Strengthening recovery actions for Southern Resident killer whales

Independent Science Panel on SRKW Recovery
March 4-6, 2025
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by Independent Science Panel on SRKW Recovery
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Full list of participants and affiliations in Appendix I

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The recommendations in this workshop were developed by a panel of killer whale, salmon, and conservation scientists. The workshop participants were: Lance Barrett-Lennard, Tanya Brown, Maithili Devdas, Allison Dennert, Graeme Ellis, Holly Fearnbach, John Ford, Cameron Freshwater, Nick Gayeski, Deborah Giles, Hussein Alidina, Ruth Joy, Michael Jasny, Eve Jourdain, Misty MacDuffee, Paul Paquet, Amy Rowley, Peter Ross, Dave Rosen, Paul Tixier, Dominic Tollit, Jared Towers, Jennifer Tennessen, Peter Thompson, Sheila Thornton, Scott Toews, Valeria Vergara, Michael Weiss, Rob Williams, Brianna Wright, Jeffery Young.

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Executive summary

An ad hoc science panel was convened in Vancouver, Canada from March 4-6, 2025, to address the conservation and recovery of the endangered Southern Resident killer whale (SRKW) population – which, as of the July 2024 census, numbered only 73 individuals. The panel assembled 31 international experts from universities, government agencies, and NGOs across Canada, the United States, and the European Union to assess the efficacy and limitations of existing threat-reduction strategies, and propose new or revised measures. Their expertise covered a range of disciplines, including killer whale biology, health and behaviour, Chinook salmon ecology and habitat, underwater noise, ecotoxicology, and conservation policy, all in support of an ecosystem-level approach to the discussions.

Prey limitation remains the primary constraint on SRKW recovery, and the panel deemed current government initiatives on both sides of the Canada - US border to address this issue to be insufficient. Their recommendations encompass maintaining SRKW priority access to Fraser River early stream-type Chinook salmon through fishing closures, identifying seasonal and annual Chinook abundance thresholds based on daily prey energetic requirements and implementing a management framework for late summer and fall if abundance thresholds are not met, and considering fishery management actions to increase Chinook salmon size and age at maturity.

Undersea noise emanating from anthropogenic sources continues to pose a significant impediment to the population's recovery, exacerbating the impact of prey limitation by interfering with echolocation and successful foraging. Consequently, the panel recommended the prompt finalization and implementation of meaningful underwater noise reduction targets that are biologically relevant to SRKWs. Additional recommendations included expanding the geographic and temporal scope of existing large vessel slowdown areas, establishing noise output standards for large commercial vessels, and increasing Canada's small vessel avoidance distance from SRKW to 1,000 m without delay – harmonizing with the 1,000 yds (914 m) buffer already in effect in Washington State.

A third risk factor, exposure to extremely high levels of contaminants, was also addressed. Specific recommendations include strengthening existing chemical regulations and their enforcement, the development of environmental quality guidelines for contaminants of greatest concern to SRKW and their primary prey, the enforced elimination of legacy polychlorinated biphenyls (PCBs) still in use in closed applications, and the introduction of new regulations and source control measures that will reduce contaminant releases into SRKW habitat or that of their anadromous prey.

The panel emphasized that most of its recommendations could be implemented without further study, but nonetheless developed a targeted list of research priorities to assist in refining and informing additional conservation measures over time. These priorities include: establishing biologically-consequential thresholds for poor body condition based on other health indicators; developing a refined index of salmon abundance that reflects salmon prey preferences; continuing studies on noise effects on foraging and investigating non-foraging impacts of noise on salmon; expanding prey fragment and faecal genetic sampling efforts to improve dietary insights; determining optimal soundscapes for salmon and quantifying loss of habitat quality from anthropogenic sound inputs; continuing social and demographic research to support understanding of population integrity; addressing knowledge gaps regarding the amount, type, and location of pesticide use and their adjuvants; and including animal longevity, trophic level, and habitat use as features to consider in the scrutiny and regulation of chemicals, pesticides, and pharmaceuticals.

Summary of recommendations

No.	Recommendation summary	Page
Recommendations for improving quality, abundance, and access to prey		
1	To support SRKW access to lipid rich prey and recover at-risk stream-type Chinook salmon, maintain low marine harvest rates in fisheries (1-5%) or reduce higher harvest rates to this level, until exploitation rate and recovery analyses identify appropriate quantitative targets. ↪	21
2	Review and refine the size, location, and timing of fishery closures in Critical Habitat to ensure alignment with SRKW foraging areas, and implement precautionary buffers s. ↪	22
3	Identify thresholds of seasonal and annual prey energy requirements of SRKW and implement a protocol for fishery closures when prey requirements for ocean-type Chinook drop below thresholds. ↪	22
4	Recognizing the value of wild salmon as prey, use of hatchery salmon should ensure production aligns with SRKW prey preferences, particularly run timing, fat content, size and age of the adult Chinook salmon, and prioritizes production for SRKWs over fisheries needs. ↪	24
5	Assess benefits of shifting marine fisheries to terminal areas (i.e., terminus of salmon migration where immature Chinook are not encountered) to increase Chinook abundance, restore larger prey, and enhance SRKW access prior to fisheries. ↪	25
6	a. Protect freshwater habitat and improve Chinook productivity by ensuring thresholds for critical environmental flows are met, and if they are not, adjust annual harvest plans accordingly. ↪ b. Restore fish passage to historical freshwater habitats to support Chinook population recovery by removing or modifying dams, floodgates and culverts. ↪	26 27

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Recommendations for reducing acoustic and physical disturbance		
7	Develop and implement regional noise reduction targets that reflect SRKWs' need for quiet time, communication space and echolocation ability, and make them a requirement for future development approvals. ↪	30
8	Implement enforceable noise output standards to large commercial vessels, focusing particularly on the noisiest vessel classes that disproportionately contribute to underwater noise. ↪	30
9	Strengthen operational quieting measures for large commercial ships by applying an 11-knot slowdown to all classes, expanding slowdown zones, adopting a seasonal approach that is fixed in summer and responsive to whale presence in winter, and testing tidal lift strategies. Improve dynamic whale avoidance measures through expanded WRAS data inputs, vessel notifications of whale presence, and predictive whale forecasting tools, especially for ferries. ↪	31
10	Advance quieter engine and propeller technologies for small vessels and mandate manufacturer-provided controls to reduce echosounder noise, including switching to frequencies beyond SRKW hearing range. ↪	32
11	Extend Canada's SRKW vessel approach distance to 1,000 m and improve small vessel compliance through better education, enforcement and Class B AIS requirements. ↪	33
12	Evaluate and redesign Vessel Restricted Zones (formerly Interim Sanctuary Zones) to better align with SRKW foraging hotspots such as the mouth of the Fraser and improve enforcement to maximize conservation benefits. ↪	34
13	Refine measures to reduce noise and disturbance on Swiftsure Bank by analyzing noise sources and relocating mid-water trawl fisheries to reduce competition, bycatch risk and disturbance. ↪	35
14	Mandate AIS use for licensed small vessels operating in SRKW critical habitat to improve compliance with whale avoidance measures. ↪	36

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15	Phase out Southern Gulf Islands anchorages to eliminate avoidable noise from bulk carriers and improve port arrival management practices to reduce anchoring needs. ↪	37
16	Adopt a lateral shift in the Strait of Georgia Traffic Separation Scheme to reduce underwater noise near key SRKW foraging areas. ↪	37
Recommendations for reducing priority contaminant discharges		
17	Eliminate all chemicals that accumulate in SRKW food chains, particularly those with high fat solubility (log K_{ow} >5), even if not currently designated as toxic. ↪	40
18	Advance remediation of contaminated sites in salmon habitats through a Canada-B.C.-First Nations working group and expanded monitoring. ↪	40
19	a. Improve chemical review and approval processes to reflect SRKW-specific vulnerabilities, including long lifespan, high trophic level and bioaccumulation risks, and wide-ranging habitat use. ↪ b. Prioritize the review of new and emerging contaminants of concern, including the per- and polyfluoroalkyl substances (PFAS) ↪	41 42
20	Prioritize water quality in freshwater Chinook salmon habitats by addressing key sources of contamination including road runoff, pesticides and wastewater. ↪	43
21	Remove loopholes in vessel wastewater regulations that allow cruise ships to discharge greywater and sewage into SRKW habitat and improve inspection and enforcement. ↪	43
22	Eliminate scrubber wastewater discharges from large vessels and ban heavy fuel oils in Canada's territorial waters to reduce toxic pollution in SRKW habitat. ↪	44
23	Review and update provincial regulations for disposal of biosolids and improve monitoring of contaminants of concern such as PFAS, PAHs, pharmaceuticals and microplastics prior to any land application. New or existing guidelines should be applied to these contaminants if biosolids are to be used by farms, forests or mines in B.C. watersheds. ↪	44

24	Require full disclosure and environmental evaluation of all adjuvants in pesticide formulations to assess their risk to salmon and SRKWs. ↪	45
25	Improve stormwater management by creating an intergovernmental panel that incorporates emerging contaminant science into policy and mitigation. ↪	46
26	Review and improve oil spill response plans and transparency, ensuring vessel inspections, tug escorts, pilot awareness and trained Indigenous Guardians. ↪	46

1. Introduction

Southern Resident killer whales (SRKWs, *Orcinus orca*) are a small and declining population of fish-eating killer whales that inhabit the waters of the NE Pacific Ocean along the west coasts of Canada and the U.S. As of the most recent census conducted by the Center for Whale Research in July 2024, there were only 73 individuals in this reproductively-isolated population, underscoring its vulnerability and the urgency of recovery efforts. The principal prey for SRKWs is Chinook salmon (*Oncorhynchus tshawytscha*), but they also feed on coho (*O. kisutch*) and chum salmon (*O. keta*), and to a lesser extent on non-salmonids, such as Pacific halibut (*Hippoglossus stenolepis)*, English sole (*Parophrys vetulus*) and sablefish (*Anoplopoma fimbria*). This population has a high probability of extinction under current conditions (Williams et al. 2024). It faces multiple, interacting, and potentially synergistic threats that jeopardize its survival. As such, the population is listed as Endangered under both the Species at Risk Act (SARA; Canada) and the Endangered Species Act (ESA; U.S.). Despite the implementation of a number of protection measures since 2019 in both countries, the population has not demonstrated discernible signs of recovery — such as higher reproductive success (successful pregnancies and calf survival), improved body condition, or population growth. This underscores the urgent need for more robust actions based on the latest scientific research.

This workshop was convened as an independent, science-focused forum to:

- evaluate the current state of the SRKW population;
- assess the effectiveness of existing management measures; and
- identify the most effective pathways for recovery.

Unlike stakeholder forums that weigh recovery measures within the context of economic interests and policy constraints, this workshop was designed to prioritize science- and evidence-based solutions for the survival and recovery of the SRKW population. While acknowledging the complexities of implementation and political feasibility, participants remained focused on measures necessary to support SRKW survival, rather than those that are politically expedient.

We convened 31 scientists from diverse disciplines and sectors, including universities, government agencies and NGOs in Canada, the U.S., France and Norway to provide an ecosystemic basis for discussions on the plight of SRKWs. The group included specialists in killer whale biology, health and behaviour, Chinook salmon ecology, salmon habitat, underwater noise and ecotoxicology. These participants reviewed and discussed SRKW population status and health indicators by considering published and unpublished research. The panel also assessed current threat-reduction strategies, their successes and limitations, and areas where enhanced conservation measures are required. Based on this analysis, participants developed a set of science-based recommendations to address SRKW recovery through increased prey availability, noise reduction, and toxic contaminant mitigation (for ease of reference, a table summarizing the full set of recommendations is included in the summary of recommendations).

These recommendations reflect the best available data and ecological understanding, emphasizing long-term, cross-border conservation strategies that support the sustained recovery of this population. Although the recommended measures target key threats to SRKWs, their implementation will likely benefit other species and ecological processes by reducing underwater noise (which also supports other acoustically sensitive invertebrates, fish and mammals), improving salmon habitat (which sustains diverse wildlife and coastal ecosystems), and enhancing water quality (which benefits entire food webs and human communities).

This report summarizes the outcomes of these discussions and outlines critically important and effective measures to support recovery of the SRKW population. In addition to management recommendations, the report highlights research priorities that are deemed essential to support the implementation of effective recovery measures. We anticipate that this report will serve as both an immediate resource and the foundation for a forthcoming peer-reviewed manuscript, which will provide a comprehensive roadmap for promoting the long-term survival of this endangered population.

Throughout this process, the guiding principle was clear: be hard on the problem, not on the people. The gravity of the SRKW crisis today demands urgent, bold, and decisive action for recovery. This report outlines the path forward — the actions that must be taken to prevent extinction and rebuild a resilient SRKW population.

2. SRKW population: Status, trends, vital rates, health, conservation efforts

As of the most recent photographic population census conducted by the Center for Whale Research (July 1, 2024), the SRKW population totalled 73 individuals. This represents a decrease of two individuals (2.7%) from the previous year's population size. Since this census date, at least four more whales have been born (L128, J61, J62, and J63), two of which have died. Adult male K26 has also died since the last census.

The first annual census was completed in 1976, following a prolonged period of live captures for aquaria that removed at least 34 individuals from the population and likely resulted in the deaths of approximately 10 additional individuals during capture operations, bringing the total impact to an estimated 44 whales (Bigg, 1982). At that time, there were 72 SRKWs. The population has fluctuated substantially since then, but has failed to show a long-term increase in numbers. The most sustained period of population growth from 1984-1995 saw the population climb from 74 individuals to 98, the highest total since the census began. However, this period was followed by six consecutive years of population decline. In the last five years (2020-2024), the population has hovered between 72 and 75 individuals, some of the lowest numbers since the earliest years of the census (1975 and 1976).

The SRKW population comprises three pods (J, K and L), each composed of closely related individuals that typically forage and travel together. Much of the population decline in recent years has been driven by the dynamics of L pod, the largest of the pods. While J and K pods have maintained relatively consistent numbers since the first census, L pod has declined since peaking in the mid-1990s and is now composed of fewer individuals than when the census began. K pod, the smallest pod, has begun to decline in recent years due to a near complete lack of reproduction, with only one successful birth in the last 10 years. K pod now numbers only 15 individuals, which is at the low end of its size range throughout the census.

