Assessing the Role of Small Vessels

in Disrupting Killer Whale Habitat in the Fraser Estuary

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Disclaimer

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Executive Summary

Southern Resident Killer Whales, an endangered population in Canadian Pacific waters, face several significant challenges that impede their recovery, including anthropogenic threats such as reduced prey availability, high levels of stored contaminants, habitat degradation, and disturbances caused by vessels in their environment.

An increase in ambient noise can drown out important acoustic signals killer whales use and damage their critical habitats. This can affect the energy intake of Southern Resident Killer Whales, as vessel disturbances make it less likely for them to hunt and catch prey. This increase is partly due to rising marine traffic from both commercial and recreational vessels. While the report acknowledges the impact of large ships on traffic and noise emissions, it focuses on the less studied non-AIS vessels. Vessels that do not use Automatic Identification Systems (AIS) are difficult to track, making it challenging to determine the true physical and acoustic disturbances in the critical habitats of killer whales. While recent research has investigated non-AIS vessel activity and found that it represents a significant proportion of vessel transits, the Fraser Estuary, an important foraging area for SRKWs in late summer, has been largely excluded from studies on small vessels in the Salish Sea.

This study provides preliminary confirmation of the significance of small vessel activity in the Fraser Estuary, aligning with prior research that highlights the prevalence of non-AIS vessels in coastal regions during the summer months and on the weekend. In both observations, 85.6% of vessels passages did not utilize AIS, and 85.6% of vessels were classified as recreational. The study emphasizes the need for more extensive research on non-AIS vessel activity in the Fraser Estuary to account for and mitigate the impact of small vessels. The study explores the potential of implementing speed reductions and increasing minimum distances to whales as preventive measures to mitigate the adverse impacts of vessels on the species.

Introduction

The water of British Columbia is inhabited by several types of killer whales (*Orcinus orca*): Bigg's, Off-Shore and Residents. Resident Killer Whales (RKWs) are piscivorous and fond of large, high-lipid Chinook salmon (DFO, 2019; Ford & Ellis, 2006).

Southern Resident Killer Whales (SRKWs) are the smallest population of whale communities in Canadian Pacific waters. According to the Center for Whale Research, the population of Southern Resident Killer Whales (SRKWs) grew from the 1970s to the mid-1990s, peaking at 98 individuals before declining to approximately 70 whales in the following decades. Consequently, SRKWs have been listed as endangered under the Canadian Species at Risk Act (SARA)[1] since 2003 (Government of Canada, 2021) and the U.S. Endangered Species Act since 2005 (Federal Register, 2005).

SARA provides the federal government with a legal obligation to manage the conservation and recovery of species and their critical habitats listed under the Act. The critical habitat of endangered or threatened aquatic species, such as SRKWs, must be identified by the Ministry of Fisheries and Oceans and legally protected by regulations or orders (Hewson et al., 2023). The critical habitat of an aquatic species is defined as the area on which the species depends directly or indirectly, such as spawning grounds and nurseries, rearing, food supply, and migration. Habitat degradation can occur through multiple means, including chemical and acoustic pollution. Acoustic degradation is considered a primary constituent of the critical habitat of SRKWs in Canada (Government of Canada, 2011).

Despite 20 years of protection under the Species at Risk Act, the population has decreased to 73 individuals, according to the most recent census (Center for Whale Research, 2022). This decline raises significant concerns regarding the future of the SRKW population, as well as the current management measures in place.

The objective of this report is to examine the effect of boat disturbances on the SRKW population in the Fraser Estuary. The Fraser Estuary is a vital habitat for SRKWs, but limited information is available about the behaviour and presence of small recreational boats in the area. This report

[1] Species at Risk Act (S.C. 2002, c. 29) https://www.laws-lois.justice.gc.ca/eng/acts/S-15.3/page-3.html#h-434768

aims to provide a preliminary analysis of non-AIS vessel traffic and distribution in parts of the estuary.

This report is structured as follows: The initial section provides background information on SRKWs and the diverse threats they face, including the influence of human activity on underwater noise levels and the significance of acoustic information for killer whales. The second section delves into the importance of the Fraser Estuary as a habitat for SRKWs. It reviews previous research on small vessel activity in the Salish Sea and other areas. The third section describes our method for observing vessel traffic and distribution and presents findings. The fourth section discusses current management measures. Ultimately, the report concludes by discussing the study's limitations, highlighting the need for further research and discussing measures to mitigate the impact of vessel disturbance on SRKWs.

1. Background

The Primary Threats to Southern Resident Killer Whale Survival

SRKWs face several significant challenges that hinder their recovery, and their decline is partly due to anthropogenic threats that act synergistically with intrinsic population factors. These primary challenges include extrinsic threats, such as diminished availability of preferred prey, accumulation of high levels of stored contaminants, habitat degradation, and disturbances caused by vessels in their habitat (COSEWIC, 2008; Lacy et al., 2017; DFO, 2018a; Government of Canada, 2021). Their challenges include intrinsic factors such as inbreeding depression, which influences population dynamics owing to their small population size (Kardos et al., 2023).

Prey Availability

The main anthropogenic reason for the decline in SRKW is thought to be related to a reduction in prey abundance (Ayres et al., 2012; Lacy et al., 2017; Stewart et al., 2021). SRKWs' preference for Chinook salmon could have stemmed from the historically high abundance and per-fish energy value (Ford & Ellis, 2006). However, Chinook salmon are declining in quantity and size (Atlas et al., 2023; Government of Canada, 2023; Oke et al., 2020; Xu et al., 2020). As of 2020, Canada's Species at Risk Public Registry has 20 Designatable Units [DUs] of Chinook Salmon listed as either Threatened or Endangered (Government of Canada, 2023).

Species with bodies and muscle mass that allow them to hunt fast-moving prey may require higher energy intake to sustain their lifestyles (Spitz et al., 2012). Spitz et al. (2012) refer to this as a species' cost of living and found that it can be an essential factor in a species' foraging strategies. Thus, the energy expenditure related to a species' daily activities may dictate the quality (high-calorie catch) of the prey they need to catch to sustain themselves (Spitz et al., 2010; Spitz et al., 2012). As a result, SRKWs may need to catch fish with high lipid content to make the hunt worthwhile, which may explain their strong preference for high-quality Chinook salmon, even during times of low abundance. The allure of the high-energy dense Chinook salmon they have learned to hunt, and the high-energy expenditure related to hunting prey may prevent them from preying on species with lower energy intake per catch.

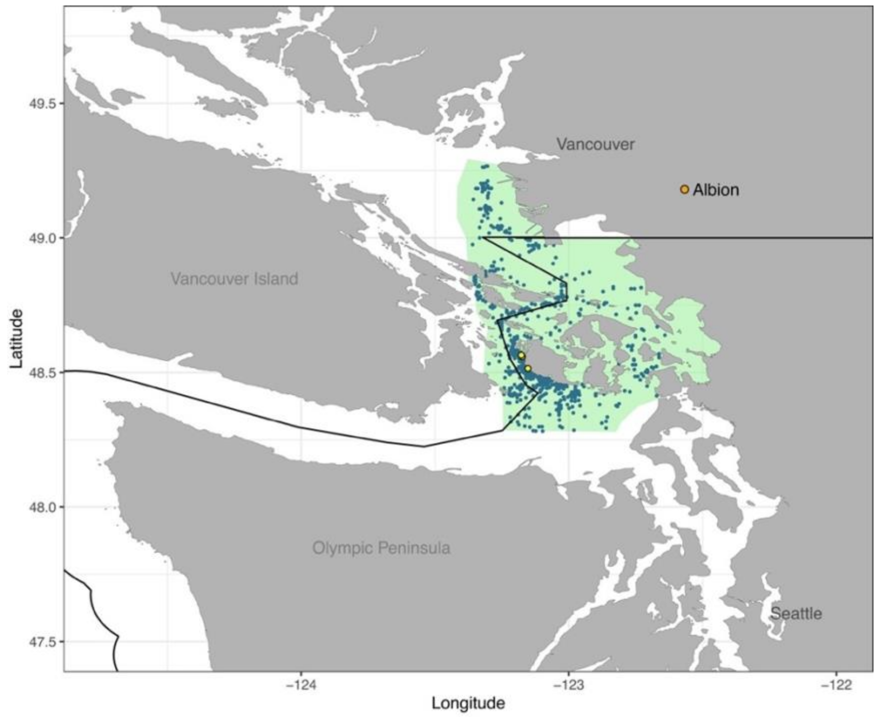
Even within the same prey species, not all catches are equal. For instance, Resident Killer Whales have been observed to prefer to feast on larger, more mature Chinook salmon (Ohlberger et al., 2019). Couture et al. (2022) found that the abundance of older Chinook salmon (aged 4 and 5 years) is an important predictor of SRKW energy intake. Both RKW populations were found to eat different proportions of Chinook salmon stocks, with NRKWs eating a more significant ratio of 5- and 6-year-old salmon, which may be due to their northern range and spawning routes (Hanson et al., 2021).

The decline in the size and abundance of Chinook salmon has important implications because it means that RKWs must catch more prey to meet their daily calorie needs. As explained by Spitz et al. (2012), changes in prey abundance and quality may be more significant for species with a high cost of living.

It has been observed that fluctuations in the physical condition of SRKWs may correlate with prey abundance (Stewart et al., 2021). A recent model found that SRKWs have been experiencing more energy deficits in recent years than in the past (Couture et al., 2022). This reduction in the abundance of Chinook salmon may affect population dynamics by reducing reproductive success due to nutritional stress (Wasser et al., 2017).

All SRKW pods were observed to spend less time in their traditional summer habitat, which correlated with the abundance of the Fraser River Chinook returns (Figure 1) (Stewart et al., 2023).

Figure 1. Traditional core summer habitat (green) for Southern Resident killer whales and sighting locations of SRKW 2014–2020 (blue points).



Note. From "Traditional summer habitat use by Southern Resident killer whales in the Salish Sea is linked to Fraser River Chinook salmon returns "by J. D. Stewart, J. Cogan, J. W. Durban, H. Fearnbach, D. K. Ellifrit, M. Malleson, M. Pinnow & K. C. Balcomb. 2023. *Marine Mammal Science*. https://doi.org/10.1111/mms.13012. (CC BY-NC 4.0)

Contamination

The levels of contaminants in SRKW habitats and bodies are also crucial for their recovery (NOAA, 2016; DFO, 2018b; Kim et al., 2022). Many persistent organic pollutants (POPs) bioaccumulate in the Salish Sea (DFO, 2018a). SRKWs' diet is a significant source of polychlorinated biphenyls (PCBs), and the dietary PCB content of SRKWs was found to be significantly higher than that of Northern Resident Killer Whales (NRKWs), whose habitat range is less urbanized (Cullon et al., 2009).

Killer whales are vulnerable to a wide variety of health problems due to exposure to these contaminants, including, but not limited to, immunotoxicity, endocrine disruption, liver and thyroid impairment, and cancer (DFO, 2018a).

Although many of these chemicals have been banned, they remain prevalent in killer whale environments (Desforges et al., 2018). Many have settled in sediments and are eventually remobilized by sediment-dwelling macrofauna and bioaccumulate in killer whales (Alava et al., 2012). In addition, many 'contaminants of emerging concern' (CECs) and new POPs, which have not yet been restricted, are still being introduced into their habitats (Lee et al., 2023).

The effect of PCBs on killer whale reproduction and health, particularly in species in industrialized habitats, has a long-term impact on population fitness and threatens population collapse (Desforges et al., 2018).

Anthropogenic Disturbance

Human activities in their habitats create disturbances that affect their fitness and ability to perform important functions. This disruption can occur through direct or indirect impact, such as the by-product of activities like noise pollution.

