of non-AIS vessels in the study area. While aerial surveys provided information on recreational fishing vessels and indicate co-

occurrence with some areas of high SRKW intensity, spatial and temporal coverage is minimal.

- The risk of lethal vessel strike is known to increase with vessel speed. The majority of AIS vessels travelling over 10 knots are large commercial vessels (Class A) in both the Swiftsure Bank Area and Haro Strait.
- This co-occurrence approach could be used to evaluate the threat of reduced prey availability.

INTRODUCTION

The Southern Resident Killer Whale (SRKW; *Orcinus orca*) population in Canadian Pacific waters is listed as Endangered under the *Species at Risk Act*. Critical habitat (CH) has been identified as portions of the waters on the continental shelf off southwestern Vancouver Island and eastward to include parts of the Salish Sea (Figure 1). The spatial extent of the CH is large and there is a need to focus recovery efforts on areas within the CH that have the greatest potential to provide benefits to the population.

Noise from vessels is a substantial contributor to the acoustic environment at the frequencies used for SRKW communication and echolocation. Exposure to anthropogenic noise in the Salish Sea and the Swiftsure Bank area has the potential to impact SRKW and interfere with life processes that support survival and recovery. Impacts from the physical presence of vessels, including the risk of vessel strike, are also possible consequences of vessel traffic.

Understanding SRKW habitat preference and use of CH plays a key role in developing effective mitigation strategies and supporting recovery. Mapping areas of high SRKW occurrence, and then overlaying with vessel presence and noise data reveals locations of elevated risk, and provides information on the timing of potential impacts.

Methodology

Habitat preference of SRKW was determined using sightings data (date, time and location) from whale watch (WW) operators (2009-2018) and SRKW encounter data from DFO surveys (2009-2020). Effort was estimated using vessel behaviour (WW) and vessel track data (DFO). Daily effort was defined as number of hours from 9 am until the first sighting for each pod, each day and was summed monthly. The number of SRKW sightings per unit search effort at a given location was modelled and outputs were expressed as intensity of SRKW occurrence with a >0.9 confidence level.

Areas where there was a >0.7, >0.8 and >0.9 probability that foraging or travelling were the dominant behaviours were identified using individual focal follow and group behavioural survey data collected every five minutes by DFO in Juan de Fuca Strait and the Swiftsure Bank area from 2018-2020, and by the National Oceanic and Atmospheric Administration (NOAA) in the Haro Strait area from 2006-2009.

Passive acoustic recorder data collected from Swiftsure Bank, Port Renfrew, and Jordan River (Figure 1) from May to October, 2018–2019 were analyzed for SRKW acoustic presence and duration of presence using an automated detector. Files with detections were manually reviewed to confirm the presence of SRKW.

Ambient noise levels were estimated over various time scales using acoustic data collected from May to October, 2018–2020 from six moorings positioned throughout the study area (Figure 1). The contribution of wind and vessel noise to the low- to mid-frequencies used for SRKW communication calls (500 Hz-15 kHz) and to the higher frequencies used for SRKW echolocation (15-100 kHz) was assessed. The propagation of vessel-derived noise from large, commercial (AIS Class A) vessel transits in the study area at low frequencies (<500 Hz) was extrapolated to 10 kHz to represent SRKW communication and 50 kHz to represent echolocation.

The effective ranges of SRKW echolocation and communication were calculated based on literature values, and transmission losses estimated from modelled and measured water mass properties. Maximum effective range was estimated by defining ‘minimum ambient’ conditions, where vessel noise was absent and noise from wind and waves was negligible. The communication and echolocation ranges were then determined under varying ambient noise levels, and compared to ‘minimum ambient’ conditions to show the relative range loss from ambient noise. The results would represent the worst-case scenario of communication and echolocation range loss due to wind or vessel noise additions.

Finally, vessel presence and speed were quantified from Automatic Identification System (AIS) data for Class A and Class B vessels (May through October, 2018-2020), and from DFO aerial surveys of recreational fishing effort for non-AIS vessels. The spatial and temporal overlap between vessels and areas of frequent SRKW occurrence was examined by overlaying AIS vessel presence with SRKW areas of high occurrence within Haro Strait and the Swiftsure Bank Area.