Concerns for the SRKW population extend beyond its population size. The demographic structure of the population has also undergone significant changes over time. The current sex ratio of 1.4 adult females to every male is significantly lower than the average of 2.5 across the entire time series to date (1976-2024; CWR, unpublished data). The paucity of reproductive-age SRKW females (29 individuals, or 39.7% of the population, as of 2024) combined with a relatively low average female lifespan (34 years, relative to 37 for Northern Resident killer whales; Nielsen et al. 2021) has resulted in very few grandmothers remaining in the SRKW population. As post-reproductive females have been shown to boost the survival of their grandoffspring (Nattrass et al. 2019), their absence could adversely affect calf and juvenile survival.

The birth rate (i.e., the annual probability that a reproductive female produces an observed calf) within the SRKW population is 0.1, but births are not distributed evenly across the three pods. While J pod has a birth rate of 0.13, that of K pod is 0.08 and that of L pod is 0.09. The impact of low birth rates is compounded by relatively high calf mortality. Of calves that were documented between 1976 and 2024, approximately 80% survived their first year (CWR, unpublished data). However, as calves that died before detection are by definition excluded from this figure, this is almost certainly an underestimate of the true calf mortality rate. Based on pregnancy data from photogrammetry and hormone analysis, more than two-thirds of detected pregnancies are lost prior to birth and/or detection (Fearnbach and Durban, pers comm; Wasser et al. 2017), with an overall first-year survival likely around 40-50% (CWR, unpublished data).

Body condition of SRKWs has been monitored using aerial photogrammetry since 2008, with annual efforts since 2015 (Fearnbach et al. 2020), providing the longest quantitative time series on SRKW health. Measurements from high-resolution still images have provided annual and seasonal measurements of body condition (nutritional and reproductive) and growth (Fearnbach et al. 2011, Fearnbach et al. 2018, Fearnbach et al. 2020). Body condition is assessed using an index called the Eye Patch ratio (EPR) that measures the fatness of the head. The EPRs of all whales measured across all years of the study are pooled, ranked based on their deviation from the predicted values for their age and sex, then divided into five body condition ‘classes’ ranging from “robust” to “poor” (for full methodological details, see Stewart et al. 2021). Whales in the lowest body condition class (i.e. the bottom 20% of whales measured in the entire time series) are considered to be in “poor” body condition and have an elevated risk of mortality relative to whales in the four higher body condition classes (Stewart et al. 2021).

In 2024, 22 out of 73 whales measured (30%) were found to be in the lowest body condition class, the most since commencement of the study in 2008. For J pod, the proportion of whales in “above normal” body condition has declined for the fifth consecutive year; for L pod, this proportion increased following two years of decline. The most frequently assigned body condition class for both J and L pods was “poor” for the second consecutive year (Fearnbach and Durban, pers comm.). Analysis of seasonal trends in SRKW body condition has revealed that it appears to reach its lowest level in the spring and early summer, before rising again to peak levels in September (Fearnbach and Durban, pers. comm.).

2.1 Current SRKW Recovery Measures in Canada and USA

Canada	
Area-based fishing closures	Specific areas within SRKW Critical Habitat are closed to commercial and recreational salmon fishing from late spring to fall (exact dates vary). 2024 closures included areas within Swiftsure Bank, the Juan de Fuca Strait, the mouth of the Fraser River and the southern Gulf Islands.
Vessel Restricted Zones	Effective from June to November, all vessel traffic is prohibited within Vessel Restricted (formerly Sanctuary) Zones off North Pender and Saturna Islands, with exceptions for emergency situations and to allow Indigenous peoples to participate in food, social, and ceremonial fishing.
Vessel slow-downs	All vessels are required to slow down to 10 knots or less in certain areas around Swiftsure Bank between June and November. There is also a voluntary commercial vessel slowdown in other areas of Swiftsure bank and in Haro Strait and Boundary Pass from approximately June to November (depending on SRKW presence). Target speeds in these areas are 14.5 knots for container ships, cruise ships and vehicle carriers, and 11 knots for bulk freighters and tankers. Additional voluntary slow-downs are in place for all vessels in Tumbo Channel, and a voluntary tug alteration route in Juan de Fuca from June to November.

Minimum approach distance	Vessels must remain at least 400 m from all killer whales and avoid positioning themselves in the whale’s path in southern B.C. coastal waters between Campbell River and Ucluelet until May 31, 2026. In other locations, vessels must remain at least 200 m away from all killer whales. Ecotourism businesses belonging to the Pacific Whale Watch Association have agreed to refrain from whale watching on SRKW, but may approach Bigg’s killer whales to a distance of 200 m.
USA	
Minimum approach distance	All vessels must remain at least 1,000 yds away from SRKW. If SRKW are spotted within 1,000 yds, vessel operators should navigate out of their path to 1,000 yds or more without exceeding a speed of 7 knots. If SRKW are within 400 yds, operators should disengage the transmission, luff sails or stop paddling (if it’s safe to do so) and wait for the animal/s to move away.
Vessel slowdowns	Voluntary commercial vessel slowdowns are in place in Admiralty Inlet and north Puget Sound in the winter months between early October and mid-January. The slowdown target speeds range between 11 and 14.5 knots depending on vessel category. Ships are also requested to turn off Ultrasonic Anti-Fouling Systems in the slowdown area.

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3. Recommendations for SRKW recovery

3.1 Improving quality, abundance and access to prey

The declining trend in Southern and Northern Resident killer whale population abundance in the 1990s was correlated with a decline in the Pacific Salmon Commission's (PSC) coast wide indices of Chinook salmon abundance over the same period. The downward population trend was driven by increases in mortality rates and declines in birth rates (Ford et al. 2010). Similar analysis conducted only on SRKWs at that time found fecundity was strongly correlated to the PSC's West Coast of Vancouver Island Chinook salmon index (a subset of the coast wide indices), with the probability of calving differing by 50% between years of low and high Chinook salmon abundance (Ward et al. 2009). Further evidence of the impact of prey limitation was provided by Fearnbach et al. 2011 and Groskreutz et al. 2019, who documented decreased lengths of adult SRKW and NRKW females that corresponded with years of low salmon availability earlier in their lives.

Recent analysis examining evidence for the ongoing strength of this prey demographic relationship found SRKW mortality rates were still associated with Chinook salmon abundance, but the correlation with birth rates is inconclusive, potentially due to poor statistical power from the low number of SRKW births or additional factors that limited prey (Nelson et al 2023). An assessment by Santiago Dominguez-Sanchez's (pers. comm.) points to the importance of prey quality. The study found total available kilocalories of Chinook salmon, i.e., accounting for lipid content and size changes, better explain the variation in SRKW birthrates than does Chinook abundance alone.

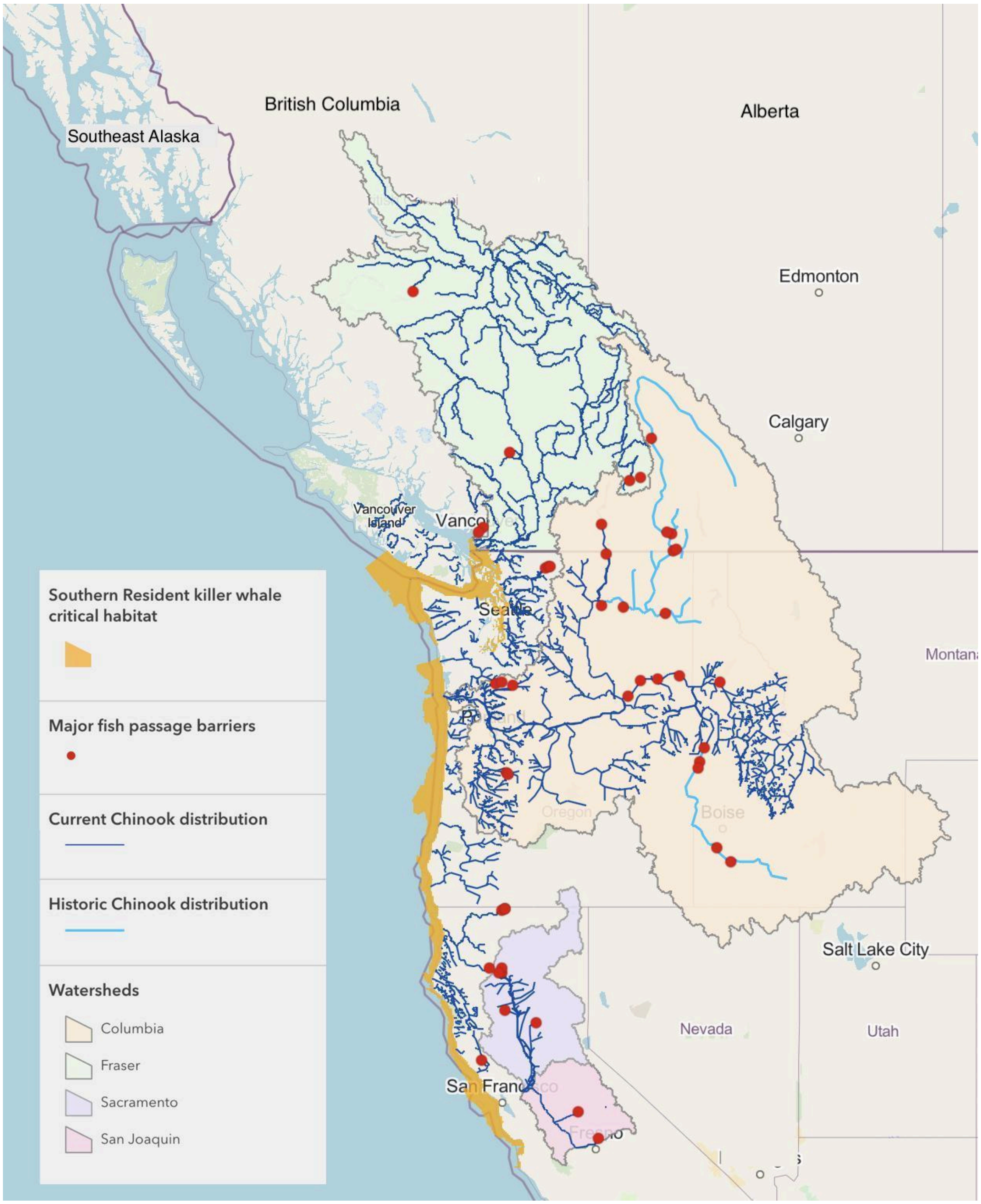
Studies over the last 15 years have deepened the understanding of this broad prey-demographic relationship. For example, assessments of body condition found Fraser River Chinook abundance is tightly linked to the survival of the J pod matriline. Only when the abundance threshold of more than 1.1 million Fraser River Chinook is met, does the probability of decline in body condition reach zero (Stewart et al. 2021). In addition, SRKW selectively forage on Chinook salmon with specific characteristics. Preferred prey are high in fat content, older in age (4-6 years), and large in size (>74 cm) (Ford et al. 2010, DFO 2025). Seasonal trends in SRKW body condition show it drops to its lowest level in the late spring and early summer, before improving to peak condition in September (Fearnbach et al 2020, Fearnbach and Durban 2022, Fearnbach and Durban pers. comm.) This is consistent with Couture et al (2022) whose model outputs suggest that SRKW were obtaining less energy from prey on a daily basis in the spring and summer than in the fall.

Stream-type Chinook salmon from the mid- and upper- Fraser River watershed that return to spawn in the spring and early summer have particularly high fat content (Lerner & Hunt 2023, Freshwater and King 2024) and return after a winter period when SRKWs may have less access to high quality food. Several Fraser River spring- and summer-run Chinook salmon stocks appear to be preferentially selected, as their presence in the diet of SRKWs is disproportionate to their abundance, emphasizing their importance as preferred prey in Canadian Critical Habitat (DFO 2025; Hanson et al 2010).

These and other expanded diet studies (see Hanson et al. 2021) support the importance of adequate Chinook salmon abundance throughout the annual cycle to the survival and recovery of SRKWs, and the need to implement prey management strategies to ensure abundance and rebuilding of key wild (i.e., non-hatchery-origin) Chinook salmon populations found in SRKW Critical Habitat. While access to large Chinook salmon is required throughout the year, Fraser River spring and summer stream-type Chinook populations are at risk of extinction (COSEWIC 2018; 2020), and the reduced abundance of these fish may be a key factor preventing recovery of SRKW. Spring-run, stream-type Chinook populations that return to the Columbia River watershed are also recognized as at-risk of extinction under the U.S. Endangered Species Act (ESA).

The science panel participants have identified the following actions as required to provide year-round access to Chinook salmon within Critical Habitat (Figure 1) in both Canada and the U.S.

Figure 1. Designated Critical Habitat of Southern Resident killer whales



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Designated Critical Habitat of Southern Resident killer whales (orange) in Canada and the U.S. showing Chinook rivers and watersheds feeding into this habitat. Dark and light blue blue lines are the current and historic Chinook distribution, respectively. Red dots are major barriers to Chinook migration (i.e. dams).

1. Protection of stream-type Chinook salmon

Stream-type Chinook salmon appear to be ideal prey for SRKW due to their migration timing (passing through Canadian SRKW critical habitat in spring and early summer) and high fat content. Their importance to RKWs has been documented since diet studies began in the 2000s (Ford and Ellis 2005, Ford et al. 2010, Hanson et al. 2010). More recent studies (DFO 2025) show positive selection for certain spring- and summer- run populations disproportionate to their abundance. Many populations of stream-type Chinook salmon are assessed as Threatened or Endangered in both Canada and the U.S. Within the Fraser River watershed, 12 of the 13 population groups with minimal hatchery enhancement have been assessed as Threatened or Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Although fall run, ocean-type Chinook salmon are present in Canadian SRKW critical habitat year-round, their body size early in the year is smaller than that of stream-type Chinook salmon that are nearly mature (DFO 2025). As a result, declining abundance of stream-type Chinook has been postulated as a reason for nutritional stress and poor body condition of SRKWs in the spring (Wasser et al. 2017, Fearnbach et al. 2020, Stewart et al. 2021, 2023) and the decline in their use of Critical Habitat inside the Salish Sea (Ettinger et al. 2022, Corgan et al 2023).