Background Information on Noise Disturbance

Acoustic Energy and Anthropogenic Activity

When an object vibrates, it produces a sound that travels through a medium as a wave (DOSITS, n.d.). The efficiency of acoustic energy propagation in water allows sound to travel more than four times faster in water than in air (DOSITS, n.d.). The way sound travels through water varies based on several variables such as depth and thermal stratification (Lurton, 2010). Sounds have physical characteristics that lead to differences in perception. The intensity[2] and frequency[3] of a sound impact our perception of its loudness and pitch.

In deep water, low-frequency sound has minimal absorption losses, allowing it to travel longer distances, whereas higher-frequency sound experiences a smaller propagation range owing to the increasing absorption losses with increasing distance and frequency (Au et al., 2000; Ladich & Winkler, 2017). Increasing the frequency of a sound generates a higher-pitched sound, whereas decreasing the frequency generates a lower-pitched sound (DOSITS, n.d.). The transmission of low-

[2] The amplitude of a wave relates to the amount of energy it carries, where a high-amplitude wave carries more energy and a low-amplitude wave carries less. The loudness of a sound is determined by its intensity, which is the amount of energy that the sound wave carries per unit area and time in the direction it's traveling. https://dosits.org/science/sound/characterize-sounds/intensity/

[3] Frequency is the number of cycles (a complete pattern repetition) per second. The unit used to measure frequency is called Hertz and is defined as the number of cycles per second. https://dosits.org/science/sound/characterize-sounds/frequency/

frequency sounds in shallow water is limited due to the inability of waves to propagate at depths below their wavelengths, causing the depth to function as a high-pass filter (Forrest et al., 1993; Ladich & Winkler, 2017). Therefore, noise pollution in shallow coastal waters may be primarily caused by local traffic and activities.

While soundscapes[4] in the environment are dynamic and constantly changing temporally and spatially, anthropogenic activities have impacted ocean noise levels (Burnham & Vagle, 2023). The use of marine environments by vessels of all sizes significantly increased maritime traffic. Both intentional (via sonar) and unintentional (via ship movement) noise emissions contribute to the underwater noise created by ships (Southall et al., 2017). Hydrodynamic flow noise, onboard machinery, and propeller cavitation contribute to the noise produced by ships, making these noises an unintentional by-product of vessel operation (Southall et al., 2017). Most noise produced by maritime vessels is caused by propeller cavitation5 and onboard machinery (Nolet, 2017).

The amount of noise that ships add to the surrounding environment depends on both intrinsic factors related to the ships themselves and extrinsic factors associated with the environmental conditions in which they operate, such as water depth, environmental conditions, salinity, and temperature (DOSITS, n.d; Parsons et al., 2021). As reviewed in a meta-analysis conducted by Parsons et al. (2021), the noise level of a vessel is positively correlated with factors such as the length, beam (width), engine power, and propeller blade design.

Different types of vessels differ in the amplitude and frequency of the sounds they emit. As shown in Figure 2, different vessel types are associated with varying source levels[6].

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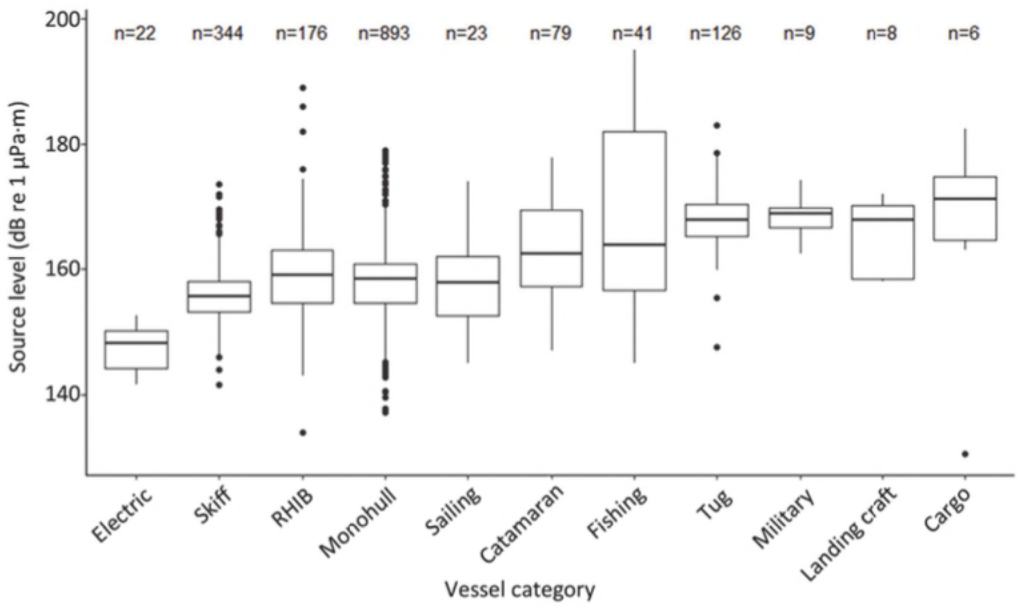
[4] The acoustic environment of an area which is created by the combination of all the sounds that can be heard in that area. https://earth.fm/glossary/what-is-soundscape-definition-and-examples/

[5] The creation of partial vacuums in a liquid by a swiftly moving solid object, such as a propeller, or by intense sound waves. https://www.merriam-webster.com/dictionary/cavitation

[6] Represents the amount of sound emitted by the sound source. The source level is given as a relative intensity in units of decibels (dB). Relative units depends on the medium. For Underwater noise, decibels refer to a pressure of 1 microPascal (Pa) and source level is reported units of dB re 1 Pa at 1 m. https://dosits.org/glossary/source-level/

Figure 2. Mean, inter-quartile, 5th/95th percentiles, and outliers (thick black line, upper/lower bounds of boxes, upper and lower extents of vertical lines, and dots, respectively).



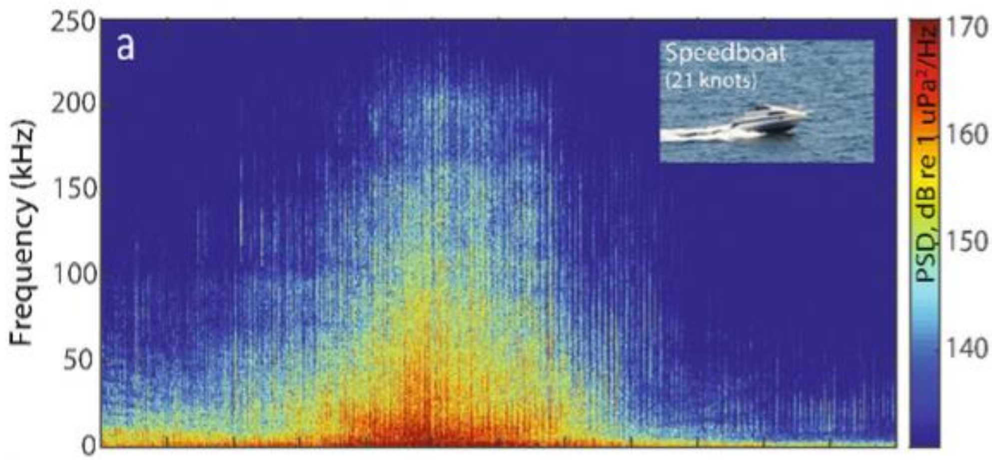
Note. From "A Review and Meta-Analysis of Underwater Noise Radiated by Small (<25 m Length) Vessels" by M. J. G. Parsons, C. Erbe, M. G. Meekan, & S. K. Parsons. 2021. Journal of Marine Science and Engineering, 9(8), 827. https://doi.org/10.3390/jmse9080827. (CC BY)

Consequently, ambient noise in the ocean has significantly increased due to the growth of international trade, which has resulted in a significant increase in marine commercial shipping activity (Frisk, 2012). The number of vessels in an area and the speed at which these vessels move are positively correlated with underwater noise levels (Holt et al., 2009; Holt et al., 2017). Over the past few decades, the growth in the abundance of commercial vessels has resulted in an estimated 12 dB increase in ambient noise in marine environments (Hildebrand, 2009).

Commercial shipping vessels significantly contribute to low-frequency noise (Hildebrand, 2009). Due to the ocean's ability to carry and amplify low-frequency sounds, the noise produced by large ships adds to the background noise level over a wide area (Hildebrand, 2005).

Smaller, often non-commercial vessels also contribute to lower and mid-to-high frequencies (Parsons et al., 2021; Veirs et al., 2016). The speed of vessels is the most important predictor of perceived noise levels, and the number of propellers is a critical variable (McKenna et al., 2013; Houghton et al., 2015). Propellers generate noise via cavitation. When propeller blades drive through a ship's wake[7], it can cause cavitation to intensify, resulting in periodic higher intensity of high-frequency noise (Pollara et al., 2017). Increasing the vessel speed increases the frequency of the noise produced, and as a result, mid-to high-frequency noise can dominate the soundscape (Hermannsen et al., 2014; Li et al., 2015). Veirs et al. (2016) found a linear relationship with a slope of approximately +1 dB/knot between the noise source level and speed of the vessel for most ship classes. Typically, the closer and faster the vessel is to the receiver, the louder the noise is.

Figure 3. A spectrogram showing the power spectral densities (PSD) of a non-AIS speed boat passing at a mean speed of 21 knots.



Note. From "Recreational vessels without Automatic Identification System (AIS) dominate anthropogenic noise contributions to a shallow water soundscape" by L. Hermannsen, L. Mikkelsen, J. Tougaard, K. Beedholm, M. Johnson & P.T. Madsen. 2019. Sci Rep, 9(1), 15477. https://doi.org/10.1038/s41598-019-51222-9. (CC BY 4.0)

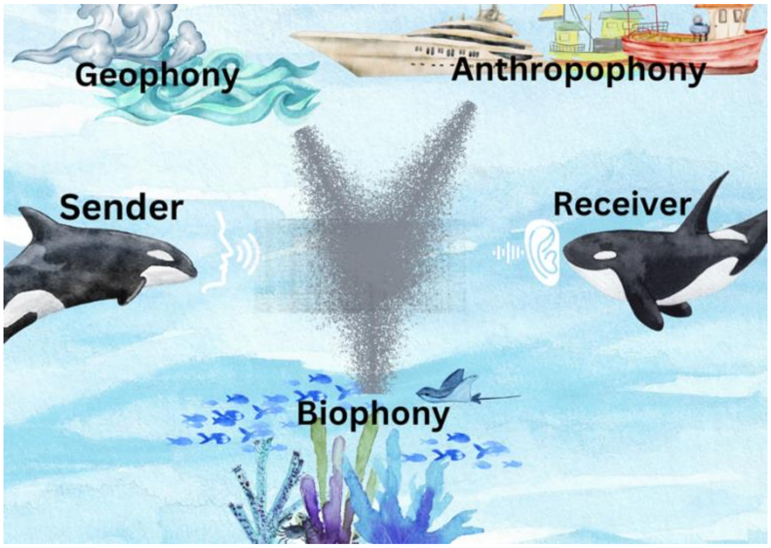
Importance of Acoustic Sense for Killer Whales

The ability to hear a sound depends on several factors, including its source level, the propagation efficiency of the medium through which it is transmitted, the level of background noise, and the listener's sensitivity to that frequency (Richardson et al., 1995). The ambient noise levels that represent a soundscape result from various abiotic, biotic, and anthropogenic activities

[7] The wake of a boat is the V-shaped pattern of disturbed water that can be seen behind it as it moves through the water. The size and weight of the boat, its speed, and the shape of the hull all contribute to the creation of the wake. https://www.boatingworld.com/question-answer/what-is-the-wake-of-a-boat/

(Burnham & Vagle, 2023). In soundscape ecology, these sound categories are called geophony[8], biophony[9], and anthropophony[10] (Bernie Krause, 2015; Pijanowski et al., 2011).

Figure 4. Conceptual illustration of the different sound categories that can add to the background noise, potentially reducing the ability to hear a target sound.