Results

Analysis of effort-corrected WW and DFO sightings data from May to October 2009-2020 identified areas of high relative occurrence of SRKW in the areas of Swiftsure Bank, Haro Strait, coastal waters near the Fraser River and other locations (Figure 2). Intensity of SRKW occurrence showed a general increase from May to August (Figure 3). In September, the intensity of occurrence diminished in the Swiftsure Bank area but continued to increase in the Salish Sea. Acoustic detections from recorders deployed at Swiftsure Bank, Port Renfrew, and Jordan River were consistent with the spatial and monthly occurrence results from these visual surveys. The temporal variation of occurrence aligns with known migratory patterns of SRKW prey (Chinook Salmon from May to August and Coho Salmon in September).

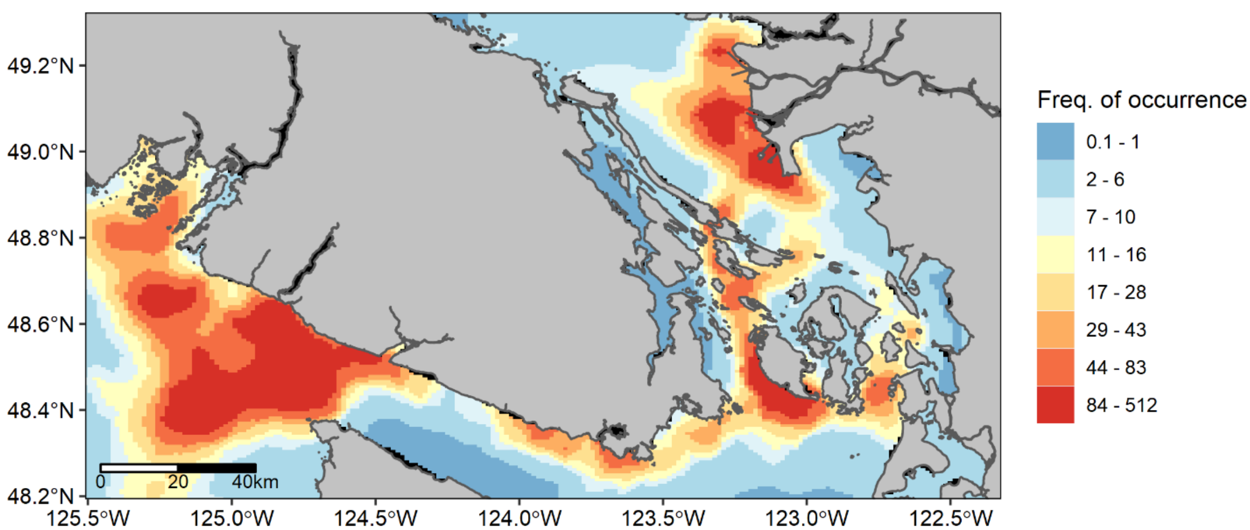

Figure 2. Annual frequency of SRKW occurrence from May to October as predicted by the SRKW occurrence model using combined WW and DFO data (2009-2020).