To provide SRKW reasonable access to lipid-rich prey early in the year and increase the probability that threatened and endangered Fraser River stream type Chinook will recover, participants **recommend** maintaining low marine harvest rates (1-5%) — or reducing higher rates to this level — until exploitation rate and recovery analyses identify appropriate quantitative targets. To achieve these targets, fishery management measures focused on maintaining low stream type Chinook salmon exploitation rates will likely remain necessary during their migratory window through SRKW critical habitat (i.e., between March and August).

To facilitate killer whale access, and protection of Threatened and Endangered Columbia River stream-type Chinook salmon in the U.S., participants **recommend** reducing the marine harvest of upper Columbia River spring Chinook (ESA endangered), Snake River spring/summer Chinook (ESA threatened), and Willamette River spring Chinook (ESA threatened) in sport, commercial and tribal commercial fisheries. This could also be facilitated by transitioning many commercial fisheries to river-based passive selective gears such as pound nets (Tuohy et al. 2019), thus allowing SRKW priority access to these fish.

2. Time and area foraging closures within SRKW critical habitat should be reviewed for their consistency with existing science

Consistent with recommendation 12 (noise and disturbance), fishing closures in important foraging areas are intended to reduce noise, disturbance and competition from recreational fishing vessels targeting Chinook salmon.

The participants **recommend** that the size, location and timing of closures be reviewed to ensure they are adequately aligned with SRKW habitat use. This may require adjusting current closures to ensure that: 1) important portions that have been excluded to date to accommodate the recreational fishery be added, 2) conversely, that areas with minimal evidence for foraging are omitted, 3) that closures are in place earlier in the year to account for access to stream-type Chinook salmon, 4) they include precautionary buffers, and 5) that monitoring and enforcement are sufficient to ensure adequate compliance.

3. Identify thresholds of SRKW seasonal and annual prey energy requirements and implement a standing protocol for fishery closures when these requirements for ocean-type Chinook drop below thresholds

Although spring and early summer has been identified as a critical time for priority access to at-risk stream-type Chinook salmon (based on poor body condition and consistent inability to meet daily prey requirements), Couture et al (2022) predicted that SRKWs failed to meet their annual prey requirements four times between 1979 and 2020 (2008, 2018, 2019, 2020). This number rose to 19 years of annual prey deficits when the higher bounds of daily energetic requirements were used, and dropped to only 1 year when lower bounds were used. Years of annual prey deficits were also consistent with higher mortality and lower births, but low statistical power limited confidence in this finding. Additionally, Lerner and Hunt (2023) found that the lower lipid content in fall ocean-type Chinook can increase the number of fish needed by 30% to meet SRKW energy demands in the fall relative to the spring.

Identifying minimum thresholds for ocean-type Chinook salmon that migrate through SRKW critical habitat in the summer and fall could serve as a 'stop-loss' mechanism, triggering in-season management action in years when the prey energy demands are projected to fall below biologically sufficient thresholds. At such times, fishery management should prioritize SRKW access to Chinook salmon. Such an approach was identified by Stewart et al. (2021) who found that when Fraser River Chinook abundance was above 750,000 (estimated from FRAM Chinook model on July 1st), J pod had a low probability (<14%) of declining body condition.

The participants **recommend** that identifying and adopting biologically sufficient prey abundance thresholds that trigger management actions based on forecasted Chinook salmon abundance (such as those from the PSC’s Chinook Technical Committee) should be developed as a pre-season framework. If in-season abundance deviates from forecasts, more timely responses may also be required. These thresholds should be applied in both

Canada and the U.S. Existing prey abundance thresholds developed under Amendment 21 for U.S. fisheries managed within the Pacific Fisheries Management Council should be evaluated for their consistency with biologically-sufficient thresholds for seasonal and annual energy demands.

4. Hatcheries should not be the focus of prey rebuilding for SRKW recovery

The objective of many hatchery programs is to produce salmon catch for recreational, commercial, and Tribal/FSC (food, social and ceremonial) fisheries. Most hatchery Chinook salmon released in Washington and southern B.C. have a subyearling, ocean-type and late-run timing life history strategy. Many of the most endangered and potentially most important salmon populations for SRKW — such as lipid rich stream-type Chinook with an early run timing, remain severely depleted.

Importantly, the production of Chinook salmon from hatcheries in Washington, Oregon and California, but also from B.C., have largely failed to recover self-sustaining populations of Chinook salmon (Hilborn 1992, Levin et al 2001, HSRG 2009, Chicote et al 2011, McMillan et al 2023). Evidence from the Salish Sea also suggests most Puget Sound hatchery fish produced for the SRKW prey increase program by NOAA and Washington State are significantly below the size and age range of Chinook preferentially targeted by Southern Residents. The mean length of a mature Puget Sound hatchery fish is now only 623 mm (24.5”) with a mean age of 2.96 years (RMPC database; RCF analysis 2023) and these populations typically have a relatively low lipid content (Freshwater and King 2024). While larger Puget Sound Chinook may be valuable prey for SRKW (particularly in the winter, Hanson et al. 2021), the small average size means that SRKW must consume a larger number of individuals to meet their caloric needs and SRKW may be less likely to target Puget Sound populations as a result. Indeed, DFO (2025) has found evidence of negative selection for Puget Sound Chinook salmon in SRKW diets on Swiftsure Bank during the late summer. Similar hatchery measures have been implemented by the Government of Canada to increase production of Chilliwack River fall-run Chinook salmon in the Fraser watershed. While the mean age-at-maturity of Fraser River fall-run fish has also declined (Freshwater et al. 2022), average size-at-maturity is considerably larger than Puget Sound populations (Xu et al. 2020).

Participants **recommend** that if hatcheries are being used to increase the availability of prey for SRKW then managers should ensure that: a) run-timing, fat content, size, and age of the adult Chinook salmon produced by the hatchery match the prey preferences of SRKW, and b) production is scaled to meet the needs of SRKWs rather than fisheries.

5. Assess benefits of shifting marine fisheries to terminal areas (where immature Chinook are not encountered) to increase Chinook abundance, restore larger prey, and enhance SRKW access prior to fisheries

Chinook salmon have exhibited long-term declines in size and age in the last century (Van Hyning 1968, Ricker 1981), with recent studies confirming that these trends have persisted or intensified through recent decades (Lewis et al. 2015, Ohlberger et al. 2018, Oke et al. 2020). These recent declines have been attributed to a variety of factors including warmer ocean conditions, increasing competition with chum salmon and hatchery-produced pink, salmon (Ruggerone et al. 2023), predators like killer whales and sharks (Ohlberger et al 2018, Manishin et al 2021) and, for more historic declines, fishing pressure (Ricker 1981). Coastal marine fisheries (both recreational and commercial) can contribute to the decline in the size and age of mature Chinook salmon due to their harvest of immature Chinook (Ricker et al. 1981, Gayeski et al. 2024). Smaller Chinook constitute lower quality prey, making it critical to explore strategies that restore a more historic population structure with a higher proportion of larger, older fish than currently observed.

Participants **recommend** the exploration of fishing strategies that would increase both the size and abundance of Chinook salmon. Terminal fisheries — those that exclude immature Chinook salmon and capture only mature adults at the terminus of salmon migration) — are one such option. Terminal fisheries can occur in the estuary, the lower river, or upstream, depending on the fishery objectives. Terminal fisheries can be stock specific as well, further enabling the recovery of depleted, threatened, or endangered Chinook salmon populations, many of which are not prioritized in recovery plans. Terminal fisheries are increasingly being implemented in B.C.'s coastal and interior river systems for First Nations, commercial, and recreational endeavors (Altas et al. 2021). They have also been successfully demonstrated in the Columbia River (Tuohy et al. 2019, Gayeski et al. 2020) and Puget Sound (NOAA 2023). Terminal fisheries would also allow SRKW access to their prey prior to harvest by humans..

6. a) Protect freshwater habitat and improve Chinook productivity by ensuring thresholds for critical environmental water flows are met, and if they are not, adjust annual harvest plans accordingly

Healthy freshwater spawning and rearing habitats are critical for the rebuilding of naturally spawning Chinook salmon populations and, by extension, for supporting SRKW recovery. Yet many of these habitats suffer from insufficient summer flows that exacerbate the effects of climate change, elevate salmon mortality and reduce Chinook productivity (Rosenfeld 2017, Gronsdahl et al. 2019, Warkentin et al. 2022). For example, in interior Fraser sub-basins such as the Nicola River, consecutive years of Stage 4 and 5 droughts between 2016 and 2021 resulted in streamflows falling below Critical Environmental Flow Thresholds (CEFTs)[1], as defined under Section 87 of the provincial Water Sustainability Act. Warkentin et al (2022) found that flow regime conditions in this heavily modified watershed are strongly associated with the productivity of an at-risk stream-type Chinook salmon population. Inadequate summer flows adversely impact Chinook productivity (Warkentin et al. 2022), contributing to their at-risk status and impeding recovery.

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[1] The volume of water flow below which significant or irreversible harm to the aquatic ecosystem of the stream is likely to occur. https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/14015#section87

Conversely, flow management that keeps minimum flows above 10% of the Mean Annual Discharge has been identified as important in rebuilding previously at-risk Chinook salmon. For example, low flows in the Cowichan River — particularly in the late summer and fall — were recognized as a key limiting factor to adult Chinook freshwater migration and Chinook rebuilding. In response, aggressive flow management designed to maintain minimum flows at 10% of mean annual discharge (about 7 m^3/s) and never below 5% mean annual discharge has been identified as a key factor in the recovery of this population (T. Rutherford, pers. com, 2024; Sutherland 2011).

Lastly, Fraser River stream-type stocks likely have low population productivity relative to ocean-type stocks (Parken et al. 2006) and are relatively more dependent on freshwater rearing habitat. As a result, stream-type populations may disproportionately benefit from efforts to improve freshwater habitat quality. Such interventions may be necessary to recover stream-type populations given evidence of particularly low productivity in recent years (DFO 2020, DFO 2021, Atlas et al. 2023).

The participants **recommend** that in watersheds providing year round habitat to at-risk Chinook populations, summer flows need to be managed to ensure that Critical Environmental Flow Thresholds are met. If streamflow drops below the CEFT, fisheries managers need to factor increased freshwater mortality and reduced productivity into more conservative and precautionary harvest plans. This is especially true for interior Fraser watersheds experiencing multiple years of Stage 4 and 5 drought with streamflows below CEFTs.

6. b) Protect and restore Chinook salmon freshwater habitat: Ensure freshwater fish passage

Enabling fish passage is a critical component of restoring and sustaining Chinook salmon populations in small and large river systems that include the Fraser, Columbia, and their tributaries. However, dams, culverts, and other migration barriers have impeded access to spawning and rearing habitat, and reduced the spatial diversity and abundance of populations. For example, in the Columbia River Basin, more than 55% of historical Chinook habitat is inaccessible due to mainstem and tributary dams (CRITFC 2014). In the Fraser River watershed, upstream and floodplain barriers associated with human infrastructure have similarly restricted movement and blocked access to former habitats. For example, more than 80% of former rearing habitat for juvenile Chinook and other salmon in the lower Fraser has been alienated behind dykes, flood gates and other structures (Finn et al. 2021).

Participants **recommend** that priority consideration be given to restoration initiatives focussed on Chinook salmon passage to former habitats — through retrofitting or removing infrastructure like floodgates, dams and culverts. This is essential for re-establishing life history diversity and supporting the recovery of both threatened and endangered Chinook populations and endangered SRKWs.

3.2 Reducing acoustic and physical disturbance

Acoustic and physical disturbance are amongst the most pressing threats to SRKW survival and recovery (GoC 2018, GoC 2024, Williams et al. 2024). Vessel noise has been shown to reduce prey capture effort by SRKWs, as indicated by fewer and shorter prey capture dives (Holt et al. 2021b) and by reductions in communication and echolocation space, particularly in high-traffic regions such as the Salish Sea (Burnham et al. 2023). Tennessen et al. (2024) recently provided further empirical evidence that vessel noise impairs the ability of SRKWs to efficiently locate and capture prey, particularly among females, who were more likely to abandon prey capture attempts in the presence of vessel noise.

Typical modern ships of the type that transit through SRKW critical habitat daily elevate underwater noise not only at low frequencies, but also across the mid-and high-frequency bands used by SRKWs. On average, ship transits raise ambient noise levels by 20-30 dB at frequencies below 1,000 Hz and by 5-13 dB at frequencies as high as 96,000 Hz at ranges less than 3 km, which is well within the range used by killer whales for echolocation and communication (Veirs et al., 2016). This broadband noise can effectively mask SRKW calls and echolocation clicks, interfering with their ability to forage, coordinate group movements and navigate in critical habitat.

These impacts are not occurring in isolation. Noise and disturbance can amplify the effects of prey limitation, making it more difficult for SRKWs to meet their energetic needs. A cumulative effects model of resident killer whale population trajectories in the Northeast Pacific (Murray et al., 2021) highlights their vulnerability to overlapping anthropogenic stressors, including prey scarcity, acoustic and physical disturbance, and environmental contaminants. Supporting this, Holt et al. (2021a) provided direct evidence that vessel presence interacts with salmon availability to influence foraging success. The probability of prey capture increased with salmon abundance, but declined with increasing vessel speed, underscoring how noise and disturbance undermine access to critical resources.

Despite mitigation efforts on both sides of the border, acoustic conditions in SRKW Critical Habitat are not improving. Approved industrial projects such as the Trans Mountain pipeline expansion and the Roberts Bank Terminal 2 (RBT2) port development are expected to further increase shipping traffic through key foraging areas, elevating noise exposure for SRKWs.

MacGillivray et al. (2025) quantified the noise contributions of different vessel types, identifying Ro-Ro ferries (roll-on roll-off vessels that carry passengers or cargo) and deep-sea cargo ships as the dominant regional source of broadband noise. Other sources, including tankers, anchored cargo vessels, fishing boats, and recreational vessels, add significant seasonal and geographic variability. By identifying the vessel types and locations contributing most to underwater noise in frequency bands relevant to SRKWs, this research helps to target management and mitigation efforts where they can be most effective.

Science panel participants believe that existing measures are insufficient to reduce vessel noise and disturbance to a level that supports recovery objectives for the population, and therefore make the following **recommendations**.

7. Develop and implement regional noise reduction targets which are biologically relevant to SRKWs

SRKWs are losing substantial opportunities to communicate due to underwater noise (Williams et al. 2014, Veirs et al. 2016). As agencies consider noise-reduction targets, it is essential that these targets more-than-mitigate current noise impacts and projected future increases in ship traffic to avoid the problem of shifting baselines.