As a result of the efficiency of acoustic energy propagation underwater, sound has a much greater range than visual cues (e.g., light), making it the preferred mode of communication for many species (Au et al., 2000; Tyack & Clark, 2000; Ladich & Winkler, 2017). Sound allows marine species to gather information from all around them in their environment over large distances (DOSITS, n.d.). Consequently, sound plays a pivotal role in underwater communication, and cetaceans rely heavily on their hearing to navigate their environment (Au et al., 2000).

Baleen whales (mysticetes) and toothed whales (odontocetes) have different hearing abilities and acoustic biology characteristics. Mysticetes emit various sounds that fall predominantly within the low-frequency spectrum (Park et al., 2017). In contrast, odontocetes primarily generate sounds in the higher-frequency range (Park et al., 2017). Odontocetes can hear very high frequencies, with some species being able to listen to frequencies of up to 180 kHz (Mooney et al., 2012). The hearing range of killer whales is estimated to be between 500 Hz and 114 kHz, with the best

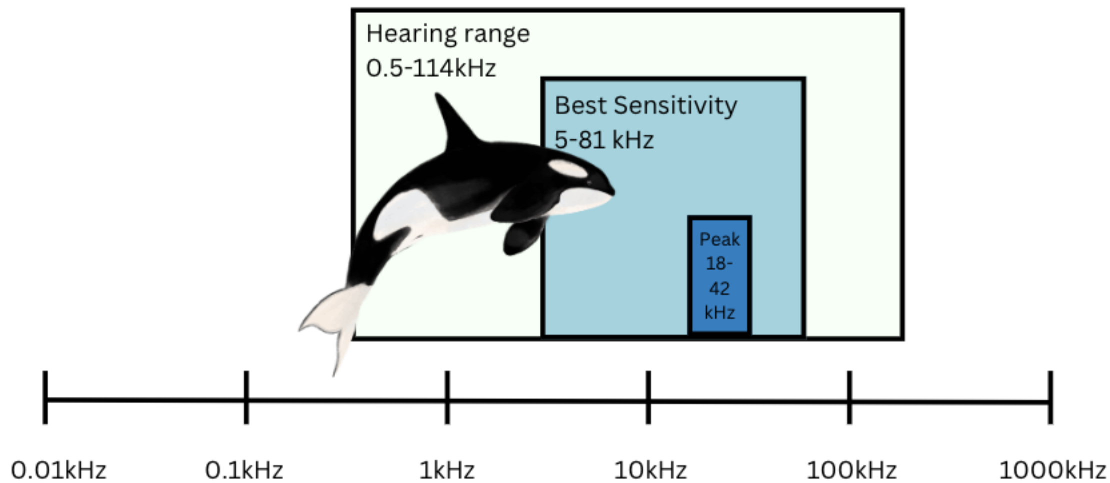
[8] The non-biological ambient sounds generated by the natural world (e.g., waves). https://earth.fm/earth-stories/soundscape-acoustic-ecology/

[9] The ambient sounds made by living organisms (except humans) in an environment (e.g., communication).

[10] All noise generated by human acitvities (e.g., boats)

sensitivity between 5 and 81 kHz and a peak sensitivity between 18 and 42 kHz (Bain et al., 1993; Branstetter et al., 2017; Szymanski et al., 1999)

Figure 5. The hearing range of killer whales.

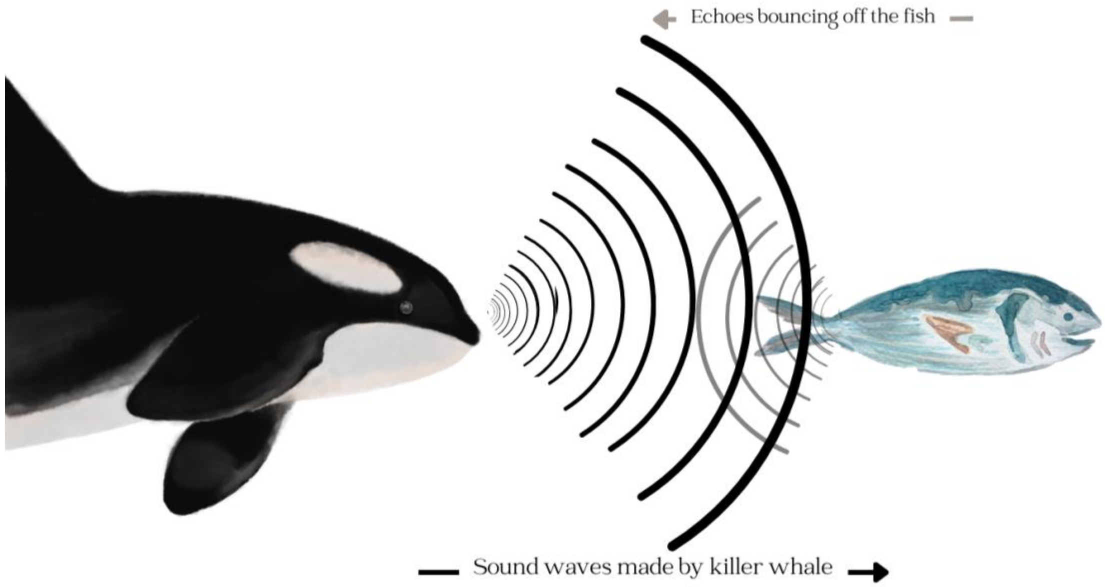


Note. Based on data from Bain et al. (1993), Branstetter et al. (2017) and Szymanski et al. (1999).

Killer whales use high-frequency modulated signals for echolocation and communication that vary in frequency and sound categories based on their purpose (Au et al., 2004; Simonis et al., 2012). Using echolocation clicks, whistles, and pulsed calls enables them to engage in essential behaviours such as locating prey, identifying and communicating with conspecifics, detecting predators, and navigating their environment (Ford, 1989; Barrett-Lennard et al., 1996; Au et al., 2004; Mooney et al., 2012). Echolocation is a type of sonar11 that is crucial for modern toothed whales such as orcas (Wood & Evans, 1980). To discern nearby objects or species and their relative sizes and locations, they emit click pulses and other short-duration broadband pulses and listen to reflected signals (echoes) (Ford, 1989; Au et al., 2004). Consequently, they can create a mental representation of their surroundings, allowing them to hunt and navigate in low-visibility environments (Au et al., 2000).

[11] A technique for acoustically detecting and determining the distance and direction of objects underwater. https://www.britannica.com/technology/sonar

Figure 6. Illustration of the use of echolocation in hunting.



The Direct Impact of Anthropogenic Noise Disturbance on Killer Whales

To assess the impact of underwater anthropophony on marine life, a calibrated recording system that can detect a broad range of frequencies can be used to monitor ambient noise (Nolet, 2017). When a noise falls within the critical frequency band of a signal emitted by an individual, it can mask the signal by reducing the range in which it can be heard (Hildebrand, 2005). In addition to masking signals of a frequency similar to noise, very loud low-frequency noise can mask higher-frequency signals (Bain et al., 1993).

Research has shown that ship noise interferes with killer whales' use of sound signals because it falls within the sound frequencies used for communication and echolocation (Hall & Johnson, 1972; Veirs et al., 2016).

Vocal organisms that operate effectively in noisy environments have acoustic niches in which their sounds are not masked by other signals (Bernie Krause, 2015). Consequently, they may change their behaviour in response to vessel proximity and speed, and their noise can lead to avoidance behaviour (Holt et al., 2021; Williams et al., 2021). SRKWs have been found to compensate for environmental noise by modifying their calls (Foote et al., 2004; Holt et al., 2009). They have been observed to increase their call amplitude by 1 dB for every 1 dB increase in noise levels in their environment (Holt et al., 2009), as well as their call duration (Foote et al., 2004).

Across all odontocete species, anthropogenic disturbances can lead to both a reduction in energy acquisition and an increase in energy expenditure (Noren et al., 2016). Current models estimate that SRKWs spend around 70-84% of their time foraging when boats are absent (Lusseau et al., 2009; Williams et al., 2021). Research also estimates that killer whales lose approximately 20% (5 h) of their daily foraging time because of noise from commercial and whale-watching boats (Tollit et al., 2017). This is partly because whales are less likely to start or continue foraging as received noise levels increase (Williams et al., 2021). Furthermore, SRKW's likelihood of catching prey while foraging decreases as ship speed increases because it masks their echolocation signals (Holt et al., 2021). Even quiet watercrafts, such as kayaks, reduce the hunting time of orcas due to disturbance (Williams et al., 2006; Lusseau et al., 2009). The vessel acoustic disturbance and avoidance behaviour exhibited by SRKWs can significantly reduce their ability to successfully forage each day, leading to a lower energy intake (Williams et al., 2006; Noren et al., 2016; Tollit et al., 2017).

This increase in noise disturbance can make it challenging to make sense of their environment and communicate with conspecifics. Research on dolphins has demonstrated that small, closed populations are more vulnerable to vessel disturbance than open populations (New et al., 2020). Due to the various behavioural responses caused by underwater noise, the reproduction of killer whales could be affected, potentially further impacting the population's chances of recovery (Nabi et al., 2018).

A recent noise pollution model found evidence that vessel noise pollution from international shipping significantly reduced fertility and increased SRKW mortality (Taylor & Mayer, 2023). They calculated that the population could have increased by 30% if anthropogenic noise levels in their habitat did not rise to the current levels but stayed at those experienced before 1998 (Taylor & Mayer, 2023). This highlights the critical importance of managing disturbances caused by vessels for SRKW recovery.

The Indirect Impact of Anthropogenic Noise Disturbance on Killer Whales

As a result of the acoustic disturbance caused by vessels, prey species may also alter their behaviour, which in turn may indirectly affect cetacean populations (Weilgart, 2007). If noise disrupts the behaviour or distribution of their preferred prey species, it can make it more difficult for cetaceans to forage successfully.

Popper & Hawkins (p.692, 2019) explain that "*Fishes use a variety of sensory systems to learn about their environments and to communicate. Of the various senses, hearing plays a vital role for fishes in providing information, often from great distances, from all around these animals. This information is in all three spatial dimensions, often overcoming the limitations of other senses, such as vision, touch, taste and smell. Sound is used for communication between fishes, mating behaviour, detecting prey and predators, orientation and migration and habitat selection. Thus, anything that interferes with the ability of a fish to detect and respond to biologically relevant sounds can decrease survival and fitness of individuals and populations".*

Therefore, anthropogenic noise can significantly affect several fish species (Cox et al., 2016). For example, studies have shown that increased noise levels can lead to acute stress responses in fish exposed to intermittent noise (Nichols et al., 2015). For instance, some fish avoid vessels and engage in less exploratory behaviour because they interpret their noise and movements as threats (Ivanova et al., 2020). This change in movement can lead to home-range displacement (Ivanova et al., 2020). When vessels transit an area, wild Pacific salmon and herring have been found to respond to underwater noise by adopting stereotypical anti-predator behaviours (van der Knaap et al., 2022). Vessels can cause recurrent activation of anti-predator responses, potentially leading to an increase in energy expenditure or a decrease in foraging (van der Knaap et al., 2022). Fish are also more vulnerable to predation when exposed to vessel-generated noise than under ambient conditions (Simpson et al., 2015; Simpson et al., 2016; Velasquez Jimenez et al., 2020). Acoustic disturbances may also affect the reproductive success of various fish species, potentially hindering spawning (de Jong et al., 2018; Blom et al., 2019).

In addition, recreational boating can result in changes in community composition and adverse effects on species richness (Eriksson et al., 2004) and the loss of vital habitats for juvenile fish by reducing the amount of aquatic vegetation (Hansen et al., 2019). Therefore, when measuring the impact of acoustic disturbances on SRKWs, it is vital to consider the effect of noise on the entire ecosystem and its potential indirect impacts.