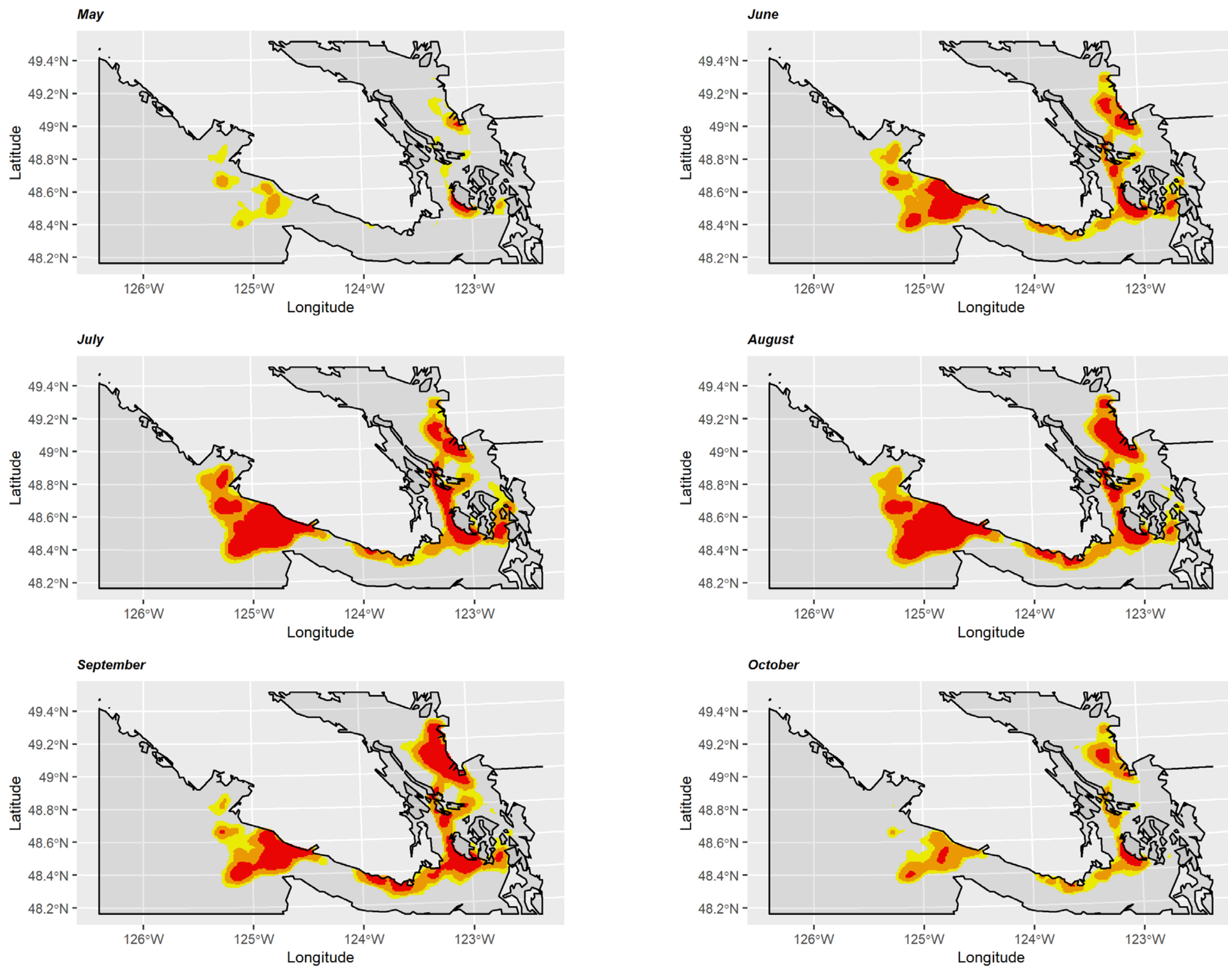

Figure 3. The expected number of SRKW sightings per unit search effort at a given location is referred to as the SRKW intensity of occurrence. The 90% polygon (red) represents the areas of highest SRKW intensity of occurrence, with diminishing intensity described by the 80% (orange) and 70% (yellow) polygons. The model outputs indicate that when SRKW are within critical habitat from May to October, these polygons represent their preferred habitat.

Analyses of SRKW behaviour confirmed Haro Strait as a foraging area (Figure 4) and identified foraging as the dominant behaviour in the waters surrounding Swiftsure Bank. The shallows of Swiftsure Bank, as well as Boundary Pass, Swanson Channel, and Juan de Fuca Strait were identified as areas of travel. The acoustic encounter durations with SRKW at the different stations were consistent with outcomes of the behaviour analyses.