The Port of Vancouver ECHO Program has undertaken substantial work to identify plausible noise reduction targets and consider and evaluate their application under existing and future traffic scenarios (Stothart et al. 2023, Zizheng et al. 2024).

Participants recognize the value of this work, and **recommend** prompt finalization and implementation of noise-reduction targets in SRKW habitat, based on the whales' ecological needs and the broader acoustic environment of the Salish Sea. In other words, such targets should consider not only broadband noise levels, but also biologically-meaningful criteria such as the availability of quiet periods and the whales' need for communication and echolocation space at spatial and temporal scales for effective communication and echolocation. Participants further **recommend** that regulatory approvals of large development projects that would increase vessel traffic noise be strictly contingent on: a) meeting the noise-reduction targets and b) including a provision requiring effective mitigation measures to protect the SRKW environment from further degradation.

8. Reduce noise from large commercial ships through the application of noise output standards

Vessel owners can substantially reduce underwater radiated noise through a variety of technologies and design approaches, some tenable only for new builds or major retrofits and others available to both new builds and existing ships (IMO Secretariat 2023, Vard

Marine 2023, ZoBell et al. 2023). As recent modeling has shown, applying such quieting methods in a standardized way could significantly improve acoustic habitat for SRKW (Zizheng et al. 2024).

Participants **recommend** the implementation of noise output standards for large commercial vessels, such as the radiated noise level criteria recently developed by Transport Canada for nine vessel classes (Dolman et al. 2024), through underwater noise management planning requirements. Participants also **recommend** adopting a focused policy on reducing noise output from the loudest cohort, such as older bulk carriers, tankers, and container ships that often have outdated or poorly maintained propulsion systems, based on findings that a relatively small percentage of vessels (15%) are responsible for 50% of aggregate underwater noise in the Salish Sea (Veirs et al. 2018). High or unusual noise output, such as from "singing" propellers, can be an indicator of needed maintenance.

9. Refine and improve operational quieting measures for large commercial ships transiting through the whales' northwest habitat

Properly applied, operational measures such as vessel slowdowns can significantly reduce the noise produced by large commercial ships (Findlay et al. 2023, MacGillivray et al. 2019, McKenna et al. 2013, ZoBell et al. 2021). In the Salish Sea, the operational measures established through the Enhancing Cetacean Habitat Observation (ECHO) Program — i.e., the slowdowns for commercial vessels in Haro Strait and Boundary Pass and on Swiftsure Bank, and the lateral displacement of tugboats along Juan de Fuca Strait have resulted in measurable reductions in underwater noise levels in frequency bands critical to SRKW echolocation and communication, with conservation benefits for SRKWs (Joy et al. 2019, Burnham et al. 2021, Stothart et al. 2023, Williams et al. 2021, Zizheng et al. 2024).

Participants believe these measures can be improved and refined. They **recommend** that a slowdown to a maximum of 11 knots be applied to all large commercial vessels, including faster vessel classes that presently observe a 14.5-knot slowdown. They also **recommend** that slowdowns be expanded to cover more of the whales' Critical Habitat — noting that container vessels coming to Deltaport terminal and the mouth of the Fraser are unlikely to incur extra overage (beyond the 8 hr shift) pilotage costs. In addition, they suggest testing and implementing a tidal lift strategy, whereby vessels transit during flood tides with benefits for noise reduction and/or transit time.

Participants further **recommend** adopting a revised approach to vessel slowdowns that is fixed or varies little in the summer months, and is adaptable to whale presence during the winter months, in recognition of SRKW occurrence in the Salish Sea at all times of year. Finally, they **recommend** that dynamic whale avoidance measures be improved by expanding inputs into the Whale Report Alert System (WRAS) by initiating vessel notifications of whale presence, and, potentially, by integrating short-term whale forecasting algorithms into vessel notifications (Randon et al. 2022). Such avoidance measures are particularly important for ferries, which generally cannot comply with the area slowdowns observed by other commercial vessels.

10. Reduce noise from small vessels through quiet engineering

In some parts of SRKW Critical Habitat, small vessels are responsible for a high proportion of average underwater noise levels, including within the whales' echolocation range (MacGillivray et al. 2024), making these vessels an important target for noise reduction efforts. Significant quieting is achievable through engineering and design, including commercial, off-the-shelf components such as outboard motors that generate much of the vessels' acoustic output.

Participants **recommend** that appropriate regulatory authorities facilitate the development and adoption of quieter engines and propellers. This could be accomplished by creating standards for acoustic output and using noise ratings and efficiency guides to inform consumers about quieter, more sustainable options.

Currently, many small vessel operators use chart plotting devices that also incorporate radar and depth sounders. These devices typically emit sound pulses in the hearing range of killer whales whenever the plotter is turned on, regardless of whether the depth sounder function is actively being used. Workshop participants **recommend** requiring manufacturers to provide simple controls to allow operators to pause sound emissions while other plotter functions remain operational, and to shift operating frequencies to those beyond the hearing range of killer whales. Behavioural audiogram data show that killer whales have best hearing sensitivity around 34 kHz, with good hearing ranging from approximately 5 to 81 kHz, and an upper hearing limit near 114 kHz (Branstetter et al. 2017). Operating echosounders at frequencies above 120 kHz would therefore reduce the likelihood of disturbing SRKWs acoustically and of interfering with their own echolocation.

11. Extend SRKW avoidance distance in Canada to 1,000 m and improve small vessel compliance through education and enforcement

Research published since 2018 indicates there are adverse effects of vessel noise and disturbance on Southern Resident killer whales at distances well beyond the 400m approach distance currently applied in Canada (Holt et al. 2021a, 2021b, Tennessen et al. 2024). In consideration of these findings, the Washington state legislature amended its SRKW protection statute, and as of January 1, 2025, it is now law that boaters must maintain a 1,000 yd (approximately 914 m) minimum distance from SRKWs. The Canadian government has stated its intention to increase its avoidance distance to 1,000 m through amendments to the federal Marine Mammal Regulations (GoC 2025).

Participants strongly support the adoption of a 1,000 m avoidance distance in Canada and **recommend** that this measure be implemented without delay. To ensure its effectiveness, participants **recommend** that governments focus on increasing on-water compliance particularly by: (1) investing in boater education and (2) expanding the Class B AIS transponder requirement. Participants also **recommend** that commercial operators be prohibited from planning, advertising, and conducting whale-watch tours on SRKWs, as has been the case of signatories to Canadian whale-watch agreements since 2019 and that they must continue to report SRKWs to the Government of Canada's Whale desk in a timely manner to allow integration with WRAS data.

12. Evaluate Vessel Restricted Zones to ensure they are appropriately placed in size, time, and space for SRKWs, and improve enforcement

Since 2019, the Canadian government has maintained Vessel Restricted Zones (previously referred to as Sanctuary Zones), where vessel transits are seasonally restricted, along the southern coasts of Pender and Saturna Islands. However, compliance remains limited. The Southern Gulf Islands Whale Sightings Network (SGIWSN, 2024) reported 1,058 infractions by AIS-equipped vessels and 844 by non-AIS vessels within these zones in 2024, underscoring the need for improved enforcement and outreach.

Participants are concerned about the effectiveness of these zones given their relatively small size, their location in waters that may not represent areas of highest habitat value, and low boater compliance. Displacement of vessel traffic is also a concern, as traffic will shifts outside these zones. Since SRKWs are most vulnerable to vessel disturbance while foraging (Lusseau et al. 2009, Holt et al 2021), protecting key foraging areas is expected to offer meaningful benefits. However, if protected areas are poorly located, displacing vessels into higher-quality foraging habitats can occur, potentially worsening impacts (Ashe et al. 2010). The zones have not been revised since they were established in 2018 despite new data on SRKW habitat usage, including evidence that key foraging areas have changed somewhat in recent years.

Participants **recommend** that governments undertake a structured review with SRKW experts to determine the optimal size, location, timing, and measures for Vessel Restricted Zones and that they improve the monitoring and enforcement mechanisms that apply. They emphasize that Vessel Restricted Zones should be designed specifically to move small vessels and fishing traffic away from key foraging areas, as originally intended, thereby maximizing conservation benefits. This review process should incorporate quantitative analyses (such as modeling gains in quiet acoustic space under different configurations) to evaluate and optimize the timing and placement of zones. In particular, participants **recommend** focusing protection on the mouth of the Fraser River given its importance for SRKW foraging (Thornton et al. 2022a), with, for example, adequate Vessel Restricted Zones within portions of Pacific Fisheries Management Area 29 to mitigate the impacts of fisheries targeting pink, chum and sockeye salmon, as well as late summer recreational fisheries on Chinook salmon. While some of these salmon species are not key prey for SRKWs, the vessel activity associated with their harvest generates significant noise and disruption for SRKW foraging in the same area for their preferred prey.

On the U.S. side, motorized commercial whale-watching vessels were required in 2020 to comply year-round with a previously-voluntary no-go zone along the west side of San Juan Island. This measure remains voluntary for recreational and non-commercial vessels.

Participants **recommend** that formal Vessel Restricted Zones that exclude all classes of vessel should also be established in the U.S. portion of SRKW critical habitat, and that ensuring compliance with all vessel regulations is an important issue on both sides of the border. Research has shown that SRKWs are particularly vulnerable to vessel disturbance while feeding, and that protected-area strategies focused on feeding 'hotspots' could provide greater conservation benefits. One study identified a candidate marine protected area where SRKWs were 2.7 times more likely to feed than in adjacent waters, underscoring the value of spatial protections targeted to areas of high foraging activity (Ashe, Noren & Williams 2010).

13. Refine measures to reduce noise and disturbance on Swiftsure Bank

Swiftsure Bank has provided SRKWs with key foraging habitat for at least the last two decades, with some of the highest recorded summer occurrence in the region (Thornton et al. 2022a, Stredulinsky et al. 2023) and potentially significant winter occurrence as well

(Ford et al. 2017). Unfortunately, the same habitat is regularly subjected to levels of noise that substantially reduce the whales' communication and echolocation ranges (Thornton et al. 2022b). In summer, most of the noise comes from small vessels, particularly fishing and recreational boats (MacGillivray et al. 2025). Currently, two parts of the area are subject to a seasonal 10-knot speed limit for small transiting vessels and to seasonal salmon fishery closures. Participants expressed the importance of improving on these measures.

Participants **recommend** further analysis to characterize boat noise around Swiftsure Bank, particularly to understand the relative contributions of commercial and recreational fishers, and to adopt further measures on that basis. They also **recommend** relocation of mid-water commercial trawling that presently occurs around the bank to reduce physical and acoustic disturbance, prey competition, and bycatch risk, noting that killer whale bycatch continues to occur in mid-water trawl fisheries in Alaska.

14. Improve small vessel compliance with whale avoidance measures by mandating the use of AIS

Small vessels contribute substantially to both acoustic and physical disturbance in SRKW foraging areas (e.g., Williams et al., 2014; Wladichuk, 2021), yet their movements and behaviour are difficult to monitor because many do not use the Automatic Identification System (AIS).

Participants **recommend** mandating the use of AIS on small vessels operating under a federal or provincial license (as is required for commercial whale watch operators in Washington state as a condition of their license), including recreational fishing, scientific research permits, and tourism-related activities in SRKW critical habitat. All vessels listed in the Small Vessel Compliance Program[2] (SVCP) should be included.

[2] https://tc.canada.ca/en/programs/small-vessel-compliance-program

15. Phase out the use of Southern Gulf Islands ship anchorages to reduce underwater noise

Bulk carriers anchored in the Southern Gulf Islands (SGI), an area that includes Critical Habitat for SRKWs, contribute significant and sustained underwater noise from onboard generators and auxiliary systems. Research in Cowichan Bay, B.C. showed that a single anchored carrier can elevate broadband sound levels (20-24,000 Hz) by 2-8 dB over distances of at least 2 km (Murchy et al., 2022), affecting frequencies important for SRKW communication and echolocation. In addition to the noise generated while anchored, these vessels transit through Critical Habitat to reach the anchorages, compounding the acoustic and physical disturbance to SRKWs.

Participants **recommend** phasing out the use of freighter anchorages in the SGI to eliminate avoidable noise sources. Efforts should focus on improving vessel traffic efficiency and reducing the need for anchoring altogether by improving port arrival management practices, such as just-in-time arrival scheduling (e.g. Senss et al., 2023).

16. Adopt a lateral shift in the Traffic Separation Scheme (TSS) in the Strait of Georgia, as described in Transport Canada's 2022 feasibility study

In 2022, on behalf of Transport Canada, Dillon Consulting undertook a study titled "Traffic Separation Scheme Feasibility Study for Southern British Columbia". Of the 13 scenarios reviewed, one option proposed modifying the TSS in the Strait of Georgia by shifting the inbound and outbound lanes west by 1 NM, which was predicted to reduce noise levels (up to nearly 3 dB) at the mouth of the Fraser River, a key foraging area for SRKWs. It scored the highest across a combined benefit and risk analysis, and would therefore complement the noise reductions being achieved by existing ship slow-downs in the Salish Sea. Participants **recommend** SRKW habitat use of this region be confirmed, and if there are no negative collateral impacts of moving the TSS, then further consultation should be expedited to achieve this TSS change. Further review of the other five high benefit, low risk scenarios was also encouraged.

3.3 Reducing discharges of priority contaminants

Southern Resident killer whales forage in waters that are surrounded by highly populated, industrialized and urbanized areas in both Canada and the U.S., which exposes them to elevated levels of complex mixtures of contaminants. Exposure to endocrine-disrupting contaminants, including polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and organochlorine pesticides (OCPs) has been identified as one of the main threats to SRKW survival and recovery (GoC 2018, GoC 2024, Ross 2006, Williams et al. 2024).

The SRKWs are among the most contaminated marine mammals in the world (Ross et al. 2000; Krahn et al. 2007, 2009; Remili and Brown 2025). PCBs and other chemical classes share three problematic features: they are persistent, bioaccumulative and toxic. They are also covered by the Stockholm Convention (2004), which requires signatories to eliminate their manufacture, use and disposal. Canada, as a signatory, is obligated to eliminate such substances, while the U.S. has relied on voluntary market withdrawals.