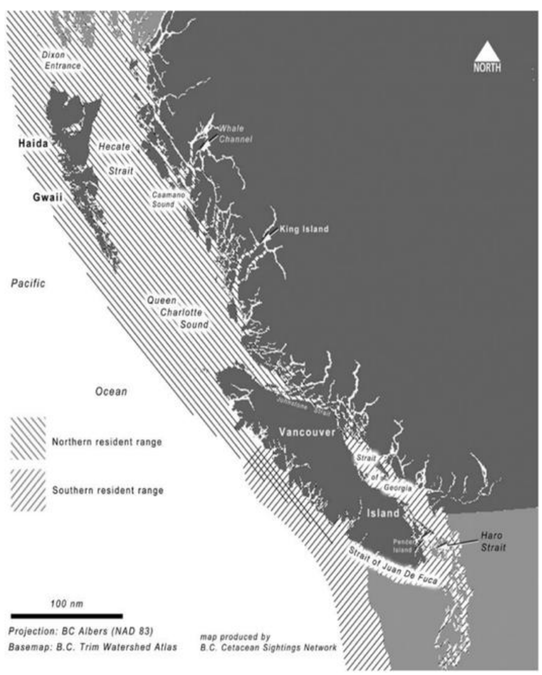
These Threats Have Cumulative Impacts

The interaction between these threats can have adverse cumulative effects (DFO, 2018). Therefore, when paired with diminished stocks of preferred prey, an increase in acoustic disturbance can make successful foraging even more challenging.

As Marla Holt, a researcher with the National Oceanic and Atmospheric Administration (NOAA), explained: *"It would be like going grocery shopping, and I am going to turn out the lights, and you only have 20 minutes and I am going to take half the food away — good luck with that"* (Mapes, 2019).

Food scarcity and nutritional deficit periods can considerably impact a population's outlook. In their population viability analysis, Lacy et al. (2017) found that no growth was projected under the conditions in 2017. If the threat to the population increases, the population is expected to decline further. Their prediction showed that, for the population to grow by 2.3%, underwater noise disturbance would need to be reduced by half, and the abundance of Chinook salmon would have to increase by 15%.

Figure 7. The coast of British Columbia and northwest Washington State showing the general ranges of Northern and Southern Resident Killer Whales



Note. From "Review of the Effectiveness of Recovery Measures for Southern Resident Killer Whales." By DFO. 2018.

Both the Southern and Northern Resident killer whales, sympatric to the waters of Coastal British Columbia, have a dietary preference for Chinook salmon (Ford et al., 1998). Although the SRKW population has been declining (Center for Whale Research, 2022), the NRKW population has steadily increased (DFO, 2018a). Both species have demonstrated an annual population growth of 3% at one point or another since they began being monitored (DFO, 2018a).

In assessing the spatial variability of large fish that may serve as prey for both resident cetacean communities, Sato et al. (2021) found a higher prey density in the SRKW habitat. These findings suggest that factors other than the differences in prey abundance play a role in the differences between the two resident populations. Although SRKWs have a higher prey density in their summer habitat than NRKWs do, both whale communities may face different challenges in meeting their energy intake requirements. Other habitat factors could also hinder the ability of whales to hunt successfully. Differences in the lipid content of Chinook salmon stocks accessible to each resident community may lead to varying net energy acquisition, as some catches yield less energy intake despite requiring similar energy expenditures (O'Neill et al., 2014; Lerner & Hunt, 2023).

As Taylor (2021) suggested, the extent of deterioration induced by vessel disturbance, paired with the loss in the abundance of prey species and their energy content, may have damaged the carrying capacity of RKWs' habitats. SRKWs encounter more significant vessel-related anthropogenic disturbances in their habitats than NRKWs do (Sato et al., 2021; Lee, 2021). This disparity in vessel disturbance has been proposed to cause asymmetric shocks in these populations, disproportionately affecting the SRKW habitat. At the same time, this disadvantage is exacerbated by competition for prey species (Taylor, 2022).

2. Mitigating Anthropophony Caused Habitat Degradation

To mitigate the adverse effects of vessel noise disturbances on aquatic species, researchers and managers must first identify locations where these species are most vulnerable. This depends on the importance of the area to the species and the amount of vessel disturbance in the area (Thornton et al., 2022b). Recent research documents by Fisheries and Oceans Canada (DFO) have identified the coastal waters near the Fraser River as an essential area for SRKWs (DFO, 2021; Thornton et al., 2022a). This includes a co-occurrence sighting data analysis that determined that the locations with the highest frequency of occurrence of SRKW from May to October were Swiftsure Bank, Haro Strait, and Fraser River Estuary (Thornton et al., 2022a).

Critical Habitat and Critical Foraging Areas

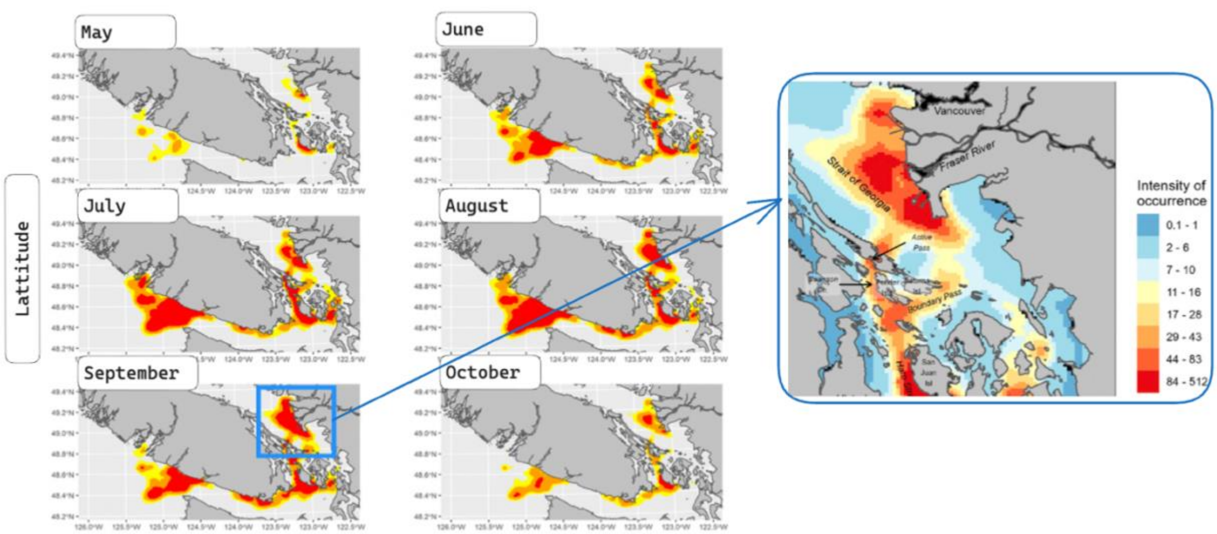
The Fraser Basin, spanning 25% of British Columbia and home to 60% of the province's population, is drained by the 1375-kilometre-long Fraser River, which empties into the Salish Sea (Fraser River Discovery Centre, n.d.). The region where freshwater from rivers meets saltwater from the ocean is known as an estuary. Due to the significant freshwater discharge from the Fraser River, the entire southern Strait of Georgia is technically part of the estuary (Flynn et al., 2006). A salinity gradient results from the mixing of water, with the highest salinity found near the ocean and the lowest salinity found further inland (Ralston et al., 2010; MacCready et al., 2021). The discharge of riverine waters into the sea results in the formation of a complex and productive ecosystem that encompasses various habitats such as floodplains, tidal flats (eelgrass and marsh), and estuaries (marine and freshwater) (Adams & Williams, 2004; Butler et al., 2021). The estuary comprises three subsites: Boundary Bay, Sturgeon Bank, and Roberts Bank (IBA Canada, n.d.; Government of British Columbia, n.d.). Habitats in and around the Fraser Estuary support 100 species that are believed to face local extinction risks (Kehoe et al., 2021).

The Fraser River is the largest river draining into the Salish Sea and is of great importance to SRKWs because of the large abundance of salmon, specifically Chinook, it historically provided (Dodge, 1989; Ford et al., 1998; Hall & Schreier, 1996; Northcote & Atagi, 1997). Salmon migrate through estuaries as they move from freshwater to marine waters, making them a vital transition zone that allows them to adapt to salinity changes. Within three months of hatching, ocean-type Chinook salmon use the estuary for weeks before transitioning to the marine environment from February through May and returning to freshwater between August and October to spawn (De Groot, 1993; Chalifour et al., 2021). This is a critical part of the salmon life cycle and is essential for the survival of this species. The number of salmon that complete this process can significantly affect overall population dynamics (Lundqvist et al., 2008). As a result, the Fraser Estuary is of significant importance to Chinook salmon, which depends heavily on this habitat (Chalifour et al., 2021).

Chinook salmon from the Fraser River plays a crucial role in the movement, habitat use, health, and demographic trends of the SRKW population. The likelihood of SRKW pods visiting their traditional core summer habitat is directly associated with the average annual return of Fraser River Chinook salmon (Hanson et al., 2010; Thornton et al., 2022a; Stewart et al., 2023). SRKWs rely heavily on Chinook salmon migrating to the Fraser River system as their primary food source from May to September when they are present in the Salish Sea (Hanson et al., 2010; Ford et al., 2016). Chinook salmon stocks in the Fraser River's upper, middle, and lower sections are significant for SRKW throughout the summer (Hanson et al., 2010). Accessing Chinook salmon during summer foraging appears essential to prepare killer whales for winter and spring when the quality and density of prey might be lower (Stewart et al., 2023).

Consequently, the occurrence of SRKWs has been found to increase from May to September in the Fraser Estuary due to prey hunting and Chinook Salmon migratory patterns (Figure 8) (Thornton et al., 2022a).

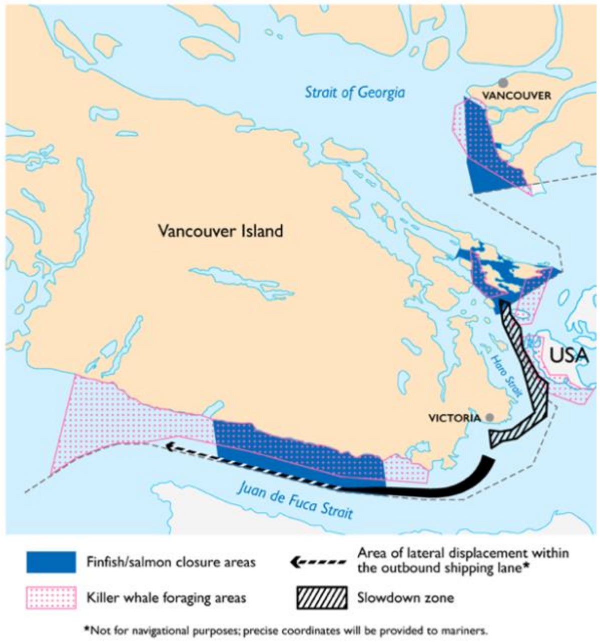
Figure 8. Predicted monthly habitat preference of SRKW in their critical habitat using data from summer months (May to October) for estimating preference thresholds.



Note. Adapted from "Southern Resident Killer Whale (Orcinus orca) summer distribution and habitat use in the Southern Salish Sea and the Swiftsure Bank area (2009 to 2020" by S. Thornton, S. Toews, E. Stredulinsky, K. Gavrilchuk, C. Konrad Clarke, R. Burnham, D. Noren, M. Holt & S. vhhVagle. 2022. DFO Can. Sci. Advis. Sec. Res., Doc. 2022/037., v + 56 p.

Therefore, sighting analysis shows that areas near the Fraser River have a high occurrence of SRKWs and are important foraging areas for the SRKW population in the summer months. Recognizing the importance of this area for killer whales for salmon foraging, DFO has established the Fraser Estuary as an essential area for foraging (Figure 9).

Figure 9. The Government of Canada's maps show key foraging areas in the Fraser Estuary.