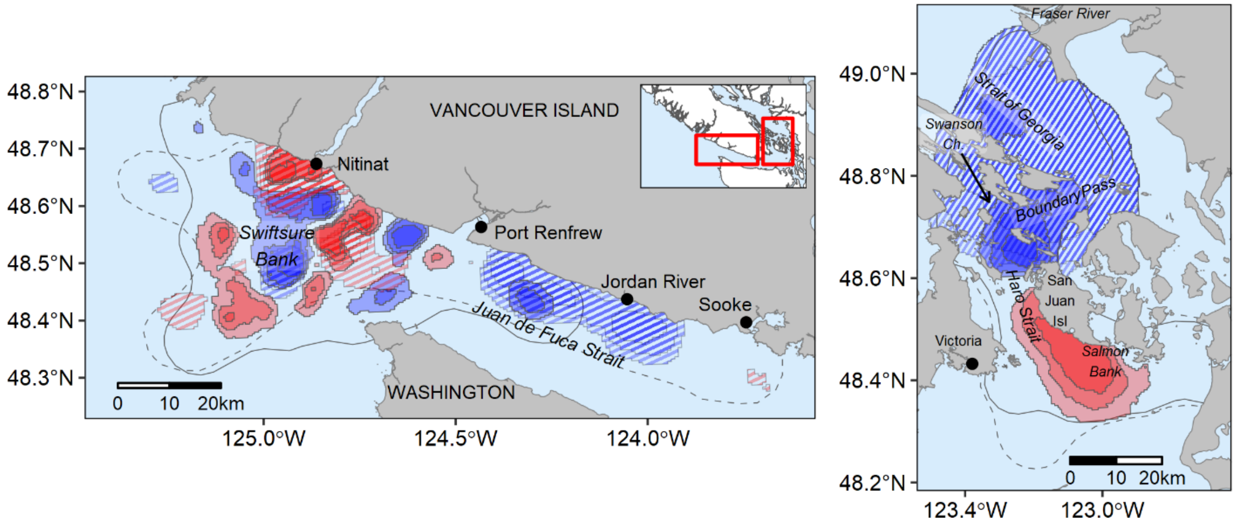

Figure 4. Areas of likely foraging (red) and travel (blue) behaviour as indicated by focal follows (hatched) or group behavioural surveys (GBS, solid) conducted by DFO in the Swiftsure Bank area (left panel) and NOAA in the Haro Strait area (right panel). Study areas are represented by the solid (GBS) and dashed (focal follow) lines, respectively. Increased transparency of the polygon denotes decreasing confidence in the identification of dominant behaviour.

The areas of high SRKW occurrence at Swiftsure Bank and Haro Strait overlap with the shipping lanes (Figure 5a). Noise impacts from AIS Class A vessel data, which were expressed in terms of proportional loss in echolocation or communication range, varied with water depth (Figure 5d) and were greater in the Swiftsure Bank area than in Haro Strait (Figures 5b-c).

Co-occurrence analyses of SRKW presence and vessel noise indicated that the eastern foreslope of Swiftsure Bank, an area where foraging behaviour dominates, was the area most impacted by Class A vessel noise (Figure 5b-d). While foraging locations to the north of Swiftsure Bank and in Haro Strait were areas with less noise from Class A vessels, additional noise from Class B and non-AIS vessels were not captured in this model and are likely important contributors to the ambient noise environment. Overall, Haro Strait had a higher proportion of class B vessels and an overall higher vessel presence when compared to the Swiftsure Bank area (Figure 6). The presence of Class B vessels increased from May to peak in July and August, and then declined in September and October (Figure 6).

Risk of vessel strike is known to increase with vessel speed, and speeds greater than 10 knots are likely to cause mortality. While AIS Class B vessels are the dominant class in Haro Strait (Figure 6, top left), the majority of vessels travelling at speeds greater than 10 knots were AIS Class A vessels, indicating that this vessel class may confer a greater risk of vessel strike to SRKW in both Haro Strait and Swiftsure Bank (Figure 6, bottom left and right).

