Fisheries and Oceans Canada
Pêches et Océans Canada

SOUTHERN RESIDENT KILLER WHALE

A science based review of recovery actions for three at-risk whale populations

Canada

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Review of the Effectiveness of Recovery Measures for Southern Resident Killer Whales

1. Context/Background

In November 2016, Canada's Oceans Protection Plan (OPP) was announced, which outlined several new initiatives aimed at addressing threats to marine mammals in Canadian waters, including the key threats of contaminants, prey availability, and underwater noise. As part of OPP, Fisheries and Oceans Canada (DFO) was tasked with launching a science-based review of the effectiveness of the current management and recovery actions for three at-risk whale species in Canada: the Southern Resident Killer Whale (SRKW), the North Atlantic Right Whale (NARW), and the St. Lawrence Estuary Beluga (SLE Beluga). This review seeks to evaluate the effectiveness of the recovery actions currently underway in order to identify how recovery objectives can be better achieved, and provide guidance on the relative priority of actions required to promote recovery. DFO adopted a phased approach for this review, and this document represents the first phase in that process and is focused on the SRKW population from a scientific perspective.

Two distinct populations of Resident Killer Whales occupy the waters off the west coast of British Columbia. These populations are referred to as the Northern Residents and Southern Residents, and although the ranges of the two populations overlap, they are acoustically, genetically and culturally distinct from each other. This document presents an assessment of the effectiveness of current management and recovery actions under way for the SRKW from a scientific perspective. The SRKW population was designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2001 and was subsequently listed as Endangered, under Canada's *Species at Risk Act* (SARA) in 2003. COSEWIC's designation was based on the following reasons, which remain valid today:

> "The population is small and declining, and the decline is expected to continue. Southern residents are limited by the availability of their principal prey, Chinook salmon. There are forecasts of continued low abundance of Chinook salmon. Southern residents are also threatened by increasing physical and acoustical disturbance, oil spills and contaminants" (COSEWIC 2008).

In 2006, SRKWs were also listed as Endangered under the US Endangered Species Act.

Between 1964 and 1973, the SRKW population was impacted by the loss of at least 46 animals from the effects of the live capture fishery. In 1974, a stock assessment program was initiated, and the first population census identified 71 SRKWs. Over the subsequent decades, the population has been assessed annually, and has fluctuated from the low of 71 animals in 1974 to a high of 96 in 1996. As of late 2016, there are 78 animals. Given the population size, the number of reproductively contributing animals in the population is small. Furthermore, SRKW females are less productive than their Northern Resident Killer Whale (NRKW) counterparts (Ward *et al.* 2009) and survival of neonates is also lower. The SRKW population exhibits lower survival overall when compared to NRKWs. Collectively, the small population size and low number of individuals contributing to reproduction (termed the effective population) heighten the impact of any mortality or loss of reproductive potential to the population's survival relative to their northern counterparts.

2. Objectives of this Review

The Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada (DFO 2011) states the following goal (population and distribution objective) for the SRKW population:

> *Ensure the long-term viability of Resident Killer Whale populations by achieving and maintaining demographic conditions that preserve their reproductive potential, genetic variation, and cultural continuity*[1] (DFO 2011).

The associated Action Plan for the Northern and Southern Resident Killer Whale (*Orcinus orca)* in Canada (DFO 2017) outlines Broad Strategies for recovery, and identifies 98 specific Recovery Measures to achieving them.

This review will provide a summary of the achievements to date on addressing the Recovery Measures and will provide an assessment of their overall effectiveness in terms of their ability to abate threats to recovery of the population. Research-based measures, while they do not directly abate threats, are also acknowledged for their role in addressing knowledge gaps in order to clarify the mechanism by which a threat impacts the population. This document also aims to identify how recovery can be better achieved by accelerating implementation of Recovery Measures not yet underway, by identifying new measures if needed, and by providing guidance on the relative priority of Recovery Measures required to promote recovery.