Concentrations of PCBs - the dominant contaminant of concern in SRKW - exceed thresholds for immune and endocrine disruption (Ross et al. 2000, 2006; Hall et al. 2003; Brown et al. 2014a). PCBs levels are predicted to increase calf mortality and inhibit population growth, and contribute to a population decline of up to 15% (Desforges et al. 2018). Biological markers in whale biopsies and fecal metabolites also indicate physiological disruption tied to contaminant exposure (Buckman et al. 2011; Brown et al. 2025a).

Efforts to assess contaminants in SRKWs are constrained by ethical and legal limits on sampling, prompting use of surrogate species such as Chinook salmon and harbour seals to estimate exposure levels, as well as non-invasive approaches using fecal (Cullon et al. 2009; Ross et al. 2013; Holbert 2023; Holbert 2025; Lundin et al. 2016). Contaminant analysis and health effects research are ongoing using such proxies.

Chinook salmon, the primary prey of SRKWs, continue to carry PCBs, DDTs, and PBDEs at levels that can impair immune and endocrine function in SRKWs (Holbert et al. 2025). SRKWs have recently been shown to ingest higher levels of these contaminants through consumption of “Shelf Resident” Chinook, which rear in more urbanized marine zones compared to offshore stocks (Holbert et al. 2024, 2025). Sediment concentrations of PCBs and PBDEs in SRKW habitat exceed environmental quality guidelines (Brown et al. 2019, 2025b, 2025c; Kim et al. 2022). The sediment concentrations of several metals in SRKW habitat also exceed environmental quality guidelines, presenting a risk to lower levels of the food chain (Kim et al. 2023).

Changes to Disposal at Sea permitting in B.C. (Canada) have sought to better manage contaminant deposition risks from dredging operations (Alava et al. 2012; Ross 2010).

Contaminants in freshwater ecosystems further jeopardize anadromous salmon. These include risks associated with both legacy pollutants and newer, more water-soluble compounds. For example, the more water soluble pesticides used in agriculture and forestry pose risks to salmon eggs, fry and returning adults (Harris et al. 2008). In the Fraser River and its tributaries, compounds such as pharmaceuticals, polycyclic aromatic hydrocarbons (PAHs), 6PPD-quinone, and current-use pesticides are found at concentrations associated with adverse effects (Lo et al. 2025; Meador et al. 2006, 2014, 2018; King et al. 2025; Tierney et al., 2010). The tire-related chemical 6PPD-quinone has caused mortality in juvenile coho at environmentally relevant levels (Tien et al. 2021, 2022, Lo et al. 2025). PAHs have been linked to reduced lipid stores in juvenile Chinook, increasing overwinter mortality risk (Meador et al. 2018). Wastewater treatment plant effluent has also been shown to impair growth and survival in Chinook salmon (Meador et al. 2014).

Together, these findings highlight the ongoing and cumulative threat of contaminants to SRKW recovery. Science panel participants agreed that current measures remain insufficient to address the threat of contaminants to SRKW survival and recovery, and have identified the following recommendations.

17. Eliminate chemicals that accumulate in SRKW food chains

Southern Resident killer whales are highly contaminated with a number of legacy (restricted) and emerging chemicals, especially those chemicals deemed to be 'Persistent, Bioaccumulative and Toxic' (PBT). These are chemicals that have a propensity to dissolve in fats rather than water (i.e., octanol:water partitioning coefficient or log K_{ow} of 5.0 or greater). While many of these chemicals have been banned in Canada or removed from the market voluntarily in the U.S., their environmental persistence means that they still can be found in the environment — sometimes at harmful levels. For example, despite being banned in 1977, PCBs are still present in SRKWs at levels where endocrine disruption and other toxicities can be expected (Ross, 2006, Krahn et al. 2007). And while PCBs have been declining in the environment (Ross et al. 2013) as a result of regulations, source control, and international agreement, closed used applications for PCBs continue, with a deadline for their elimination in Canada being extended from Dec. 31, 2025 to Dec. 31, 2029 for a number of applications, including electrical transformers and other equipment. PCBs remain in storage and in contaminated sites in Canada.

Participants **recommend** that all chemicals that have a high log K_{ow} (>5.0) in current use in Canada be critically reviewed and targeted for possible elimination — including those that have not yet been deemed to be 'toxic' (e.g. Muir and Howard 2006).

18. Remediation of contaminated sites

Contaminated sites can serve as a source of contaminants to food webs that support salmon and killer whales. PCBs have contaminated a number of areas around military facilities, urban centers, harbours and industrial activities across Canada (Brown et al 2014b). This highlights the importance of surveillance and remediation, extending beyond just the federal and crown sites identified under the Federal Contaminated Sites Action

Plan.[3] The coastal sediment and mussel monitoring program in B.C. (PollutionTracker.org) has charted out those coastal areas that are particularly contaminated with PCBs and related products, such as Victoria Harbour and Burrard Inlet. The importance of contaminated sediments has been demonstrated in the accumulation of PCBs by English sole and Pacific herring in Puget Sound (West et al. 2009).

Participants **recommend** that the Government of Canada establish an ongoing Canada-B.C.-First Nations 'Contaminated sites working group' to review the status of currently designated sites, as well as candidate sites, and to advance monitoring and remediation initiatives across government jurisdictions. This working group should consider the particular vulnerabilities of SRKWs (mobile, long lived and high trophic level) and anadromous salmon (running a gauntlet of discharge locations and contaminated sites in freshwater and marine habitats). The high PCB levels in Puget Sound food webs underscores the importance of Salish Sea-wide initiatives, and continued efforts in Washington State to remediate hotspots and sources of priority pollutants.

19a. Improve procedures for chemical review and approval

New chemicals should be reviewed in a revamped process that considers the vulnerable life history and habitat use features of SRKWs and anadromous salmon (and other wildlife), notably their long lifespan, feeding ecology and metabolic constraints to eliminate certain compounds. Toxicity testing data should not only consider lab species such as the water flea (*Daphnia spp.)* and rainbow trout (*O. mykiss*) in short term assays, but additional species in the lab or the field that provide complementary value-added information.

Toxicological endpoints other than just growth, reproduction and mortality should be considered during regulatory reviews of new chemicals, to take advantage of the abundance of molecular and cellular techniques that demonstrate harm. New chemicals,

[3] About federal contaminated sites: https://www.canada.ca/en/environment-climate-change/services/federal-contaminated-sites.html

pesticides and pharmaceuticals should be reviewed before approval for the Canadian market by regulators under the terms of the Canadian Environmental Protection Act (Chemical Management Plan, ECCC), the Pest Control Products Act (Canada Pest Management Regulatory Agency, Health Canada), and the Food and Drugs Act (Health Canada), respectively.

Participants **recommend** that each of all relevant federal legislative agendas implicitly consider the following features of SRKWs — something that will strengthen Canada's ability to protect the wider environment: long lifespan (up to 100 years), high trophic level (the vulnerability of species at the top of the food chain to contaminants that bioaccumulate and biomagny in the food chain), and large habitat needs (mobile over large areas that include a mix of remote, urbanized and industrialised areas).

19b. Per- and polyfluoroalkyl substances (PFAS)

The State of Washington is implementing a suite of actions (Washington Department of Ecology, 2025) to reduce contamination in SRKW, including regulations targeting PFAS (2021).

Participants **recommend** that regulatory priority be given to new and emerging contaminants of concern in both Canada and the U.S., including the per- and polyfluoroalkyl substances (PFAS). The fate and effects of the ~15,000 members of this category of chemicals are poorly understood, but are seen to be of increasing concern in the environment.

20. Prioritize water quality within salmon habitat

Beyond abundance, the quality of salmon, particularly Chinook salmon, has been deemed critical to the health, reproduction, and recovery of SRKWs. Freshwater Chinook habitat continues to face multiple threats, including stormwater and road runoff that often contain oil, road salt, and toxic compounds from brake and tire wear -like 6PPD-quinone, as well as agricultural, forestry and railroad bed pesticides. Industrial and municipal wastewater also carries a suite of harmful pollutants. These contaminants enter waterways where they can directly impact the health and survival of salmonids (Scholz et al. 2000, Meador et al. 2006, Tierney et al. 2010, McIntyre et al. 2015, Brown et al. 2024), and/or their quality as prey for SRKWs (Krahn et al 2007, Wasser et al. 2017, Holbert et al. 2024). Protecting and restoring salmon habitat must therefore include a focus on water quality.

Participants **recommend** that freshwater salmon habitat (Figure 1), draining to SRKW Critical Habitat, be viewed as important to the recovery of SRKWs, and that land use and other activities that contribute to degraded water quality be evaluated as potential stressors on both SRKWs and Pacific salmon species, and addressed accordingly.

21. Remove loopholes in vessel wastewater regulations that prevent protection of SRKW and their habitat

There have been long-awaited improvements to the management of liquid (grey and black water) waste from vessels, notably cruise ships, in recent years (2023). With cruise ships carrying as many as 6,000 passengers plus crew, these vessels must process and release large amounts of liquid waste, which invariably contains PPCPs, fecal coliform, metals and hydrocarbons. However, the loopholes in the most recent Canadian regulations allow for the release of treated greywater and blackwater outside of 3 NM from shore — or even within 3 NM of shore in certain circumstances, thus allowing cruise ships to discharge treated grey and blackwater pretty much anywhere in B.C. waters.

Participants **recommend** that current loopholes be closed, and that compliance be monitored through regular inspections and enforcement. Without changes in the Canadian regulatory environment, B.C. risks becoming a dumping ground for cruise ship wastes accumulated in Canada as well as those accumulated in US waters, where discharge rules are stricter (i.e., see Washington Department of Ecology, 2025b).

22. Scrubber wastewater from large vessels should be eliminated as a major source of acids, metals and hydrocarbons to SRKW habitat

Heavy Fuel Oils should be banned from vessel use within Canada's territorial waters as a means to reduce harmful air pollution and water pollution. Scrubbers have been installed on many large vessels as a more cost effective way of reducing atmospheric pollution and avoiding a switch to cleaner-burning, but more costly, fuel oils. This has improved air quality in coastal areas, including the cities of Victoria and Vancouver, but at a cost. Rather than being released into the atmosphere, the pollution is released into the water. This introduces harmful metals and other compounds that can impact plankton, fish, and other marine wildlife. The Port of Vancouver has implemented a ban on the discharge of scrubber wastewater within areas of the Port's jurisdiction, but once 3 NM away from shore, discharge is allowed.

Participants agreed that scrubber wastewater presents an unacceptable risk to SRKWs, and **recommend** that the use of heavy fuel oils in Canada's territorial waters cease.

23. Review provincial regulations for disposal of biosolids and improve monitoring of chemicals in biosolids

Biosolids from municipal wastewater treatment plants contain a wide variety of contaminants of concern, but current guidance and legislation in B.C. (Canada) only stipulates that metals and fecal coliform be determined before application to farms, forests and mining reclamation projects. The B.C. Environmental Management Act (EMA) Organic Matter Recycling Regulation (OMRR) follows the Canadian Council of Ministers of the Environment (CCME) "*Canada-wide approach for the management of wastewater biosolids*". The 'Approach' promotes the beneficial use of resources including nutrients, organic matter and energy contained within municipal biosolids, municipal sludge and treated septage.

Participants **recommend** the following: the CCME should review and modernize its guidance for the screening and use of biosolids, and the B.C. OMRR should expand its

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measurement of contaminants of concern including — but not limited to — per- and polyfluoroalkyl substances (PFAS), polycyclic aromatic hydrocarbons (PAHs), pesticides, pharmaceuticals and microplastics. New or existing guidelines should be applied to these contaminants if biosolids are to be used or sold for applications to farms, forests, or mines in watersheds, where they can enter streams, rivers, lakes and marine waters. Source control, regulations and treatment provide opportunities to 'clean up' the nutrient-rich biosolids.

24. Commercial pesticide formulations should identify and list adjuvants added to active ingredients to better evaluate environmental risk

Adjuvants (sometimes referred to as inert ingredients or additives) are used in pesticides as a means of enabling adequate dispersal — or not — of the applied product. Does the application practice for the pesticide target the pest by coating plants, embedding itself in the soil, or remaining in granules? While designed to improve the efficacy of the pesticide in targeting the pest, some adjuvants have been associated with significant endocrine disruption and severe impacts on salmon. For example, the adjuvant nonylphenol ethoxylate in the spruce budworm pesticide Aminocarb was associated with the loss of millions of Atlantic salmon returning to New Brunswick rivers (Fairchild et al. 1999).

Participants **recommend** that the Pest Management Regulatory Agency (PMRA; Health Canada) evaluate the full list of compounds found in commercial pesticide products using a suitable risk-based model, and the full list of ingredients must be made available to the public.

25. Improve stormwater management

Non-point source contamination in urban areas is increasingly seen as a significant source of water pollution. The identification of the tire chemical breakdown product 6PPD-quinone as the likely agent responsible for the deaths of as much as 90% of pre-spawn coho salmon in areas of Washington state (Tian et al., 2021) has renewed concerns about the role of impervious surfaces and artificial turf in delivering harmful pollutants to salmon habitat in B.C. The contamination of salmon, or a contaminant-associated injury to salmon, both have the potential to impact SRKWs by reducing the abundance or the quality of adult salmon.

Participants **recommend** that the federal government establish an intergovernmental panel that collates updated scientific findings on contaminants of emerging concern in salmon habitat and distributes results to policy and management circles in municipal, regional and wastewater authorities, as well as provincial and federal governments. Participants **recommend** safe disposal of tires and immediate regulations for 6PPD and related tire additives.

26. Oil spill plans should be reviewed and made transparent

The three-fold increase in TMX pipeline capacity to Westridge Terminals, the consequent seven-fold increase in petroleum tanker traffic, and the proposed expansion of the Roberts Bank Terminal all point to increased risk of an oil or chemical spill. Virtually all of this increased tanker traffic transits the designated SRKW Critical Habitat. While this results in notable increases in underwater noise, air pollution and scrubber wastewater discharges that demand attention, an updated review of oil spill plans for vessels of all sizes is timely and necessary. With SRKWs being a small and reproductively isolated population, any spill, even small spills, could lead to extinction (Jarvella-Rosenberger et al. 2017).