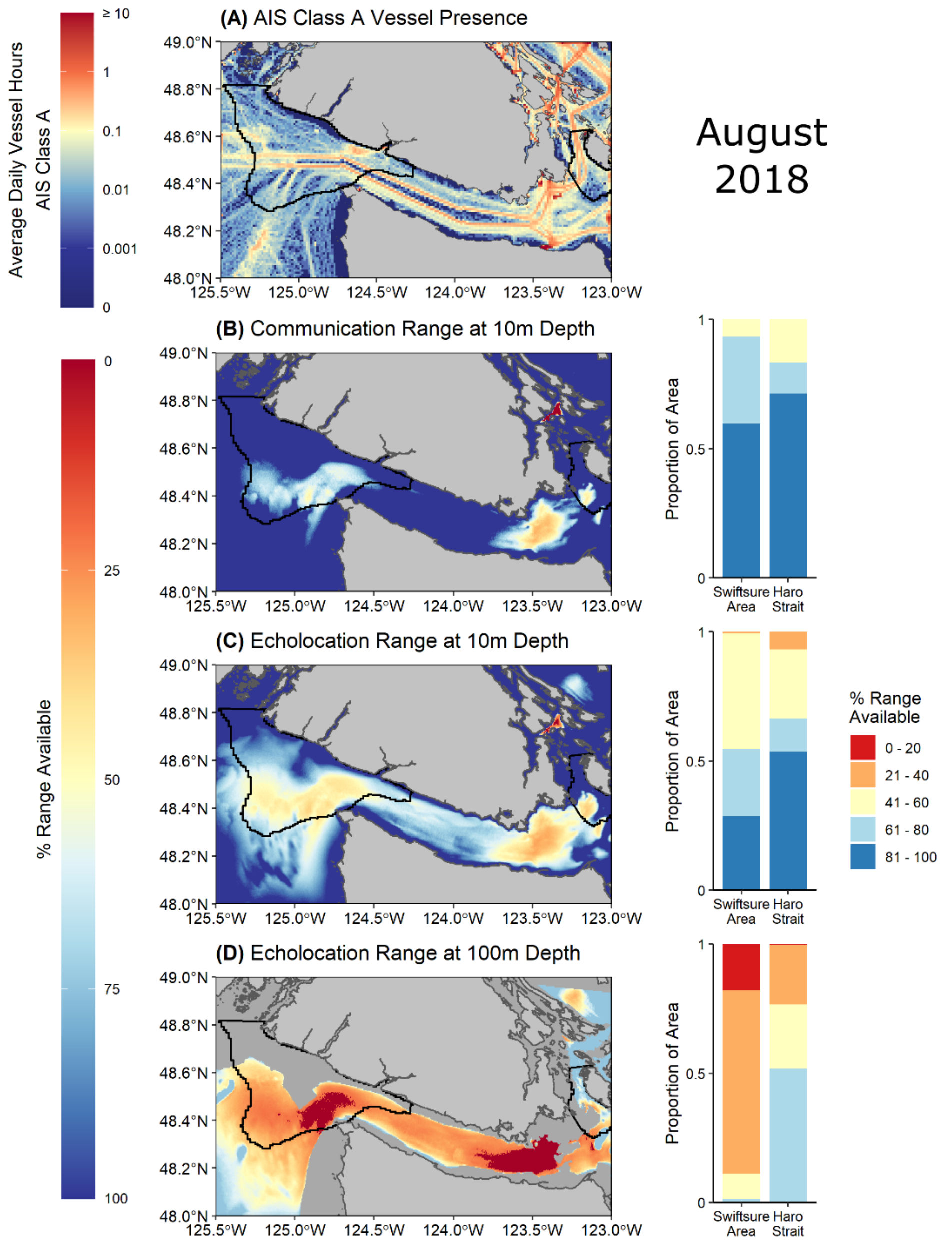

Figure 5. Example of SRKW co-occurrence with vessel presence and range loss of echolocation and communication space from AIS Class A vessels (August 2018 data shown); SRKW 70% intensity of occurrence in the Swiftsure Bank and Haro Strait is defined by black lines. A) Average daily vessel presence, B) average loss of communication range at 10 m depth, C) average loss of echolocation range at 10 m depth, and D) average loss of echolocation range at 100 m depth.