3. Sources of Information

The Recovery Strategy for Northern and Southern Resident Killer Whales in Canada was developed in 2008 and amended in 2011 (DFO 2011). The associated Action Plan for Northern and Southern Resident Killer Whales which was published in 2017 (DFO 2017a) builds on the information presented in the amended Recovery Strategy and identifies 98 specific Recovery Measures to so support achievement of the recovery goal. A subsequent report on the Progress of Recovery Strategy Implementation for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada (DFO 2016a) describes activities that were either completed or underway during the period 2009-2014. This review was informed by the information presented in these aforementioned SARA recovery documents; current scientific literature

[1] Culture refers to a body of information and behavioural traits that are transmitted within and between generations by social learning

relevant to SRKWs and in particular, the threats they face; a review of recovery documents and reports from the National Oceanic and Atmospheric Administration (NOAA) related to this population; relevant reports of policies and strategic initiatives related to SRKW; and information gathered in interviews with science and management staff in DFO and Environment and Climate Change Canada (ECCC).

4. Methods for Assessing Effectiveness of Recovery Measures

In the context of this review, assessing the effectiveness of Recovery Measures is understood as examining the degree to which the actions completed and currently underway and those proposed in existing recovery documents have contributed, or will directly contribute to abating threats to support recovery of the SRKW population. Actions already completed, underway, or not yet started since the date the species was listed under SARA (2003) will be considered, and this will also be the baseline from which any changes in threats will be examined to assess the effectiveness of Recovery Measures. Given the transboundary nature of the distribution of SRKW, and their habitat and their reliance on stocks of salmon that are transboundary, consideration is also given to recovery actions listed in the US Recovery Plan for SRKWs.

The recovery objectives included in the recovery documents were developed at a time when the understanding of SARA was different than it is today and did not take into consideration the 2016tri-departmental Proposed Policy on Survival and Recovery (Government of Canada 2016); therefore, neither does this review.

5. Review of Recovery Measures

5.1 Identified Threats and Broad Strategies

Killer Whales are long lived animals with a long maturation time. Consequently, outcomes of threat abatement could take years before a measureable effect on the population trajectory is realized and it is challenging to causally link the achievements, or lack thereof, of a particular Recovery Measure to a specific measurable population outcome for SRKWs in short time periods. In the short term, measures are assessed in terms of their efficacy at reducing threats to the population. The 2011 Recovery Strategy identifies three major threats to SRKWs and these remain major threats today (Table 1).

Table 1 – Threats to the recovery of SRKWs as identified in the 2011 Recovery Strategy

Threat	Summary Description	Occurrence	Level of concern
Reduced prey availability	Resident Killer Whale mortality rates (Ford *et al.* 2010a) and fecundity (Ward *et al.* 2009) are correlated with coast-wide Chinook abundance, the primary prey species from May through September. While winter prey of Resident Killer Whales are still not well understood, Chum Salmon are identified as being seasonally important to Resident Killer Whale populations. Factors such as habitat degradation and poor marine survival continue to negatively affect wild salmon populations.	Current	High
Disturbance	Both physical and acoustic disturbance, from chronic or acute sources, can affect Killer Whales, though the long-term effects of disturbance are unknown. Vessel traffic (both commercial and recreational), industrial activities (including dredging, drilling, and construction), seismic testing and military sonar all have the potential to disturb Resident Killer Whales.	Current	High
Environmental Contaminants	Chemical pollutants, including PCBs, DDT, PBDEs, dioxins, and other POPs, are found in high levels in RKWs, and are linked to reproductive impairment, immunosuppression, endocrine disruption, cancer in other mammalian and by weight of evidence in Resident Killer Whales. Biological pollutants, including pathogens and antibiotic-resistant bacteria resulting from human activities or exotic species, may also threaten the health of Resident Killer Whales, their habitat or their prey.	Current	High

The 2011 Recovery Strategy also identifies objectives for recovery of SRKWs, three of which (2-4) are aimed at abating threats:

1. *Monitor and refine knowledge of Resident Killer Whale population and distribution in Canadian Pacific waters.*
2. *Ensure that Resident Killer Whales have an adequate and accessible food supply to allow recovery.*
3. *Ensure that disturbance from human activities does not prevent the recovery of Resident Killer Whales.*
4. *Ensure that chemical and biological pollutants do not prevent the recovery of Resident Killer Whale populations.*
5. *Protect critical habitat for Resident Killer Whales and identify additional areas for critical habitat designation and protection.*

These objectives formed the basis of the five Broad Strategies described in the Action Plan, and provided a framework for the development of the 98 specific recovery measures.