Participants **recommend** the following: 1) Tankers and other commercial vessels must be subject to inspection and enforcement to ensure safe operations in B.C. waters; 2) Tug escorts must be deployed seamlessly to provide backup safety; 3) Pilots and vessel crews must be aware of the presence (and needs) of SRKWs and the boundaries of their Critical Habitat; 4) Western Canada Marine Response Corporation (WCMRC) and Indigenous Guardians must receive updated training and perform inspections of equipment and response vessels. Indigenous Nations have increasing capacity to respond to oil and chemical spills in B.C. (WCMRC, 2025).

Oil and chemical spill response

In British Columbia, a spill response typically includes representatives from the polluter, Canadian Coast Guard, affected First Nations and municipalities, the B.C. Ministry of Environment and Climate Change Strategy, Transport Canada, the Department of Fisheries and Oceans, Environment and Climate Change Canada and WCMRC. NOAA Fisheries has a spill response plan for SRKW (NOAA Fisheries 2025).

Western Canada Marine Response Corporation (WCMRC) is an industry-funded organization with more than 2,300 members. Membership is mandatory for vessels of a certain size calling on Canadian ports, as well as for oil-handling facilities receiving or shipping oil across their docks. WCMRC is activated by the Polluter or Canadian Coast Guard.

4. Research recommendations

The panel debated whether to include a list of research recommendations in this report, because current science already points to what needs to be done. Nearly all of the recommendations presented in this report can, and in our opinion should, be implemented without further delay. However, ongoing research in an adaptive management framework can play an important role in detecting whether threats are changing over time and whether our management actions are achieving the desired effect. Acknowledging that caveat, we present research recommendations identified by the panel to directly advance SRKW recovery objectives and guide the implementation of future conservation measures.

This list is not exhaustive, but it does prioritize those questions that address key threats, inform management actions, measure effectiveness of those actions, and contribute to evidence-based recovery strategies.

Importantly, the impact of research itself on SRKWs must be carefully considered. Some data collection methods (such as frequent vessel-based follows and DTAG deployments, both of which often require close and prolonged approaches to the whales) can introduce additional stress to an already vulnerable population. A cost-benefit analysis should be applied to assess whether the knowledge gained from a given study justifies the potential disturbance it causes. Non-invasive or minimally invasive approaches should be prioritized wherever possible, ensuring that research efforts support rather than compromise the well-being of the population.

This section outlines key research gaps and opportunities that will enhance our understanding of SRKW health, prey availability, noise impacts and social structure — areas of study that will guide effective conservation action.

1. Continue body condition monitoring and add additional metrics to evaluate SRKW health

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- Aerial photogrammetric monitoring should be continued and used to assess nutritional condition using eye patch ratios, reproductive condition (pregnancy and calving success) and length-based growth rates.
- Update SRKW body condition relationships with more recent data; extend the analysis to consider seasonal patterns in body condition and abundance estimates for focal Chinook salmon stocks and additional SRKW prey species.
- Establish biologically meaningful thresholds for poor body condition based on other health indicators.
- Identify drivers of body condition in addition to prey availability — this may require fine-scale analyses at the individual level.
    - Investigate impacts of factors other than prey on SRKW body condition. E.g. How do social and demographic factors and social connectedness affect body condition?
    - Broaden body condition assessments to include multiple health metrics (e.g., fecal, blow, and skin condition), using minimally invasive data collection methods).
- Strengthen collaboration in SRKW health monitoring programs, with an emphasis on data sharing.

2. Develop an index of salmon abundance that reflects SRKW dietary preferences

- Evaluate Chinook salmon prey abundance indices that better reflect SRKW prey preferences and seasonal foraging patterns to improve understanding of prey availability. Such an index could incorporate factors such as Chinook population life histories, age and size classes, and stock composition.

- Develop an integrated or composite “super index” that could offer a more comprehensive and nuanced understanding of prey availability, including considerations for chum and coho salmon

3. Continue investigating how noise affects echolocation and foraging behaviour in SRKWs

- Use aerial observations to determine if successful prey capture events can be reliably detected acoustically, and whether whales catch fish while traveling.
- Study potential Lombard effect in echolocation i.e. how whales adjust their echolocation in noisy conditions (perhaps during focal follows).
- Prioritize the development of less invasive, longer-duration tags to enhance the quality and quantity of behavioural and acoustic data collected.

4. Investigate non-foraging impacts of noise and environmental factors on SRKWs

- Investigate the specific acoustic features of SRKW communication used in coordinating group foraging and prey sharing, and assess how noise may interfere with these signals and associated behaviours.
- Study changes in stress physiology, and other potential sub-lethal impacts of noise exposure, using indicators like hormone levels from blow and fecal sampling.
- Quantify communication range loss and acoustic transmission loss due to noise, and define the critical range for intra-matriline communication and group cohesion and coordination.
- Explore how environmental cues such as tides, currents, weather and wave action affect SRKW behaviour and communication.

5. Expand prey fragment sampling and fecal genetic efforts to improve dietary insights

- Analyze prey fragment samples to identify species, stocks, and age classes consumed by SRKWs in a greater portion of their range and throughout the annual cycle to improve understanding of prey selection.

- Account for spatial and seasonal variability in diet; recognizing that SRKWs do not feed exclusively on Chinook salmon and may shift prey preferences seasonally and interannually.

- Collect samples from SRKW key foraging areas that are currently data limited, including the mouth of the Fraser River, northern Strait of Georgia and Puget Sound.

- Investigate the flexibility of SRKW foraging behaviour:

  - What drives spatial or temporal shifts in foraging areas?

  - Are there differences in foraging areas between J pod, K and L pods? Address data gaps in prey selectivity between J, K and L pods. These dietary differences would be important to know.

- Conduct behavioural observations from the mouth of the Fraser River to Point Roberts to better understand foraging patterns.

6. Examine SRKW foraging efficiency in relation to salmon abundance

- Use focal follows to estimate catch-per-unit-effort (CPUE) by whales across different environmental and prey contexts (e.g., foraging area, Chinook salmon abundance) to better understand prey selectivity and detect periods of food stress. This approach is relatively non-invasive and could be paired with prey fragment sampling.

7. Determine optimal soundscapes for SRKWs

- Identify the acoustic characteristics of habitats that best support SRKW foraging, communication, and social behaviour. This habitat use and metric-focused research avenue is associated with recovery recommendation #7: Develop and implement regional noise reduction targets that are spatially, temporally and biologically relevant.

- Establish a standardized methodology and a set of biologically relevant metrics that can be used to assess the benefits of current and future management actions.

8. Quantify recreational vs. commercial fishing noise at Swiftsure Bank

- Assess the relative contribution of noise from recreational versus commercial fishing vessels at Swiftsure Bank to determine which sector has the greatest impact on the local acoustic environment.

9. Continue social network research to understand population integrity

- Examine how social demographics influence SRKW population structure and levels of individual interaction.
- Determine how social dynamics might reflect demographic health, and explore how this knowledge informs conservation actions and recovery timelines.
- Assess how the loss of key individuals disrupts group stability and behaviour.
- Investigate how social relationships affect foraging behaviour, including potential differences between males and females in hunting strategies and prey sharing.
- Monitor ongoing shifts in social structure to understand how SRKWs function as a unit and adapt to environmental change.

10. Evaluate and prioritize habitat restoration in key Chinook spawning and rearing areas

- In addition to addressing critical flow thresholds and fish passage raised in recovery recommendation #6, degraded freshwater and marine habitats exist throughout the rearing, spawning and migratory habitats of Chinook salmon including, for example, water quality issues behind migration barriers like flood gates. Habitat assessments should be conducted to identify areas with the highest potential to increase productivity, followed by the implementation of scientifically sound restoration plans.

11. Address knowledge gap on the amount, type, and location of pesticides applications in Canada

- Identify the type, quantity, and location of pesticide applications in Canada, particularly in areas adjacent to critical SRKW habitat and in watersheds supporting salmon spawning.

12. Contaminant research and monitoring

- Establish dedicated funding for research and monitoring on the presence, extent, and trends of contaminants of concern, and their effects, in salmon and whale habitat, with participation from academia, Indigenous communities, governments, and NGOs.

- Conduct regular status reviews on contaminants of emerging concern, their presence, environmental distribution, fate and effects, and publish them (annually) to document trends in valued ecosystem components (SRKW, proxy species, salmon and sediments) and to characterise response to regulations and source control.

- Use these status reports to provide an integrated assessment of contaminants of emerging concern, priorities in SRKWs, their prey, and their habitat, and assist in conservation, protection and restoration strategies in marine and freshwater environments.

- Conduct research on the extent of, and effects of, road runoff in areas adjacent to roads and other impervious surfaces, with a focus on salmon.

5. Works cited

Alava, J.J., Ross, P.S., Lachmuth, C.L., Ford, J.K.B., Hickie, B.E. and Gobas, F.A.P.C. 2012. Habitat-based PCB environmental quality criteria for the protection of endangered killer whales (*Orcinus orca*). *Environ. Sci. & Tech.*, 46: 12655-12663. https://doi.org/10.1021/es303062q

Atlas, W. I., Sloat, M.R., Satterthwaite, W.H., Buehrens, T., Parken, C.K., Moore, J.W., Mantua, N.,Hart, J., & Potapova, A. (2023). Trends in Chinook salmon spawner abundance and total run size highlight linkages between life history, geography and decline. *Fish & Fisheries*, 24, 595–617. https://doi.org/10.1111/faf.12750

Atlas, W.I., Ban, N.C., Moore, J.W., Tuohy, A.M., Greening, S., Reid, A.J., Morven, N., White, E., Housty, W.G., Housty, J.A. Service, C.N., Greba, L. Harrison, S., Sharpe, C., Butts, C.I.R., Shepert, W.M., Sweeney-Bergen, E., Macintyre, D., Sloat, M.R., Connors, K. 2021. Indigenous Systems of Management for Culturally and Ecologically Resilient Pacific Salmon (*Oncorhynchus* spp.) Fisheries, *BioScience*, Vol 71, Issue 2, Pages 186–204, https://doi.org/10.1093/biosci/biaa144

Bigg, M.A. (1982). An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Report of the International Whaling Commission, 32, 655–666.

Bigg, M.A., Olesiuk, P.F., Ellis, G.M., Ford, J.K.B., & Balcomb, K.C. (1990). Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission, Special Issue 12, 383–405.

Brown, T.M., Reger, S., Liao, X., Gallilee, C. (2023). Identifying and characterizing tire-related chemical (6PPD-quinone) toxic hotspots in salmon habitat in British Columbia, Canada. Canadian Ecotoxicology Workshop, Ottawa, Ontario, October 2-5.

Brown, T.M., Thornton, S., Xiao, X., Ross, A., Warner, A., & Barrett-Lennard, L. (2025). Contaminant associated health effects revealed through a non-invasive metabolomics platform in at-risk killer whales in the Northeastern Pacific. 5th international symposium on orcas, Tarifa, Spain, February 16-25.

Buckman, A.H., Veldhoen, N., Ellis, G., Ford, J.K.B., Helbing, C., and Ross, P.S. 2011. PCB-associated changes in mRNA expression in killer whales (*Orcinus orca*) from the NE Pacific Ocean. *Environ. Sci. & Tech.* 45: 10194-10202. https://doi.org/10.1021/es201541j

Burnham, R.E., Vagle, S., Thupaki, P. & Thornton, S.J. (2023). Implications of wind and vessel noise on the sound fields experienced by southern resident killer whales *Orcinus orca* in the Salish Sea. *Endang. Species Res.*, 50, 31–46. https://doi.org/10.3354/esr01217

Chilcote, M.W., Goodson, K.W. & Fallacy, M.R. (2011). Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. *Can. J. of Fish & Aq. Sci.* 68(3): 511-522. https://doi.org/10.1139/F10-168

COSEWIC. (2018). COSEWIC assessment and status report on the Chinook Salmon (*Oncorhynchus tshawytscha*), Designatable Units in Southern British Columbia (Part One – Designatable Units with no or low levels of artificial releases in the last 12 years). Committee on the Status of Endangered Wildlife in Canada. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

COSEWIC. (2020). COSEWIC assessment and status report on the Chinook Salmon (*Oncorhynchus tshawytscha*), Designatable Units in Southern British Columbia (Part Two – Designatable Units with high levels of artificial releases in the last 12 years). Committee on the Status of Endangered Wildlife in Canada. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

CRITFC. 2014. Spirit of Salmon 2014 Plan Update. Wy-Kan-Ush-Mi Wa-Kish-Wit. Columbia River Inter-Tribal Fish Commission. Available at: https://plan.critfc.org/2013/spirit-of-the-salmon-plan/about-spirit-of-the-salmon/wy-kan-ush-mi-wa-kish-wit-update/

Cullon, D.L., Yunker, M.B., Alleyne, C., Dangerfield, N.J., O'Neill, S., Whiticar, M.J., and Ross, P.S. (2009). Persistent organic pollutants in chinook salmon (*Oncorhynchus tshawytscha*): implications for resident killer whales of British Columbia and adjacent waters. *Environ. Toxicol. Chem.* 28: 148-161. https://doi.org/10.1897/08-125.1

Desforges, J.P., Hall, A., McConnell, B., Asvid, A.R., Barber, J.L., Brownlow, A., De Guise, S., Eulaers, J., Jepson, P.D., Letcher, R.J., Levin, M., Ross, P.S., Samarra, F., Víkingson, G., Sonne, C. & Dietz, R. (2018). Predicting global killer whale population collapse from PCB pollution. *Science* 361: 1373-1376. https://doi.org/10.1126/science.aat1953

DFO. 2020. Recovery Potential Assessment for 11 Designatable Units of Fraser River Chinook Salmon, Oncorhynchus tshawytscha, Part 1: Elements 1 to 11. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/023.

DFO. 2021. Recovery Potential Assessment for 11 Designatable Units of Fraser River Chinook Salmon, Oncorhynchus tshawytscha, Part 2: Elements 12 to 22. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/030.

DFO. 2025. Southern Resident Killer Whale Prey Selectivity in Relation to Chinook Salmon Stock and Size Composition within Canadian Critical Habitat. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2025/016.

Dolman, J. N., Matthews, M.-N. R., Hannay, D. E., Grooms, C. H., & Li, Z. (2024). Vessel underwater radiated noise (URN) analysis in support of Underwater Vessel Noise Reduction Targets (UVNRT) Working Group. Technical report by JASCO Applied Sciences for Transport Canada Innovation Centre.