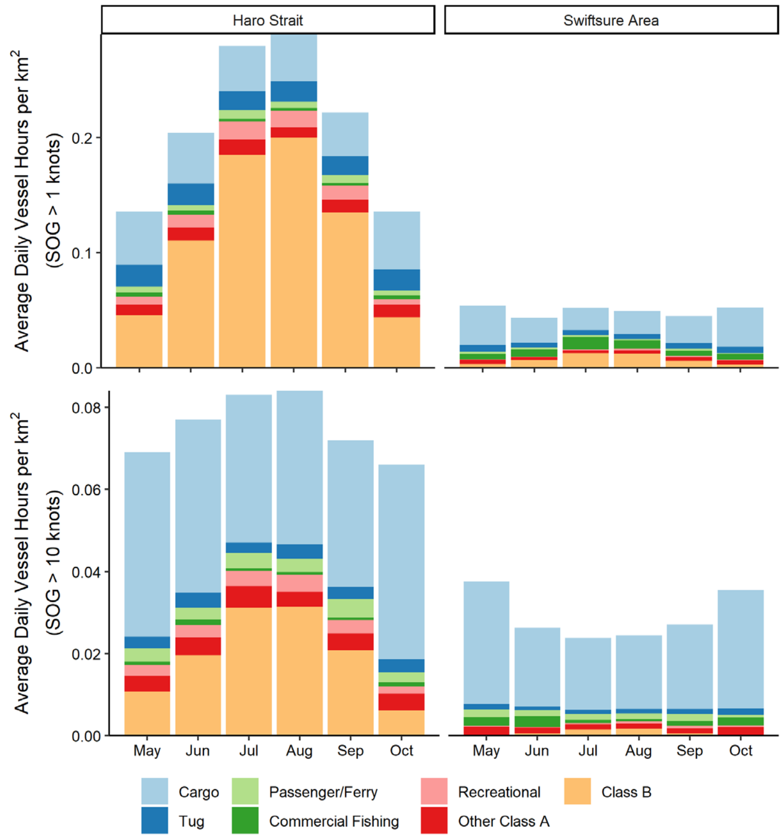

Figure 6. Average daily vessel traffic (hours per km per month) in areas of high SRKW occurrence (see Figure 3 -70% intensity of occurrence area boundaries). The overall proportion of each AIS vessel class in Haro Strait (left) and in the Swiftsure Bank area (right) is shown by expressing vessels travelling at 'speed over ground' (SOG) greater than 1 knot (top panel). In each area, the vessel class that is more likely to pose a risk of vessel strike is estimated by expressing the proportion of vessels that are travelling at SOG greater than 10 knots (bottom panel).

Sources of Uncertainty

Assumptions related to distance travelled, vessel routes, and search effort may result in inaccuracies in assignment of effort for the whale watch data. Also, daily effort estimates using the first daily sighting of each pod may result in a locational bias that favours sightings in areas closer to ports of departure.

As DFO data are primarily from surveys that originated in Canadian waters, additional effort in US waters would improve the results of the models.

The spatial extent of the behavioural analysis is limited by a paucity of data, and the behaviour model outputs for some areas (Boundary Pass, Swanson Channel and the southern Strait of Georgia) are based on a limited number of observations and should be interpreted cautiously. Behavioural data were also limited to observations collected from June to August.

Inaccuracies in the AIS data set and variabilities in vessel sound source level data that were used to model vessel noise may introduce uncertainties into the modelled outputs. Variations in substrate and bathymetry also contribute to uncertainties in the model outputs. The model was produced using AIS Class A data only and therefore represents noise inputs from one vessel class rather than the overall acoustic environment.

Whales use a range of acoustic frequencies to communicate and echolocate. However, acoustic impacts on communication and echolocation range estimates were calculated using a single representative frequency and source level. Echolocation loss does not account for directionality of the source and echo signal; this may contribute to an overestimation of echolocation range loss. The ability of a whale to discern sound through a noisy environment (termed “masking release”) is not known and was not taken into account in these analyses.

As calculation of echolocation and communication range loss used minimum ambient conditions as a baseline, they likely overestimated the loss of range for a given source level, and were considered to be precautionary.

CONCLUSIONS AND ADVICE

Areas of high SRKW occurrence from May to October were identified in the Swiftsure Bank area, Haro Strait, coastal waters near the Fraser River and other locations. Marine spatial planning and conservation efforts that include these areas are likely to increase the success of threat mitigation actions.

The noise from large (AIS Class A) vessels decreased the potential communication and echolocation ranges in SRKW foraging areas of the Swiftsure Bank area and Haro Strait. The SRKW population is characterized as nutritionally stressed, as evidenced by an observed decline in body condition. As SRKW use echolocation signals to locate and pursue prey, noise inputs into foraging areas are more likely to have detrimental impacts on SRKW.

The eastern slope of Swiftsure Bank is a foraging area that is exposed to elevated level of noise, vessel presence, and vessel speed. While the SRKW occurrence in the Swiftsure Bank area diminishes from May to October, the intensity of occurrence in the Swiftsure Bank foreslope area remains elevated throughout the summer.

Haro Strait exhibits a high frequency of SRKW occurrence in all months examined, with foraging as the dominant behaviour, particularly around Salmon Bank (Figure 4). While this study showed that the Swiftsure Bank area has a greater proportional loss of echolocation and communication range from AIS Class A vessels when compared to Haro Strait, the impacts from Class B and non-AIS vessels were not captured in the noise model and likely represent a substantial contribution to the sound field of Haro Strait.

Further information is needed on small vessel presence and its relative contribution to the acoustic environment. Improvements in AIS coverage, quality of data received, and expansion of AIS requirements to other vessel classes would increase resolution of vessel traffic data for future analyses.

Existing management actions for SRKW recovery (e.g., fishery closures, interim sanctuary zones) that were initiated prior to this study may not align with the areas of high SRKW occurrence.

OTHER CONSIDERATIONS

While these analyses were limited to vessel-related impacts, future plans include the use the co-occurrence approach to incorporate prey information, such as the timing of various Chinook stock migrations, Chinook abundance data, removals, and fishing effort, as well as data related to contaminant loads in various prey stocks. These analyses may provide further scientific evidence for management decisions that support the survival and recovery of the endangered SRKW population.

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SOURCES OF INFORMATION

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