Note. From "Whales Initiative: Protecting the Southern Resident Killer Whale" *by* Transport Canada. 2022. https://tc.canada.ca/en/initiatives/oceans-protection-plan/whales-initiative-protecting-southern-resident-killer-whale

Recreational Boasting in Coastal Areas

The increasing popularity of recreational boating in coastal areas has contributed to the growing problem of underwater noise pollution because recreational boating areas often overlap with critical habitats for marine species (Burgin & Hardiman, 2011; Iburg et al., 2021; Hansen et al., 2019). Although the overall cumulative impact of smaller recreational vessels on the environment can be significant, it is often overlooked (Byrnes & Dunn, 2020; Pine et al., 2021; Wilson et al., 2022a). In contrast to larger recreational vessels, which are more commonly found in open oceanic water bodies with more significant dilutive potential, smaller recreational vessels typically navigate in smaller, less water-exchanged inland shallower waters (Byrnes & Dunn, 2020; Hansen et al., 2019). For example, small recreational vessels are found to more easily cause damage to sensitive estuarine banks than more regulated commercial vessels in Tasmania (Department of Primary Industries, Water and Environment. Tasmania, n.d.). The wake generated by vessels can cause damage to estuarine coastal landscapes upon hitting banks, resulting in rapid and severe erosion (Department of Primary Industries, Water and Environment. Tasmania, n.d.). The influence of the

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wake can also stir up sediments, which can have negative effects on the water environment for plants and animals.

Much of the research on anthropophony has utilized Automatic identification systems (AIS) data due to the availability and mandatory transmission of the data (Joy et al., 2019; McKenna et al., 2012; McKenna et al., 2013; Tollit et al., 2017). As defined by the International Maritime Organization, "AIS transponders are designed to be capable of providing position, identification, and other information about the ship to other ships and coastal authorities automatically" (IMO., n.d.). AIS can be divided into two types: AIS-A and AIS-B. The International Maritime Organization's (IMO) SOLAS regulation V/19 mandates fitting AIS-A on all passenger ships, cargo ships of 500 gross tonnage and above that are not engaged in international voyages, and ships of 300 gross tonnage and above on international voyages (IMO, n.d.). AIS-B is primarily used for pleasure crafts and other non-SOLAS vessels and has limited functionality (NATO Shipping Centre, 2021). Consequently, smaller vessels are often not represented by AIS data because they are not required to carry these systems. Accordingly, AIS data are poor predictors of true vessel-related anthropophony and its impact (Hermannsen et al., 2019).

In shallow coastal waters, small recreational boats without AIS transmitters are often the most common vessels and important sources of underwater noise (Barlett & Wilson, 2002; Hermannsen et al., 2019; O'Hara et al., 2023; Parsons et al., 2021; Serra-Sogas et al., 2018; Wilson et al., 2022b). As a result of their abundance, speed, and proximity to the coast, the noise caused by these vessels can dominate the coastal soundscape (Hermannsen et al., 2019). The number of recreational vessels that circulate in an area every hour has been found to significantly influence environmental noise levels (Haviland-Howell et al., 2007). During busy summer months, when boat traffic is high due to increased recreational boating, anthropogenic noise becomes continuous rather than episodic, making it a pervasive stressor (Haviland-Howell et al., 2007).

At the beginning of summer, when SRKWs arrive in the Salish Sea, Fraser River Chinook salmon and the number of vessels in the area are of lower abundance, but both increase until they peak at the end of the summer (Ayres et al., 2012). This increase in small vessel activity during critical foraging time can significantly affect the population's fitness. The increased levels of noise associated with this increase in vessel abundance and speed reduce the habitat quality of the Fraser Estuary, which has been identified as an area of increased risk for ship-related physical and acoustic impacts (Thornton et al., 2022b).

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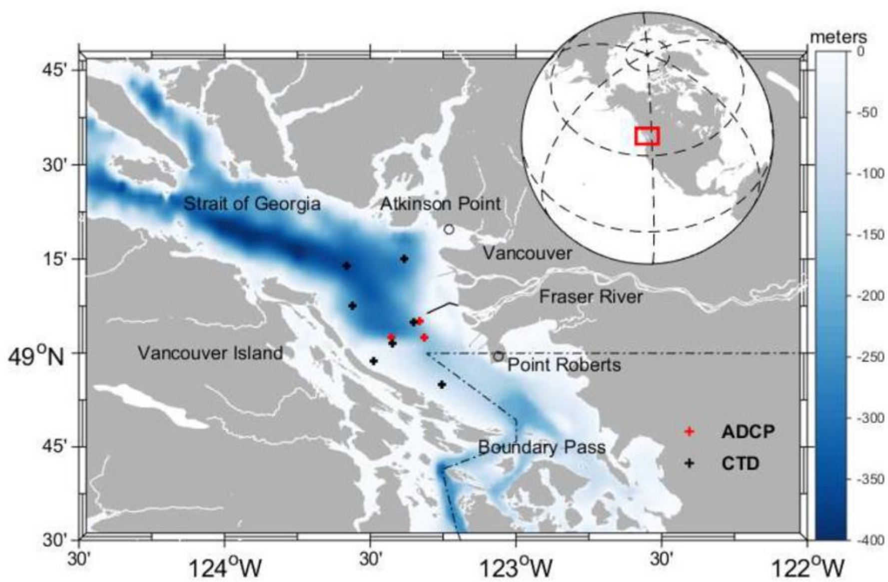
Understanding and modelling an area's cumulative sound exposure levels requires knowledge of vessel abundance and the generated noise associated with vessel characteristics and navigation (e.g., distance and speed) (Lo et al., 2022; Parsons et al., 2021). However, small non-AIS vessels are often excluded from vessel activity- and noise-level studies. This is partly because most pleasure crafts and other small vessels are not required to use AIS and are not limited to shipping lanes, making it much more challenging to monitor their movements. Moreover, unlike commercial ships, there is limited understanding of the noise characteristics of recreational boats (Svedendahl et al., 2021). Furthermore, sound exposure measurements and models in shallow coastal waters represent additional challenges because of the propagation loss caused by shallow depths, requiring information on sound speed profile, bottom composition, and relative source-receiver position (Picciulin et al., 2022).

Figure 10. Bottom topography map of the Strait of Georgia.



Note. From "Studies of Internal Waves in the Strait of Georgia Based on Remote Sensing Images" by C. Wang, X. Wang & J. C. B. Da Silva. 2019. Remote Sensing, 11(1), 96. https://doi.org/10.3390/rs11010096. (CC BY)

Therefore, to ensure that vessel disturbances are managed and mitigated, it is important to understand the vessel abundance and activity, the types of noise (broadband and narrowband) generated by these vessels and how they propagate in shallow coastal environments (Matzner et al., 2010).

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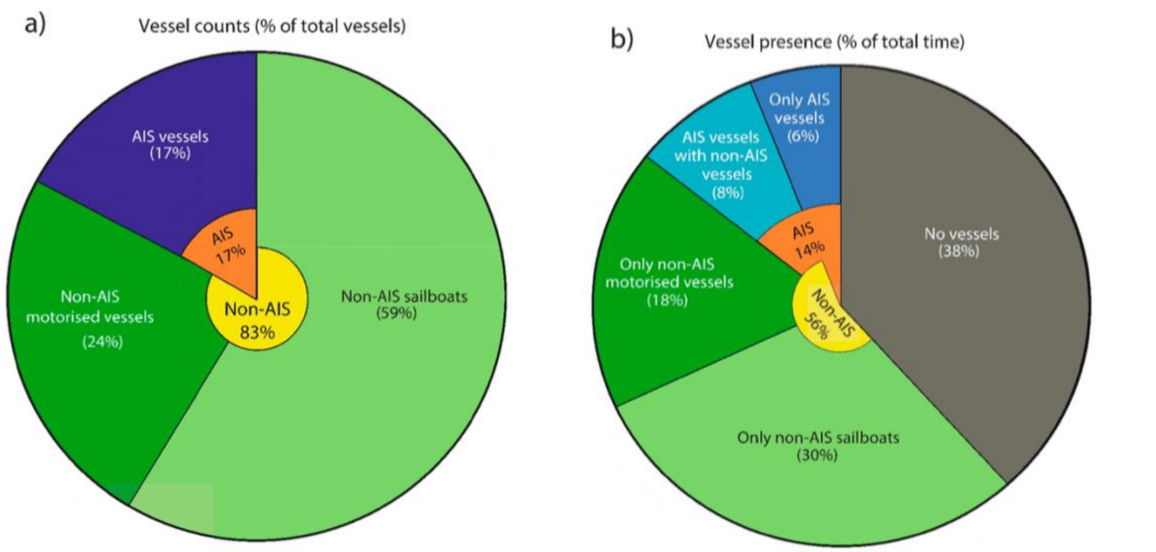
Research on the behaviour of small vessels without AIS has been conducted in several ways. For example, Hermannsen et al. (2019) used theodolite and AIS data. Lo et al. (2022) used theodolite data and photogrammetry to estimate the number of boats, their distance from whales, and their speed. Another study used GoPro cameras to calculate the positions of vessels using an image-processing system (Magnier and Gervaise, 2020). O'Hara et al. (2023) compared land-based and aerial imagery captures with AIS data (O'Hara et al., 2023).

Hermannsen et al. (2019) showed that non-AIS vessels in coastal areas accounted for most vessel transits (83%) in their case study in the Inner Danish waters.

Figure 11. Percentage of vessel types observed (out of 198 total passes) and the percentage of time for vessel presence.

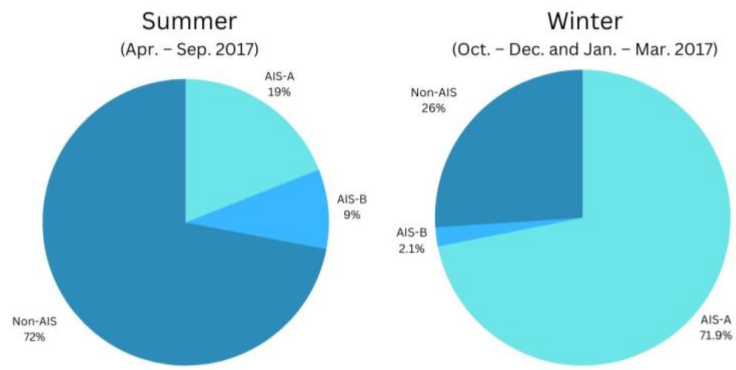


Note. From "Recreational vessels without Automatic Identification System (AIS) dominate anthropogenic noise contributions to a shallow water soundscape" by L. Hermannsen, L. Mikkelsen, J. Tougaard, K. Beedholm, M. Johnson & P.T. Madsen. 2019. Sci Rep, 9(1), 15477. https://doi.org/10.1038/s41598-019-51222-9. (CC BY 4.0)

Furthermore, motorized pleasure crafts in this study led to third-octave band noise pollution at 0.125, 2, and 16 kHz, increasing by 47-51 dB (Hermannsen et al., 2019). Non-AIS motorized vessels were the leading cause of the exceeded high-frequency (16 kHz) threshold, most likely due to their high travelling speed. The study found that recreational boats caused 49-85% of noise events that could provoke behavioural responses in harbour porpoises (Hermannsen et al., 2019). The distribution of boaters, boat traffic, and the impact of boating activities on the marine environment vary by locality and season.

In the Salish Sea, research on non-AIS small vessels has shown that they constitute a significant proportion of the vessel traffic. A recent study by O'Hara et al. (2023) found that, in summer, approximately 72% of vessels might not use AIS (Figure 12). Non-AIS traffic is higher during the summer and on weekends, corresponding with popular periods for recreational boating activity (O’Hara et al., 2023; Venturini et al., 2016).

Figure 12. The percentages of AIS-A, AIS-B, and non-AIS vessels during Winter and Summer were observed to pass through the Boundary Pass.