Emmons, C. K., Hanson, M. B., & Lammers, M. O. (2021). Passive acoustic monitoring reveals spatiotemporal segregation of two fish-eating killer whale (*Orcinus orca*) populations in proposed critical habitat. *Endang. Species Res.*, 44. https://doi.org/10.3354/esr01099

Environment Canada. 1999. Health of the Fraser River Aquatic Ecosystem Vol. I: A Synthesis of Research Conducted under the Fraser River Action Plan. Eds: Gray, C. Tuominen, T. In 1998; Vol. DOE FRAP 1998-11.

Erbe, C., Marley, S.A., Schoeman, R.P., Smith, J.N., Trigg, L.E. & Embling, C.B. (2019). The effects of ship noise on marine mammals-A review. *Front. Mar. Sci*, 6, 606. https://doi.org/10.3389/fmars.2019.00606

Fairchild, W.L., Swansburg, E.O., Arsenault, J.T., & Brown, S. (1999). Does an association between pesticide use and subsequent declines in catch of Atlantic salmon (Salmo salar) represent a case of endocrine disruption? *Env. Health Persp.* 107: 349 – 358. https://doi.org/10.1289/ehp.99107349

Fearnbach, H., Durban, J. W., Barrett-Lennard, L. G., Ellifrit, D. K., & Balcomb, K. C. (2020). Evaluating the power of photogrammetry for monitoring killer whale body condition. *Mar. Mam. Sci.*, 36, 359–364. https://doi.org/10.1111/mms.12642

Fearnbach, H., Durban, J.W., Ellifrit, D.K. & Balcomb, K.C.. (2018). Using aerial photogrammetry to detect changes in body condition of endangered southern resident killer whales. *Endang. Species Res.* 35: 175–180. https://doi.org/10.3354/esr00883

Fearnbach H., Durban, J.W., Ellifrit, D.K., & Balcomb K.C. (2011). Size and long-term growth trends of Endangered fish-eating killer whales. Endang. Species Res. 13:173-180 https://doi.org/10.3354/esr00330

Fearnbach, H. & Durban, J. W. (2022). Final Programmatic Report to National Fish and Wildlife Foundation. Monitoring the Nutritional Health of Southern Resident Killer Whales for Management (WA). Grant 66318.

Findlay, C. R., Rojano-Doñate, L., Tougaard, J., Johnson, M. P., & Madsen, P. T. (2023). Small reductions in cargo vessel speed substantially reduce noise impacts to marine mammals. *Sci. Advances*, 9, eadf2987. https://doi.org/10.1126/sciadv.adf2987

Finn, Riley J.R, Chalifour, L., Gerge, S.E., Hinch, SG.. Scott, D.C .& Martin, TG. (2021). Quantifying lost and inaccessible habitat for Pacific salmon in Canada's Lower Fraser River. *Ecosphere* 12, no. 7: e03646. https://dx.doi.org/10.1002/ecs2.3646

Fisheries and Oceans Canada. (2025). Southern Resident Killer Whale prey selectivity in relation to Chinook salmon stock and size composition within Canadian critical habitat. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2025/016).

Ford, J.K.B., Wright, B.M., Ellis, G.M. & Candy, J.R. (2010). Chinook salmon predation by resident killer whales: Seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/101.

Ford, J.K.B., Pilkington, J.F., Reira, A., Otsuki, M., Gisborne, B., Abernethy, R. M., Stredulinsky, E. H., Towers, J. R. & Ellis, G.M. (2017). Habitats of special importance to resident killer whales (*Orcinus orca*) off the west coast of Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep., 2017/035, viii + 57 pp.

Gayeski, N., Tuohy, A. & Jorgenson, A. (2020). Evaluation of pound nets as stock selective fishing tools in the lower Columbia River basin. Final Report prepared for NOAA Fisheries Service Bycatch Reduction Engineering Program (BREP). Wild Fish Conservancy.

Gayeski, N., Swanson, D., MacDuffee, M. & Rosenberger, A. (2024). Productivity and resilience of Chinook salmon compromised by 'Mixed-Maturation' fisheries in marine waters. *bioRxiv*. unpublished preprint https://doi.org/10.1101/2024.04.25.591098

Gronsdahl, S., Moore, R.D., Rosenfeld, J., McCleary, R. & Winkler, R. (2019). Effects of forestry on summertime low flows and physical fish habitat in snowmelt-dominant headwater catchments of the Pacific Northwest. *Hydrolog. Processes*, 33(21), 3152–3168. https://doi.org/10.1002/hyp.13580

Government of Canada. (2018). Southern resident killer whale: Imminent threat assessment. Assessment prepared under the Species at Risk Act. https://www.canada.ca

Government of Canada. (2024). Southern resident killer whale (*Orcinus orca*): Imminent threat assessment 2024. Assessment prepared under the Species at Risk Act. https://www.canada.ca

Government of Canada. (2025). Government of Canada's approach to addressing the imminent threats to killer whale, Northeast Pacific southern resident population. Decision issued under the Species at Risk Act. https://www.canada.ca

Hall, A.J., McConnell, B.J., Schwacke, L.H., Ylitalo, G.M., Williams, R. and Rowles, T.K., (2018). Predicting the effects of polychlorinated biphenyls on cetacean populations through impacts on immunity and calf survival. *Environ. Poll*. 233, 407-418. https://doi.org/10.1016/j.envpol.2017.10.074

Hanson, M.B., Baird, R.W., Ford, J.K.B., Hempelmann-Halos, J., Van Doornik, D M., Candy, J.R., Emmons, C.K., Schorr, G.S., Gisborne, B., Ayres, K.L., Wasser, S.K., Balcomb, K.C., Balcomb-Bartok, K., Sneva, J.G. & Ford, M.J. (2010). Species and stock identification of prey consumed by endangered Southern Resident killer whales in their summer range. *Endang. Species Res.*, 11, 69–82. https://doi.org/10.3354/esr00263

Hanson, M.B., Emmons, C.K., Ford, M.J., Everett, M., Parsons, K., Park, L. K., et al. (2021). Endangered predators and endangered prey: Seasonal diet of Southern Resident killer whales. *PLoS ONE*, 16(3), e0247031. https://doi.org/10.1371/journal.pone.0247031

Harris K.A., Dangerfield N., Woudneh M., Brown T.G., Verrin S. & Ross, P.S. (2008). Partitioning of current-use and legacy pesticides in salmon habitat in British Columbia, Canada. *Environ. Toxicol. & Chem.* 27:2253-2262. https://doi.org/10.1897/07-651.1

Holbert, S., Colbourne, K. Fisk, A.T.. Ross, P.S., MacDuffee, M., Gobas, F.A.P.C., Brown, T.M. (2024). Polychlorinated biphenyl and polybrominated diphenyl ether profiles vary with feeding ecology and marine rearing distribution among 10 Chinook salmon (*Oncorhynchus tshawytscha*) stocks in the North Pacific Ocean. *Environ. Res.* Vol 241. https://doi.org/10.1016/j.envres.2023.117476

Holt, M.M., Tennessen, J.B., Ward, E.J., Hanson, M.B., Emmons, C.K., Giles, D.A., & Hogan, J.T. (2021a). Effects of vessel distance and sex on the behavior of endangered killer whales. *Front. Mar. Sci.*, 7, 582182. https://doi.org/10.3389/fmars.2020.582182

Holt, M.M., Tennessen, J.B., Hanson, M.B., Emmons, C.K., Giles, D.A., Hogan, J.T. & Ford, M.J. (2021b). Vessels and their sounds reduce prey capture effort by endangered killer whales (*Orcinus orca*). *Mar. Environ. Res.*, 170, 105429. https://doi.org/10.1016/j.marenvres.2021.105429

IMO Secretariat. (2023). Outcome of the workshop on the relationship between energy efficiency and underwater radiated noise from ships. IMO Document SDC 10/INF.3.

Jarvela-Rosenberger, A.L., MacDuffee, M., Rosenberger A.G.J. & Ross, P. (2017). Oil spills and marine mammals in British Columbia, Canada: development and application of a risk-based conceptual framework. *Arch. Environ. Contamin. & Tox.* 73: 131-153. DOI: 10.1007/s00244-017-0408-7

Joy, R., Tollit, D., Wood, J., MacGillivray, A., Li, Z., Trounce, K. & Robinson, O. (2019). Potential benefits of vessel slowdowns on endangered Southern Resident Killer Whales. *Front. Mar. Sci.*, 6, 344. https://doi.org/10.3389/fmars.2019.00344

King, M.D., Rodgers, T.F.M., Sharma, G., Reger, S., Liao, X., Ross, A.R.S., Mueller, M., Drew, S., Scholes, R.C. & Brown, T.M. 2025. Tracking 6PPD-Quinone dynamics in a coho salmon-bearing stream following rain reveals elevated concentrations for multi hour periods during high flow. *Env. Sci & Tech. Letters.* https://doi.org/10.1021/acs.estlett.5c00477.

Krahn M.M., Hanson, M.B., Baird R.W,. Boyer R.H., Burrows D.G., Emmons C.K., Ford J.K, Jones L.L, Noren D.P., Ross P.S., Schorr G.S. & Collier T.K. (2007). Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. *Mar. Poll. Bull.* 54(12):1903-11. https://doi.org/10.1016/j.marpolbul.2007.08.015

Lo, B., Marlatt, V.L., Liao, X., Reger, S., Gallilee, C. Ross, A.R.S., Brown, T.M. (2023). Acute Toxicity of 6PPD-Quinone to Early Life Stage Juvenile Chinook (*Oncorhynchus tshawytscha*) and Coho (*O. kisutch*) salmon. *Environ. Tox. Chem.*, 42: 815–822. https://doi.org/10.1002/etc.5568

Lerner, J.E., & Hunt, B.P.V. (2023). Seasonal variation in the lipid content of Fraser River Chinook Salmon (*Oncorhynchus tshawytscha*) and its implications for Southern Resident Killer Whale (*Orcinus orca*) prey quality. *Sci. Reports*, 13, 2675. https://doi.org/10.1038/s41598-023-28321-9

Levin, P.S., Zabel, R.W. & Williams, J.G. (2001). The road to extinction is paved with good intentions: Negative association of fish hatcheries with threatened salmon. *Proc R. Soc. B: Bio Sci.* 268(1472), 1153–1158. https://doi.org/10.1098/rspb.2001.1634

Lundin, J.I., Dills, R.L., Ylitalo, G.M., Hanson, M.B., Emmons, C.K., Schorr, G.S., Ahmad, J., Hempelmann, J.A., Parsons, K.M. & Wasser, S.K. (2016). Persistent organic pollutant determination in killer whale scat samples: Optimization of a gap chromatography/mass spectrometry method and application to field samples. *Arch. Environ. Contam. Toxicol*. 70: 9-19. DOI: 10.1007/s00244-015-0218-8

MacDonald, D., Sinclair, J., Crawford, M., Prencipe, H., Meneghetti, M. (2011). Potential effects of contaminants on Fraser River sockeye salmon. MacDonald Environmental Sciences Ltd. Cohen Commission Tech. Rep. 2: 164p & appendices. Vancouver, B.C. www.cohencommission.ca.

MacGillivray, A.O., Li, Z., Hannay, D.E., Trounce, K.B., & Robinson, O.M. (2019). Slowing deep-sea commercial vessels reduces underwater radiated noise. *J. Acoust. Soc. Am.*, 146(1), 340–351. https://doi.org/10.1121/1.5116140

MacGillivray, A.O., Stothart, F.M.C., Grooms, C.H., Li, Z. & Zykov, M.M. (2025). Ocean noise contributors in southern resident killer whale habitat. *Mar. Poll. Bull.*, 215, 117859. https://doi.org/10.1016/j.marpolbul.2025.117859

McIntyre, J.K., Davis, J.W., Hinman, C., Macneale, K.H., Anulacion, B.F., Scholz, N.L. & Stark, J.D. (2015). Soil bioretention protects juvenile salmon and their prey from the toxic impacts of urban stormwater runoff. *Chemosphere*, 132, 213–219. https://doi.org/10.1016/j.chemosphere.2014.12.052

Manishin K.A., Cunningham C.J., Westley P.A.H. & Seitz A.C. (2021). Can late-stage marine mortality explain observed shifts in age structure of Chinook salmon? *PLOS ONE* 16:e0247370 https://doi.org/10.1371/journal.pone.0247370

McKenna, M.F., Wiggins, S.M., & Hildebrand, J.A. (2013). Relationship between container ship underwater noise levels and ship design, operational, and oceanographic conditions. *Sci. Reports*, 3, 1760. https://doi.org/10.1038/srep01760

McMillan, J.R., Morrison, B., Chambers, N., Ruggerone, G., Bernatchez, L., Stanford, J. et al. (2023). A global synthesis of peer-reviewed research on the effects of hatchery salmonids on wild salmonids. *Fish. Mgmt & Ecol.*, 30, 446–463. https://doi.org/10.1111/fme.12643

Meador, J.P., Sommers, F.C., Yitalo, G. & Sloan, C. (2006). Altered growth and related physiological responses in juvenile Chinook salmon (*Oncorhynchus tshawytscha)* from dietary exposure to polycyclic aromatic hydrocarbons (PAH). *Can. J. of Fish. & Aq. Sci.*. 63. 2364-2376. https://dx.doi.org/10.1139/f06-127

Meador, J.P. (2014). Do chemically contaminated river estuaries in Puget Sound (Washington, USA) affect survival rate of hatchery-reared Chinook salmon? *Can. J. of Fish & Aq. Sci.*. 71: 162-180. https://doi.org/10.1139/cjfas-2013-0130

Meador, J.P. (2015). Tissue Concentrations as the dose metric to assess potential toxic effects of metals in field-collected fish: copper and cadmium. *Env. Toxicology & Chem*. 34(6): 1309-1319. https://doi.org/10.1002/etc.2910

Meador, J.P., Yeh, A., Gallagher, E.P. (2018). Adverse metabolic effects in fish exposed to contaminants of emerging concern in the field and laboratory. *Environ. Pollut.* 236: 850-861. https://doi.org/10.1016/j.envpol.2018.02.007

Muir, D.C.G. and Howard, P.H. (2006). Are there other Persistent Organic Pollutants? A challenge for environmental chemists. *Environ. Sci. & Technology* 2006, 40, 23, 7157–7166. https://doi.org/10.1021/es061677a