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5.2 A Review of Recovery Measures

To support a detailed assessment of the effectiveness of recovery actions, Table 2 lists the 98 specific Recovery Measure from the Action Plan along with a brief summary of key achievements that can be associated or align with each measure since 2003.

Table 2 - Recovery Measures currently identified in the Action Plan for the Southern Resident Killer Whale population in Canada (DFO 2017)

Measures are organized under their associated Broad Strategy. "Priority" refers to the priority assigned in the Action Plan. "Threat" refers to the threats that may be reduced by a particular measure, as identified in the Action Plan. In many cases one measure is expected to address more than one threat. The status of each Recovery Measure is assigned "Completed" (the recovery measure, as currently written and in its entirety, describes an activity or task that was completed at a certain time in the past), "Underway"(the recovery measure, as currently written and in its entirety, contains multiple elements, some of which have been completed and others that have not) or "Ongoing" (the recovery measure describes an activity or a task that needs to reoccur at some regular interval or that takes place on a continuum, and likely never has an end date;), "Not started"(a situation where, to our knowledge, no actions have been undertaken) or "Uncertain"(a situation where effort was made to find information on the status of the recovery measure but no information was found in the timeframe of this review). Recovery Measures are also numbered according to the number assigned in the Action Plan. These are retained for ease of cross referencing between this document and the Action Plan. Achievements listed are examples of activities associated with a measure, but the list may not be exhaustive.

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
1	Undertake an annual census to monitor and assess Resident Killer Whale population dynamics (multi-species ship surveys and dedicated vessel surveys).	High	Prey availability Disturbance Contaminants	Ongoing	DFO provides regular census data (photo-identifications) to the Center for Whale Research, the NOAA-supported organization that maintains updated information on the population demographics of SRKW.
2	Estimate the carrying capacity of Resident Killer Whale habitat (population modeling).	High	Prey availability	Not started	
3	Examine indicators of (salmon) aggregation to identify potential Resident Killer Whale foraging areas (e.g. salmon fishing effort, catch success).	High	Prey availability	Ongoing	Salmon stock assessment work led by Fisheries and Oceans Canada (DFO) provides information on the annual abundance and distribution of salmon in SRKW habitat.

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
4	Identify features that define "quality" prey for Resident Killer Whales and determine a means of assessment (e.g. length, age, caloric value, lipid content, contaminant load).	Medium	Prey availability	Underway	Previous DFO studies have shown that RKWs typically forage selectively for large prey. They target 4-5 year old Chinook that weigh 8-13 kg and when foraging on chum salmon select large individuals (4.0-5.5 kg) (Ford and Ellis 2005, 2006). Ongoing prey sampling efforts with SRKWs by DFO are continuing to monitor features of prey quality. Further studies of caloric value, lipid content and contaminant load of SRKW prey have not yet been initiated.
5	Assess the quality of identified prey species on an annual basis.	Medium	Prey availability	Not started	
6	Take into account both the seasonal (acute) as well as the cumulative (chronic) effects of poor returns for Chinook and other important prey species on Resident Killer Whales when managing fisheries.	High	Prey availability	Not started	
7	Investigate the benefits of strategic salmon fishery planning approaches and management actions to reduce Resident Killer Whale prey competition in specific feeding areas (e.g. modeling, retention limits, fishery area boundary adjustments or closures), and implement where appropriate.	High	Prey availability	Underway	In 2017, DFO initiated efforts to better identify and characterize key foraging areas for SRKWs within their critical habitat as a first step towards implementing this measure.
8	Evaluate the potential impacts of disturbance and prey competition from fisheries on foraging success in key Resident Killer Whale foraging areas.	High	Prey availability	Underway	In 2017, DFO initiated efforts to better identify and characterize key foraging areas for SRKWs within their critical habitat as a first step towards implementing this measure.
9	Develop and implement reporting systems for the fishing sectors that improve	High	Prey availability	Ongoing	DFO collects fishery catch and release information for First Nations, Recreational and Commercial fisheries, stores this