Note. Data from Table 1 in "Automated identification system for ships data as a proxy for marine vessel related stressors" by P.D. O'Hara, N. Serra-Sogas, L. McWhinnie K. Pearce, N. Le Baron, G. O'Hagan, A. Nesdoly, T. Marques & R. Canessa. 2023. Sci Total Environ, 865, 160987. https://doi.org/10.1016/j.scitotenv.2022.160987 (CC BY-NC-ND).

Serra-Sogas et al. (2018) found similar results in their analysis of vessel activity through aerial surveys during summer and winter. They found that, overall, the Strait of Georgia had the highest proportion of non-AIS vessels at 74%, followed by the Gulf Islands, Juan de Fuca Strait, and Boundary Pass/Haro Strait (Serra-Sogas et al., 2018). In all study areas, recreational vessels comprised the highest proportion of vessels present in AIS and non-AIS classes within the Canadian SRKW critical habitat.

Furthermore, Matthews and Grooms (2021) found that only approximately 22% of recreational vessels (including recreational fishing) and 16% of powered sailboats observed in the southern Gulf Islands were equipped with AIS in 2018 (Figure 13).

Figure 13. Estimated percentage of vessel classes using AIS in the southern Gulf Islands.

Vessel class	Proportion fitted with AIS	Density scaling factor
Container	100%	1.0
Cruise ship	100%	1.0
Ecotourism	45%	2.2
Ferry	100%	1.0
Fishing (commercial fishing only)	91%	1.1
Government	100%	1.0
Merchant	100%	1.0
Passenger (less than 100 m in length)	100%	1.0
Recreational and Sailing		
Recreational (including recreational fishing)	22%	4.6
Sailing (under power)	16%	6.3
Tanker	100%	1.0
Tug	100%	1.0
Vehicle carrier	100%	1.0
Other/miscellaneous	100%	1.0

Note. From "*Assessment of Vessel Noise within Southern Resident Killer Whale Interim Sanctuary Zones.* (Document number 01979, Version 2.0.)" by M.-N. R. Matthews & C. H. Grooms. 2021. Technical report by JASCO Applied Sciences for Transportation Development Centre of Transport Canada.

3. Small and Recreational Vessel Traffic in the Fraser Estuary

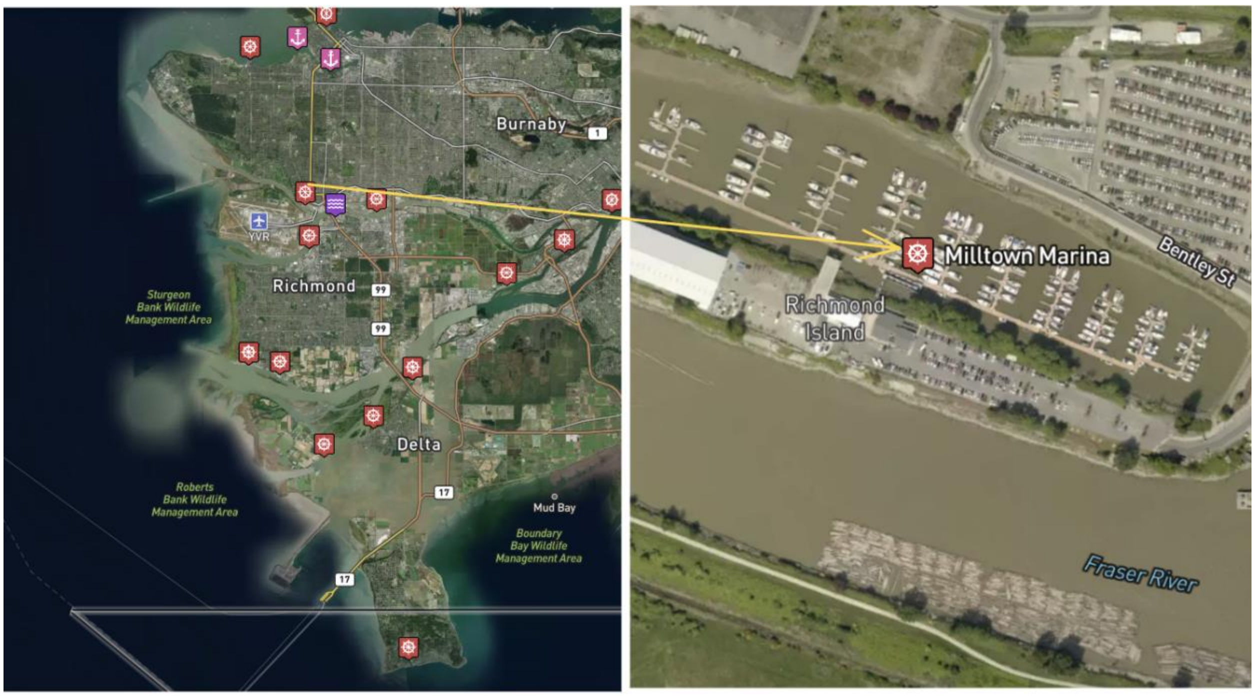
The Fraser Estuary has mainly been excluded from studies that have examined the activity and abundance of non-AIS vessels in the Salish Sea, either because of a lack of data or because other study areas have been prioritized (O'Hara et al., 2023; Serra-Sogas et al., 2018). DFO's review of areas most at risk of vessel-related disturbance to SRKWs also largely excluded the Fraser Estuary (Thornton et al., 2022b).

While studies of small recreational vessels have been conducted in the Salish Sea, the distribution of vessels and associated activities, as well as impacts on the coastal ecosystem and its species, may vary by area (Sidman & Fik, 2005). Factors such as water depth, channel locations and navigational aids play a role in recreational vessel trip trajectories (Sidman & Fik, 2005). An extensive part of the Fraser Estuary has shallow depths (as displayed in Figure 10), which has implications for the propagation of noise from smaller boats that generally travel faster and emit higher frequency noise than larger vessels. As a result, there is a lack of data regarding small vessel activity in the Fraser Estuary and the mouth of the Fraser River that needs to be filled.

In addition, there is little data on the noise levels produced by small vessels in the estuary. The lack of information on small vessel activity in the estuary makes it difficult to develop effective regulations for pleasure craft and ensure that the cumulative impacts of these vessels are assessed, as noise levels and frequency content can be very localized in coastal environments (Matzner et al., 2010).

Yet, it appears the estuary may be a major area for recreational boating. There are many marinas for recreational vessels at the mouth of the Fraser River (Figure 14). Many marinas have the capacity to house hundreds of vessels simultaneously. For example, Miltown Marina has a capacity of 219 in-water slips and 236 dry-stack storage units (Miltown Marina, n.d.).

Figure 14. Marinas (red), harbours (purple), and anchorages (pink) locations on the mouth of the Fraser River and Estuary.



Note. Map from Marinas.com. © Mapbox © OpenStreetMap © Maxar

Research Approach

Two methods were employed in this study to gain insights into the small vessel activities in the Fraser Estuary: the first involved analyzing commercially available AIS vessel data to investigate the activities of specific vessels in the area, with the data filtered to only include small vessels measuring less than 25 meters. As previously reported, AIS data do not accurately represent actual vessel activity, which prompted me to carry out two brief, opportunistic land-based observations of vessel activity (as depicted in Figure 15).

- Observation 1: A Saturday in early August from 3:30 to 4:30 PM
- Observation 2: A Sunday in late August from 3:30 to 5:30 PM

These locations were selected due to their accessibility by land and the fact that vessels transiting in the area were restricted to certain regions by the depth and landmasses surrounding the mouth of the river. Additionally, these areas are located within the critical foraging area for killer whales, as depicted in Figure 9.

Figure 15. Map of the study area (left) and a field photo of a land-based observation (right).

Note. Map taken from Google Earth.

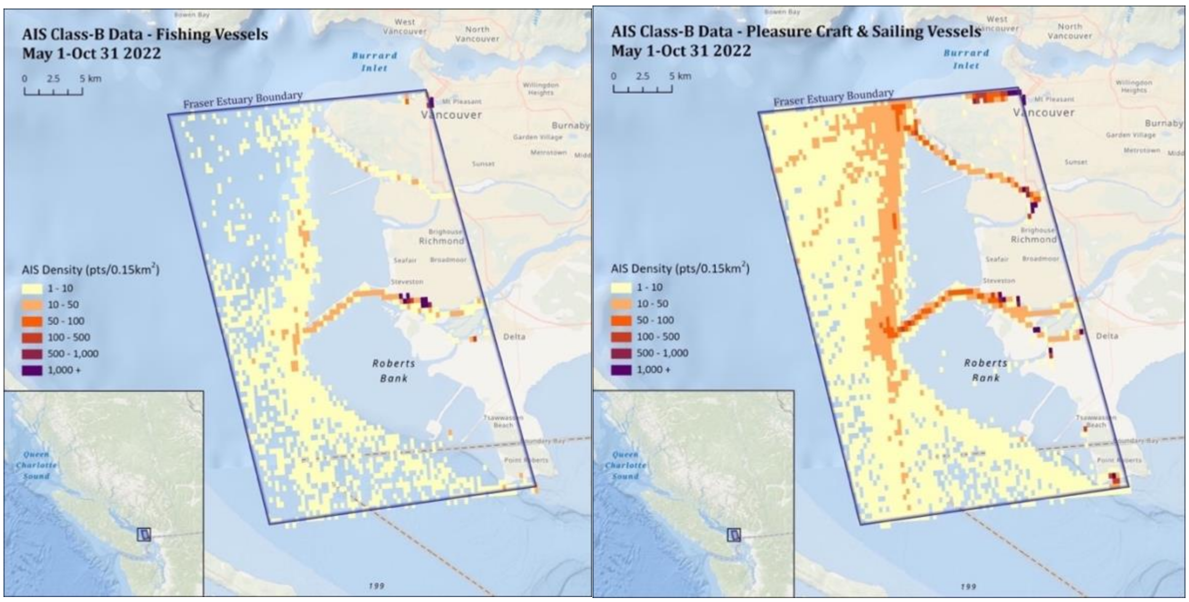
To determine non-AIS vessel composition and to see whether small vessel activity in the Fraser Estuary aligns with previous research in the Salish Sea, vessels transmitting AIS data were tracked in real-time through online platforms during the observations, and those that passed through the study area were filmed for further analysis.

Findings

AIS-B Data

Two heat maps were created using AIS data for two types of vessels: fishing and recreational vessels (pleasure craft and sailing). As depicted by the heat map, a high concentration of vessel density was observed at the mouth of the Fraser River and along the Traffic Separation Scheme (TTS).

Figure 16. Heat maps showing the AIS density of fishing vessels (left) and recreational vessels (pleasure craft and sailing vessels) from May 1st to October 31, 2022.



Note. Map by Chris Liang. Data purchased from commercially available sources.

The data from all small vessels in the study area were analyzed for minimum, maximum and mean reported speeds and listed in Appendix A.

Observations

During the land-based observations, non-AIS vessels were prominent.

Observation 1

Twenty-one vessels were observed passing through the study area. Of these vessels, only two transmitted AIS data. Non-AIS vessels comprised the most significant proportion (90.5%) of vessel passage observed. While one AIS vessel was commercial (tug), the other was recreational. The tug travelled at a speed of 9 knots, whereas the motorized recreational vessel travelled at a speed of 25 knots. The speed of the vessels was estimated and categorized as low, medium, high, or very high. Vessel speed was ranked based on the time it took vessels to clear the distance between two landscape cues (wooden posts) (Figure 17) and was compared to the speed reported by AIS-B vessels that transited the area. The passage in this area is relatively narrow. Hence, the differences between the distances from the observer for these vessels were similar and were not considered an issue for speed estimation.

Figure 17. Screenshot taken from a video filming boat passage as part of Observation 1, showing the narrow river and posts used to estimate the speed of vessels based on the time it took to clear the area compared to available speed from AIS vessels.