Murchy, K.A., Vagle, S. & Juanes, F. (2022). Anchored bulk carriers have substantial impacts on the underwater soundscape in Cowichan Bay, British Columbia. *Mar. Poll. Bull.*, 182, 113921. https://doi.org/10.1016/j.marpolbul.2022.113921

Nattrass, S., Croft, D.P., Ellis, S., Cant, M.A., Weiss, M.N., Wright, B.M., Stredulinsky, E., Doniol-Valcroze, T., Ford, J.K.B., Balcomb, K.C., & Franks, D.W. (2019). Post Reproductive killer whale grandmothers improve the survival of their grandoffspring. *Proceed. of the Nat. Acad. Sci. U.S.A.* 116(52), 26669–26673. https://doi.org/10.1073/pnas.1903844116

Nelson, B.W., Ward, E J., Linden, D.W., Ashe, E., & Williams, R. (2024). Identifying drivers of demographic rates in an at-risk population of marine mammals using integrated population models. *Ecosphere*, 15(2), e4773. https://doi.org/10.1002/ecs2.4773

Nielsen, M.L.K., Ellis, S., Towers, J.R., et al. (2021). A long postreproductive life span is a shared trait among genetically distinct killer whale populations. *Ecol. Evol.* 11, 9123–9136. https://doi.org/10.1002/ece3.7756

NOAA (2023). Washington State Reef Net Fisheries. Current Classification on the List of Fisheries. https://www.fisheries.noaa.gov/marine-mammal-protection/washington-salmon-reef-net-fishery-mmpa-list-fisheries#current-classification-on-the-list-of-fisheries

NOAA Fisheries. Accessed 2025: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/oil-spill-response-and-killer-whales.html

Ohlberger, J, Ward, E.J, Schindler, D.E. & Lewis, B. (2018). Demographic changes in Chinook salmon across the Northeast Pacific Ocean. *Fish & Fisheries* 19: 533 – 546. https://doi.org/10.1111/faf.12272

Oke, K.B., Cunningham, C.J,. Westley, P.AH., Baskett, M.L., Carlson S.M., Clark, J., et al. (2020). Recent declines in salmon body size impact ecosystems and fisheries. *Nature Comm.* 11:4155 | https://doi.org/10.1038/s41467-020-17726-z.

Randon, M., Dowd, M., & Joy, R. (2022). A real-time data assimilative forecasting system for animal tracking. *Ecology*, 103(8), e3718. https://doi.org/10.1002/ecy.3718

Raincoast Conservation Foundation. (2023). AMICI CURIAE Brief of the Raincoast Conservation Foundation, Skeenawild Conservation Trust, Watershed Watch Salmon Society, David Suzuki Foundation et al. in support of the Plaintiffs -Appellants/Cross-Appellees in the United States Court of Appeals for the Ninth Circuit. Available at raincoast.org/wp-content/uploads/2024/02/Amici-brief-CDN-Conservation-Amicus-Part-II-231206.pdf

Remili, A., Brown, T.M. (2025). WHALE, THAT'S TOXIC: A global review of persistent organic pollutants (POPs) in killer whales. 5th international symposium on orcas, Tarifa, Spain, February 16-25.

Ricker, W.E. (1981). Changes in the average size and average age of Pacific salmon. *Can. J. of Fish & Aq. Sci.* 38, no. 12: 1636-1656. https://doi.org/10.1139/f81-213

Rosenfeld, J.S. (2017). Developing flow–ecology relationships: Implications of nonlinear biological responses for water management. *Freshwater Biol*. 62: 1305–1324. https://doi.org/10.1111/fwb.12948

Ross, P.S., Ellis, G.M., Ikonomou, M.G., Barrett-Lennard, L.G. & Addison, R.F. (2000). High PCB concentrations in free-ranging Pacific killer whales, *Orcinus orca*: effects of age, sex and dietary preference. *Mar. Pollut. Bull.* 40: 504-515. https://doi.org/10.1016/S0025-326X(99)00233-7

Ross, P.S. (2006). Fireproof killer whales (*Orcinus orca*): flame-retardant chemicals and the conservation imperative in the charismatic icon of British Columbia, Canada. *Can. J. of Fish & Aq. Sci.*. 63(1): 224-234. https://doi.org/10.1139/f05-244

Ross, P.S. (2010). Impact of at sea disposal on resident killer whale (*Orcinus orca*) Critical Habitat: Science in support of risk management. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.2010/046: 1-9.

Ross, P.S., Noël, M., Lambourn, D.M., Dangerfield, N., Calambokidis, J.C., & Jeffries, S.J. (2013). Declining concentrations of PCBs, PBDEs, PCDEs and PCNs in harbor seals from the Salish Sea. *Prog. Ocean*. 115: 160-170. https://doi.org/10.1016/j.pocean.2013.05.027

Ruggerone, G.T., A.M. Springer, G.B. van Vliet, B. Connors, J.R. Irvine, L.D. Shaul, M.R. Sloat, and W.I. Atlas. (2023). From diatoms to killer whales: impacts of pink salmon on North Pacific ecosystems. *Mar. Ecol. Prog. Series* 719: 1-40. https://doi.org/10.3354/meps14402

Scholz, N.L., Truelove, N.K., French, B.L., Berejikian, B.A., Quinn, T.P., Casillas, E. & Collier, T.K. (2000). Diazinon disrupts antipredator and homing behaviors in chinook salmon (*Oncorhynchus tshawytscha*). *Can. J. of Fish & Aq. Sci.*, 57(9), 1911–1918. https://dx.doi.org/10.1139/cjfas-57-9-1911

Senss, A., Canbulat, O., Uzun, D., Gunbeyaz, S. A. & Turan, O. (2023). Just in time vessel arrival system for dry bulk carriers. *J. of Shipping & Trade*, 8 (12). https://doi.org/10.1186/s41072-023-00141-0

Stewart, J.D., Durban, J.W., Fearnbach, H., Barrett-lennard, L.G., Casler, P.K., Ward, E.J. & Dapp, D.R. (2021). Survival of the fattest: linking body condition to prey availability and survivorship of killer whales. *Ecosphere*, *12*(8), e03660. https://doi.org/10.1002/ecs2.3660

Stewart, J.D., Cogan, J., Durban, J.W., Fearnbach, H., Ellifrit, D.K., Malleson, M.,Pinnow, M. & Balcomb, K.C. (2023). Traditional summer habitat use by Southern Resident killer whales in the Salish Sea is linked to Fraser River Chinook salmon returns. *Mar. Mamm. Sci.* , 39(3), 858–875. https://doi.org/10.1111/mms.13012

Stredulinsky, E.H., Toews, S., Watson, J., Noren, D.P., Holt, M.M., and Thornton, S.J. (2023). Delineating important killer whale foraging areas using a spatiotemporal logistic model. *Global Ecology & Conserv.* 48: e02726. https://doi.org/10.1016/j.gecco.2023.e02726

Stothart, F.M. C., Li, Z. & MacGillivray, A.O. (2023). ECHO modeling of existing and potential future noise scenarios: Haro Strait and Boundary Pass slowdown areas. Technical report by JASCO Applied Sciences for Vancouver Fraser Port Authority.

Sutherland, C. 2011. Cowichan Lake Weir Operation – Rule Curve vs Rule Band. Report to the Cowichan Watershed Board, Kerr Wood Leidal.

Tian Z *et al.* 2021. A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon. *Science* 371, 185-189. DOI:10.1126/science.abd6951

Tennessen, J.B., Holt, M.M., Wright, B.M., Hanson, M.B., Emmons, C.K., Giles, D.A., Hogan, J.T., Thornton, S.J., & Deecke, V.B. (2024). Males miss and females forgo: Auditory masking from vessel noise impairs foraging efficiency and success in killer whales. *Global Change Biol.*, 30, e17490. https://doi.org/10.1111/gcb.17490

Thornton, S.J., S. Toews, E. Stredulinsky, K. Gavrilchuk, C. Konrad, R. Burnham, D.P. Noren, M.M. Holt, and S. Vagle. (2022a). Southern resident killer whale (*Orcinus orca*) summer distribution and habitat use in the southern Salish Sea and the Swiftsure Bank area (2009 to 2020). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep., 2022/037.

Thornton, S.J., Toews, S., Burnham, R., Konrad, C.M., Stredulinsky, E., Gavrilchuk, K., Thupaki, P. & Vagle, S. (2022b). Areas of elevated risk for vessel-related physical and acoustic impacts in Southern resident killer whale (*Orcinus orca*) critical habitat. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep., 2022/058.

Tierney, K.B., Baldwin D.H., Hara T.J., Ross P.S., Scholz N.L., Kennedy C.J. (2010). Olfactory toxicity in fishes. *Aqu. Toxicol*; 96(1):2-26. doi: 10.1016/j.aquatox.2009.09.019.

Tierney, K.B., Sampson,J.L., Ross,P.S., Sekela,M.A. and Kennedy, C.J. (2008) Salmon olfaction is impaired by an environmentally realistic pesticide mixture. Environmental Science & Technology: 42: 4996-5001. https://doi.org/10.1021/es800240u

Tuohy, A.M., Skalski, J.R. & Gayeski, N.J. (2019). Survival of Salmonids from an Experimental Commercial Fish Trap. *Fisheries*, 44: 423-432. https://doi.org/10.1002/fsh.10292

Vard Marine. (2023). Ship energy efficiency and underwater radiated noise. Report by Vard Marine for Transport Canada.

Veirs, S., Veirs V. & Wood J.D. (2016). Ship noise extends to frequencies used for echolocation by endangered killer whales. *PeerJ* 4:e1657 https://doi.org/10.7717/peerj.1657

Veirs, S., Veirs, V., Williams, R., Jasny, M., & Wood, J. (2018). A key to quieter seas: Half of ship noise comes from 15% of the fleet. *PeerJ Preprints*, 6, https://doi.org/10.7287/peerj.preprints.26525v1

Ward, E.J., Holmes, E.E. & Balcomb K.C. (2009). Quantifying the effects of prey abundance on killer whale reproduction. *J. of App. Ecol.* 46. 632-640. https://doi.org/10.1111/j.1365-2664.2009.01647.x

Washington Department of Ecology. Accessed June 2025. https://ecology.wa.gov/waste-toxics/reducing-toxic-chemicals/addressing-priority-toxic-chemicals

Washington Department of Ecology. Accessed 2025b. https://ecology.wa.gov/regulations-permits/permits-certifications/cruise-ship-memorandum-of-agreement-mou

Wasser, S.K., Lundin, J I., Ayres, K., Seely, E., Giles, D., Balcomb, K., Hempelmann, J., Parsons, K. & Booth, R. (2017). Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (*Orcinus orca*). *PLoS ONE*, 12(6), e0179824. https://doi.org/10.1371/journal.pone.0179824

WCMRC (Western Canada Marine Response Corporation) Accessed 2025: https://coastalresponse.ca/wp-content/uploads/2020/11/Marine-Oil-Spill-Response-Community-Guide-Web.pdf

West, J.E., O'Neill, S.M. & Ylitalo, G.M. Time Trends of Persistent Organic Pollutants in Benthic and Pelagic Indicator Fishes from Puget Sound, Washington, USA. *Arch Environ Contam Toxicol* 73, 207–229 (2017). https://doi.org/10.1007/s00244-017-0383-z

Williams, R., Lacy, R.C., Ashe, E., Barrett-Lennard, L., Brown, T.M., Gaydos, J.K., Gulland, F., MacDuffee, M., Nelson, B.W., Nielson, K.A., Nollens, H., Raverty, S., Reiss, S., Ross, P. S., Collins, M. S., Stimmelmayr, R. & Paquet, P. (2024). Warning sign of an accelerating decline in critically endangered killer whales (*Orcinus orca*). *Comm. Earth & Environ.,* 5, 173. https://doi.org/10.1038/s43247-024-01327-5

Williams, R., Erbe, C., Ashe, E., Beerman, A. & Smith, J. (2014). Severity of killer whale behavioral responses to ship noise: A dose–response study. *Mar. Poll. Bulletin*, 79(1–2), 254–260. https://doi.org/10.1016/j.marpolbul.2013.12.004

Williams, R., Veirs, S., Veirs, V., Ashe, E. & Mastick, N. (2019). Approaches to reduce noise from ships operating in important killer whale habitats. *Mar. Poll. Bulletin*,139, pp.459-469. https://doi.org/10.1016/j.marpolbul.2018.05.015

Wladichuk, J.L. (2021). Modelling underwater sound from small vessels in Southern Resident killer whale critical habitat: Noise reductions for increased approach distances of 400, 600, 800, and 1000 m and changes in listening distances (Document 02365, Version 4.0). Technical report by JASCO Applied Sciences for Innovation Centre, Transport Canada.

Zizheng, L., MacGillivray, A.O. & Stothart, F.M.C. (2024). ECHO modeling of existing and future ship noise scenarios—Phase 2: Haro Strait and Boundary Pass slowdown areas. Technical report by JASCO Applied Sciences for Vancouver Fraser Port Authority.

ZoBell, V.M., Frasier, K.E., Morten, J.A., Hastings, S.P., Peavey Reeves, L E., Wiggins, S.M. & Hildebrand, J.A. (2021). Underwater noise mitigation in the Santa Barbara Channel through incentive-based vessel speed reduction. *Sci. Reports*, 11, 18391. https://doi.org/10.1038/s41598-021-96506-1

ZoBell, V.M., Gassmann, M., Kindberg, L.B., Wiggins, S.M., Hildebrand, J.A., & Frasier, K.E. (2023). Retrofit-induced changes in the radiated noise and monopole source levels of container ships. *PLoS ONE*, 18(3), e0282677. https://doi.org/10.1371/journal.pone.0282677

Appendix I – SRKW Science Workshop participants and affiliations

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Holly Fearnbach, PhD	SR3, SeaLife Response, Rehabilitation & Research
John Ford, PhD	Fisheries and Oceans Canada (DFO) - Retired
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Nick Gayeski, PhD	Wild Fish Conservancy (WFC)
Deborah Giles, PhD	The SeaDoc Society
Hussein Alidina	World Wildlife Fund Canada (WWF-Canada)
Michael Jasny	Natural Resources Defense Council (NRDC)
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Strengthening recovery actions for Southern Resident killer whales

By Independent Science Panel on SRKW Recovery

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