Most observed vessels passed in the study area at high or very high speeds, particularly jet skis and high-speed boats (Table 1).

Table 1. Table summarizing the estimated vessel passage speeds.

Estimated Speed	Motorized pleasure craft	Jet Ski	Tug	Total
Very high (over 30 knots)	2	2		
High (20-29 knots)	7	2		
Medium (10-19 knots)	6			
Low (under 10 knots)	1		1	
				21

Observation 2

During the two-hour observation period, 118 vessel passages were recorded. Of the vessels observed, nearly 85% were non-AIS recreational vessels. Recreational vessels made up around 84% of the total vessels observed, with nearly 92% of them not using AIS.

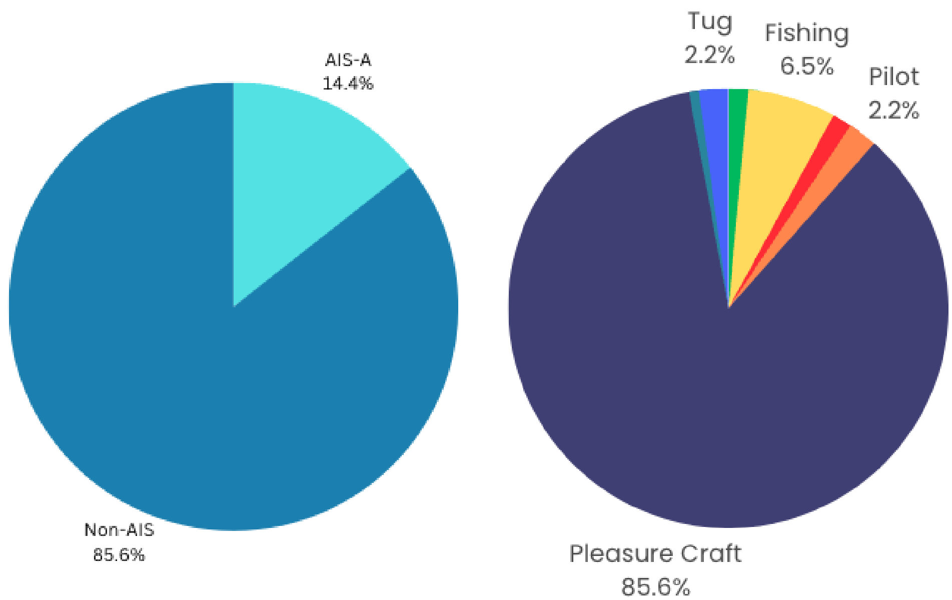
Table 2. Table Summarizing composition of vessel passage observed.

Type	AIS Count	% AIS	Non-AIS Count	% Non-AIS	Total	Total %
Cargo	2	1.7%		0.0%	2	1.7%
Fishing		0.0%	9	7.6%	9	7.6%
Passenger	2	1.7%		0.0%	2	1.7%
Pilot	3	2.5%		0.0%	3	2.5%
Pleasure Craft	8	6.8%	91	77.1%	99	83.9%
SAR	1	0.8%		0.0%	1	0.8%
Tug	2	1.7%		0.0%	2	1.7%
Grand Total	**18**	**15.3%**	**100**	**84.8%**	**118**	**100%**

Figure 18. Screenshot of vessel passage recording.

While these preliminary observations were limited temporarily and spatially, the observations appear to align with those observed in previous, more formal research (Hermannsen et al., 2019; O'Hara et al., 2023; Serra-Sogas et al., 2018). Most vessels observed were non-AIS, and of the recreational type.

Figure 19. Overview of vessels AIS composition (left) and vessel type (right) for both observations combined.



It is important to note that the AIS-B data analysis discussed above and opportunistic land-based observations have important limitations in their generalizability to all small non-AIS vessel activities in the Fraser Estuary. As a result, there is yet to be a comprehensive overview of small-vessel activity in the Fraser Estuary. Based on the information provided in previous research on small vessels in other areas of the Salish Sea and the world, these observations support the consensus that non-AIS vessel activity in coastal areas is important and should be measured to ensure an adequate understanding of noise disturbance in the area.

4. Current measures for managing small vessel traffic in the Salish Sea for recovery of SRKW

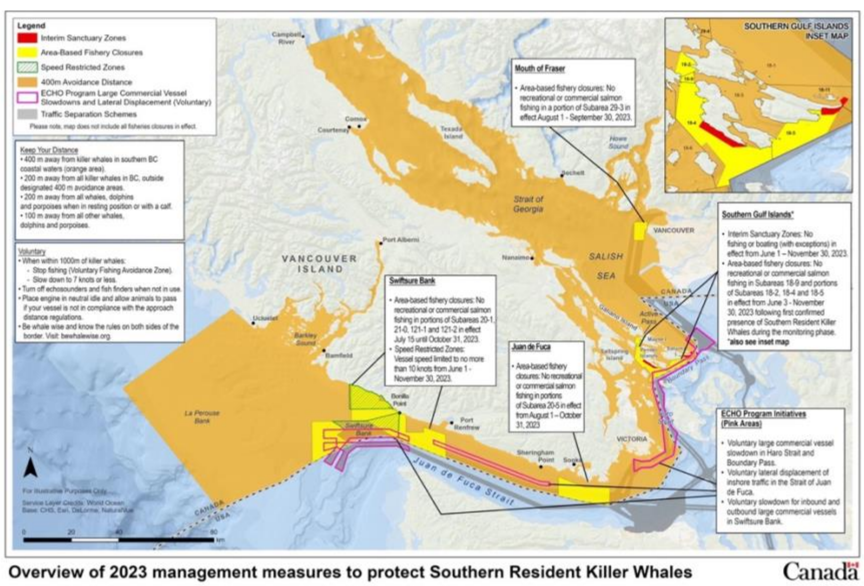
Under the Fisheries Act, the Marine Mammal Regulations Provision manages marine mammals. The legislative power to implement vessel management regulations or measures involving small vessels in the Fraser Estuary also falls under the Minister of Transport according to the Canada Shipping Act 2001 (Transport Canada, 2010). This act, described as "*the umbrella act for marine activities*," is the most comprehensive legislation related to maritime activities (Transport Canada, 2010). The act allows the Minister of Transport to make regulations "respecting the protection of the marine environment from the impacts of navigation and shipping activities," which includes regulating activities such as vessel navigation, anchoring, and vessel design (Transport Canada, 2010). The Canada Shipping Act allows ministers to enact regulations controlling noise levels from recreational craft engines to address noise pollution issues and their environmental impacts (Transport Canada, 2010; Government of Canada, 2019).

Recognizing that the SRKWs faced an imminent threat to their survival, the Minister of Transport ordered the Interim Order for the Protection of Killer Whales (Orcinus orca) in the Waters of Southern British Columbia to deal with a direct or indirect risk to the marine environment, as supported by sections 35.1(1) and 136(1)(f) (Transport Canada, 2020). Since then, the Interim Order has allowed the annual implementation of regulations on vessel-related disturbances of SRKWs (Transport Canada, 2020; Transport Canada, 2021b; Transport Canada, 2021c; Transport Canada, 2022a; Transport Canada, 2023). Both voluntary and mandatory measures have been implemented.

Current Management Activities

The Government of Canada's 2023 management measures to aid in recovering the Southern Resident killer whale are outlined in Figure 20.

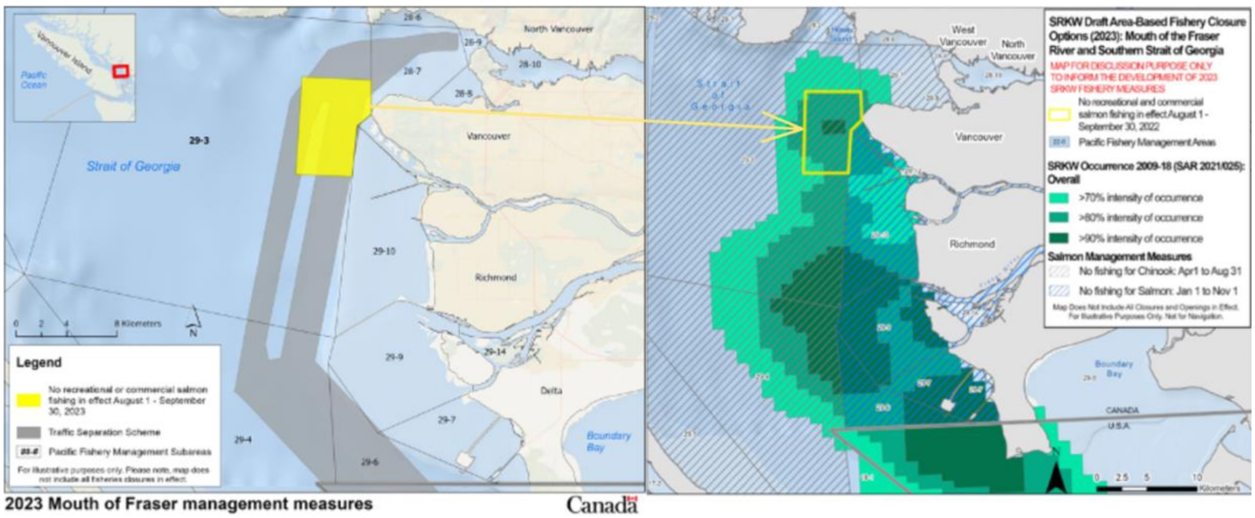
Figure 20. Overview of 2023 measures to protect SRKWs.



Note. From "Management Measures to Protect Southern Resident Killer Whales" by DFO. 2023. https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/srkw-measures-mesures-ers-eng.html#maps

Two measures were applied to the Fraser Estuary. The mandatory 400m approach distance, which applies to most of the Salish Sea, and a recreational and commercial salmon fishery closure in the mouth of the Fraser River from August 1st to September 30th, corresponds to the area and months of the highest occurrence of SRKWs, as outlined in Figure 8.

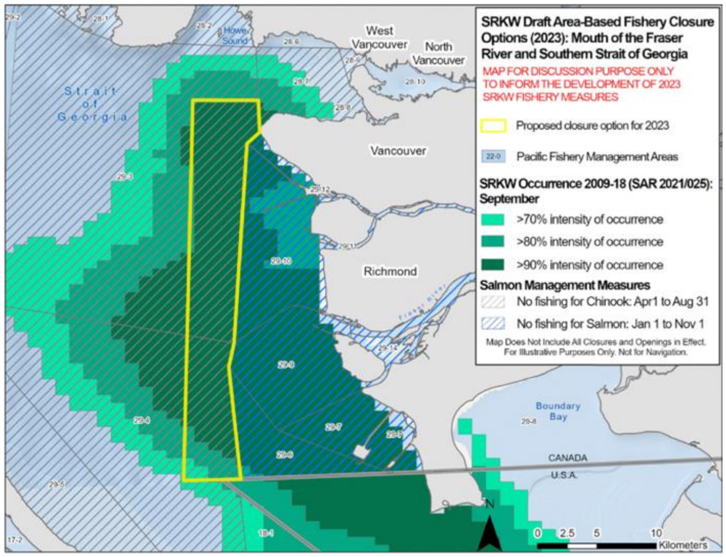
Figure 21. 2023 Management measures in the Fraser River Mouth to support Southern Resident killer whale recovery.



Note. From "Management Measures to Protect Southern Resident Killer Whales" by DFO. 2023. https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/srkw-measures-mesures-ers-eng.html#maps

The rationale behind the 2023 measures was to maintain consistency with the 2022 measures to increase compliance and target an area where SRKWs are likely to be present because of the return of Chinook salmon. Another option was proposed for the 2023 measures that offered more protection for Southern Resident Killer Whales. It sought to increase their feeding opportunities and success but was not adopted (Figure 22).

Figure 22. The second option was proposed for fishery closures in the Fraser Estuary for 2023.



Note. From “Review of Consultation Feedback on Proposed 2023 Southern Resident Killer Whale Management Measures.” by DFO. 2023.

Current measures aim to protect whale access to Chinook salmon in key foraging areas with minimal disruption (Transport Canada, 2021a). Although closing these areas to fishing activity also reduces the abundance of fishing vessels in the immediate area, it does not reduce the noise and disturbance caused by recreational and fishing vessels transiting through the site. While increasing salmon availability in the area is essential for nutritionally stressed SRKWs, noise and vessel disturbance must also be addressed to ensure whales can echolocate and catch their prey effectively. In a 2017 workshop that brought together technical experts on killer whales and chinook salmon to discuss short-term management actions to increase prey availability for SRKWs, the consensus was that reducing acoustic and physical disturbances from vessels in crucial foraging areas was more likely to succeed than reducing fishery extractions in specific areas (Marine Mammal Research Unit, 2017).

Discussion and Recommendations

In the core summer habitat of SRKWs, vessel noise levels are higher than median background levels at both low and high frequencies (Veirs et al., 2016). The coast borders the critical feeding ground in the Fraser Estuary and the Traffic Separation Scheme (TSS) that traverses through it, resulting in important vessel activity and related disturbances from both recreation and commercial vessels.

The areas with a high occurrence of SRKWs in the Fraser Estuary are exposed to traffic from large commercial vessels using AIS and smaller, often recreational vessels that do not use AIS. The disturbance of vessels can mask killer whale communication and echolocation and cause changes in behaviour that can impact energy input/output.

The preliminary observations of non-AIS coastal vessel traffic in the present study show that they are an important proportion of vessel traffic in the summer, which aligns with what has been observed in previous research and other areas of the Salish Sea (O'Hara et al., 2023; Serra-Sogas et al., 2018). Furthermore, the speed of recreational vessels appeared high, which is consistent with previous research on recreational vessels (Hermannsen et al., 2019). According to the vessel abundance heatmaps in Figure 16, most AIS-B vessels appear to navigate relatively close to the TSS. The current data may not accurately reflect the behaviour of non-AIS vessels, as they are typically smaller and more recreational compared to AIS-B vessels. Previous studies have indicated that non-AIS vessel traffic is more concentrated near the shore, and the distance to the coast is a crucial factor in explaining spatial patterns in non-AIS vessel activity (O'Hara et al., 2023).

While it is still early to propose specific policies targeting the activity of small vessels in the Estuary, the following section will examine the relevance of two general measures related to vessels in the Fraser Estuary.

Regulating Speed

Regulating speed is one of the easiest methods for mitigating vessel disturbances on aquatic species, as it does not require modifying vessels and can be temporarily and spatially adjusted (Findlay et al., 2023). The speed of vessels is also the most observable variable when mitigating vessel noise emissions. Since speed affects the amplitude and frequency of vessel noise, slowdowns are a promising approach for minimizing vessel disturbance in marine mammals.

Regulating vessel speeds can significantly decrease the noise emitted during operation. There is strong consensus that reducing vessel speed in ecologically significant areas is an effective method for reducing the underwater noise emitted despite the increased transit time (Houghton et al., 2015; Putland et al., 2018; Joy et al., 2019; Parsons et al., 2021). The amount of noise produced by a recreational vessel greatly depends on the manner and how fast it is driven. For example, maintaining a slower speed and a more direct path can reduce underwater noise levels (Matzner et al., 2010). Additionally, previous research shows significant decreases in noise levels when comparing speeds of over 15 knots to speeds under 7 knots across multiple boat types (Wladichuk et al., 2018). This may be an effective way to alleviate the impact of vessels without restricting their presence, as research indicates that it is preferable to keep a constant speed rather than making abrupt changes near whales to minimize acoustic interference (Garrison et al., 2022; Lagrois et al., 2022).

Figure 23. Recommended Speed in the St-Lawrence Estuary to protect Beluga whales.

Note. From "Rules of Navigation around Beluga Whales in the St. Lawrence Estuary and Saguenay River" by DFO. 2023. https://inter-l01-uat.dfo-mpo.gc.ca/infoceans/en/rules-navigation-around-beluga-whales-st-lawrence-estuary-and-saguenay-river

As a result, considering the speed of vessels plays such an important role in the noise from vessels, implementing a blanket speed reduction in the Fraser Estuary during months of highest SRKWs presence (August-September) may be an essential precautionary approach to mitigate the disturbance of these vessels while more research is conducted to understand their activity and the disturbance they cause. Moreover, decreasing the speed of vessels, in general, has the additional advantages of decreasing carbon emissions, minimizing the likelihood of collisions with whales, and mitigating the impact of vessel wake on sensitive coastlines (Department of Primary Industries, Water and Environment. Tasmania, n.d.; Leaper, 2019).

The recommended maximum speed to help mitigate the impact of vessels typically ranges from 5 to 10 knots (DFO, 2023a; 2023c). While the current guidelines in the Salish Sea for vessels in Canada recommend reducing speed to 7 knots or less within 1000 meters of killer whales, regulations in Washington State mandate a speed limit of 7 knots within half a mile (~805 meters) of SRKWs (Be Whale Wise, 2022).

Increasing Minimum Distance

According to the *Marine Mammal Regulations*, a minimum approach distance of 100 meters is legally required for most whales, dolphins, and porpoises in Canadian waters (DFO, 2023b). While this is the general minimum approach distance for whales, some whale species and areas mandate a higher minimum approach distance (DFO, 2023b)

In Southern BC coastal waters, water users must stay 400 meters from all killer whales. Research shows most non-compliance with mandatory marine mammal distance regulations for killer whales involved recreational vessels (Fraser et al., 2020). Ensuring adequate knowledge of these regulations by recreational boaters is crucial.

The state of Washington recently passed a new law that requires ships to maintain a 1,000-yard buffer around SRKWs starting in January 2025 (WDFW, 2023). This measure aims to minimize vessel disruptions and is based on a scientific report that found that increasing the minimum approach distance for vessels allows the population to have better foraging success at a critical point in its population trajectory (WDFW, 2023).

"The Southern Resident orcas need our help now, and reducing vessel traffic near the whales provides an immediate benefit. Every boater that slows down, stays back 1,000 yards, and avoids approaching the whales is in that moment giving a Southern Resident orca a better chance of catching the salmon it needs to meet its daily caloric needs, or to share with a calf to improve its odds of survival."- *Julie Watson, Ph.D., Washington Department of Fish and Wildlife Killer Whale Policy Lead.*

A newly introduced regulation mandates that ships must maintain approximately 914 m from the critical habitat of the Southern Resident Killer Whales (SRKWs), which is in transboundary waters. This distance is more than double the current regulations in Canada, where crossing the border on the water is relatively easy. This discrepancy in measures could potentially impact boaters who cross the border and create confusion about the regulations. Therefore, it would be preferable that the minimum distance regulation in the Canadian waters of the Salish Sea be increased to help minimize vessel disturbance of the SRKWs.

Conclusion

This study attempted to get an overview of vessel activity in the Fraser Estuary to see if AIS data was representative of vessel activity. The preliminary observations showed that most vessel passage in the coastal area of the estuary is from non-AIS and mostly recreational vessels. As a result, management efforts primarily concentrate on large commercial vessels equipped with AIS, and current noise models of low-frequency noise emissions from ships using AIS data significantly underestimate the true impact of vessel activity in the Fraser Estuary and on SRKWs.

As presented in this report, noise pollution is a significant threat to SRKWs and may hinder their recovery. Although large vessels have been the subject of intensive research in recent years, recent studies have shown that small vessels can also cause considerable damage to coastal ecosystems due to their proximity to the shore, high numbers, unpredictable trajectories, and speed changes.

While this study provides insight into non-AIS vessel activity in the Fraser Estuary, there is still limited knowledge of non-AIS vessel activity and associated noise, making it impossible to draw definitive conclusions on the impact of non-AIS vessels on the estuary or SRKWs. Furthermore, the data gap does not allow for specific recommendations on necessary measures. Therefore, further research is necessary to understand the impact of recreational vessels on SRKWs in the Fraser Estuary. However, precautionary measures such as limiting vessel speeds and increasing mandatory minimum approach distances to killer whales in months of high presence should be considered since they have been shown to be effective measures for mitigating disruption.

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Appendix

Table 3. Table showing the minimum, maximum and average speed of various vessel types separated by months in the Study Area. Note. Speed under 1 knot was excluded since those were likely moored or stationary.

Vessel Type	Count	Minimum Speed	Maximum Speed	Average Speed
MAY	**5590**	**1**	**40**	**8**
Cargo	65	4	12	9
Diving	3	6	27	13
Dredging	2	11	11	11
Fishing	447	1	12	7
Not Available	9	8	23	15
Passenger	831	1	38	14
Pilot	2	5	8	7
Pleasure Craft	1687	1	38	8
Sailing	1320	1	10	6
SAR	323	1	40	8
Towing	789	1	29	5
Tug	99	1	10	4
Vessel With Anti-Pollution Equipment	13	2	21	9
JUIN	**7896**	**1**	**44**	**8**
Cargo	51	6	11	9
Diving	47	1	31	14
Dredging	6	1	14	8
Fishing	699	1	14	7
HSC	12	2	35	12
Not Available	66	1	11	7
Passenger	1084	1	40	15
Pleasure Craft	2584	1	40	9
Sailing	1572	1	14	5

SAR	387	1	44	8
Towing	1243	1	33	5
Tug	100	1	9	4
Unknown	5	2	7	4
Vessel With Anti-Pollution Equipment	40	1	24	9
JULY	**10734**	**1**	**45**	**8**
Cargo	87	7	22	10
Dredging	6	10	17	13
Fishing	391	2	13	7
HSC	5	2	18	11
Not Available	106	2	32	11
Other	18	3	33	11
Passenger	1541	1	38	15
Pilot	4	4	28	17
Pleasure Craft	3960	1	36	9
Sailing	1954	1	11	6
SAR	470	1	45	8
Towing	2041	1	30	5
Tug	122	1	10	5
Unknown	2	3	7	5
Vessel With Anti-Pollution Equipment	27	1	25	15
AUGUST	**10686**	**1**	**42**	**8**
Cargo	43	4	20	9
Diving	28	2	30	21
Dredging	5	3	18	9
Fishing	343	1	13	7
Not Available	60	5	28	10

Other	12	1	23	10
Passenger	1457	1	37	14
Pilot	3	15	17	16
Pleasure Craft	3789	1	34	9
Sailing	1587	1	12	6
SAR	377	1	42	8
Towing	2719	1	29	4
Tug	243	1	11	5
Unknown	1	2	2	2
Vessel With Anti-Pollution Equipment	19	2	29	15
SEPTEMBER	**13381**	**1**	**40**	**6**
Cargo	74	7	18	9
Diving	6	22	27	25
Fishing	2094	1	26	6
Not Available	11	6	12	9
Other	22	1	32	11
Passenger	981	1	34	13
Pleasure Craft	5216	1	37	7
Port Tender	15	2	30	25
Sailing	1784	1	11	5
SAR	439	1	40	7
Towing	2482	1	27	4
Tug	250	1	10	4
Unknown	1	3	3	3
Vessel With Anti-Pollution Equipment	6	2	4	3
OCTOBER	**5830**	**1**	**43**	**7**
Cargo	65	7	11	9

Diving	1	3	3	3
Dredging	3	2	22	14
Fishing	468	1	16	6
Other	6	14	14	14
Passenger	559	1	35	14
Pilot	3	31	32	31
Pleasure Craft	1475	1	40	8
Port Tender	32	3	30	23
Sailing	1027	1	11	5
SAR	446	1	43	6
Spare	1	27	27	27
Towing	1566	1	30	5
Tug	152	1	10	4
Vessel With Anti-Pollution Equipment	26	1	15	4
Grand Total	**54117**	**1**	**45**	**8**

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