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	salmonid catch, release, and retention data to more accurately portray potential fishery impacts.				information in Departmental databases and reports out on these data annually during post-season reviews. DFO is also reviewing these activities as part of the plan for implementing the Strategic Framework for Fishery Monitoring and Catch Reporting in Pacific Region Fisheries.
18	Identify year round Resident Killer Whale distribution and diet using acoustic monitoring and dedicated vessel surveys.	High	Prey availability	Ongoing	Acoustic monitoring, on-the-water vessel encounters and assessment of movements from tagged animals have and are being undertaken by DFO, NOAA and ENGOs (Ford *et al.* in press; Hanson *et al.* 2013). SRKWs concentrate their activity in the Salish Sea June to November. In addition to the Salish Sea, all SRKW spend a relatively large proportion of time off the outer coasts of Washington coast and Vancouver Island, but detections of J pod were almost exclusively farther north than K and L pods. K and L pods were briefly detected off California in 2011. Passive acoustic recorders have been deployed by DFO in northern Strait of Georgia in 2016 and2017 to monitor winter use of area by SRKW and ambient noise.
19	Further identify Resident Killer Whales' prey preferences (species/size/sex/stock).	High	Prey availability	Ongoing	Current knowledge indicates Chinook salmon of primarily Fraser River origin are the preferred prey of SRKW. Chum and coho salmon are of secondary importance (J. Ford *et al.* 2010b; Hanson *et al.* 2010b; M. Ford *et al.* 2016). Recent DFO studies of SRKW diet off the entrance to Juan de Fuca Strait have identified further species and Chinook stock identity (Ford *et al.* in press).
20	Incorporate aboriginal traditional knowledge (ATK) on the behavior and distribution of Resident Killer Whales and their prey into measures for the recovery of the species.	Medium	Prey availability Disturbance Noise pollution	Not started	
21	Undertake a catch per unit effort assessment of Resident Killer Whale	High	Prey availability	Not	

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	foraging effort and success rate to provide information on foraging areas and inform management decisions.			started	
22	Continue to investigate the role of abundance of Chinook and other important salmonid prey species in the population dynamics of the Northern and Southern Resident Killer Whale populations.	High	Prey availability	Ongoing	KW survival and calving rates have been studied and correlate with Chinook abundance index over long term (Ford *et al.* 2010a; Ward et al 2009; Noren 2011). Killer whale energy requirements based on summer occupancy and proportion of the diet that is estimated to come from Chinook salmon for the SRKW population is modelled to be ~59,000 Chinook (Williams *et al.* 2011).
23	Assess seasonal and inter-annual changes in body condition and growth of Resident Killer Whales and refine the relationship between prey abundance to inform management actions in support of prey availability.	High	Prey availability	Ongoing	Photogrammetry studies to measure body condition of 69 SRKWs were conducted in 2008 and again in 2013 (Fearnbach *et al.* 2011). A decline in body condition was noted in 2013 compared to 2008; of the 12 SRKW identified as pregnant based on breadth measurements in 2013, only 2 were subsequently seen with a calf (Fearnbach *et al.* 2015). On-going photogrammetry efforts by NOAA and the Vancouver Aquarium in 2014-16 have documented body condition of SRKW and NRKW (Matkin *et al.* 2017). Formal linkage to prey abundance had not yet been conducted.
24	Assess the potential impact of prey competition between Southern Resident Killer Whales, Northern Resident Killer Whales and other salmonid predators.	High	Prey availability	Underway	Use of important SRKW habitat on Swiftsure Bank by NRKWs was recently quantified through passive acoustic monitoring by DFO (Ford *et al.* in press). Assessment of potential impact of competition not yet undertaken.
25	Continue to monitor abundance, distribution and age specific composition of Chinook and other important salmonid prey species.	High	Prey availability	Ongoing	DFO conducts annual stock assessment activities for several Fraser River Chinook populations through a range of activities including in-season abundance estimates based on test fishery catch and post-season assessments, using a variety of methods including coded-wire tag analysis, mark-recapture methods, electronic counters, fence counts, and

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
					visual surveys (DFO 2014). Stocks of Chinook from the west and east coasts of Vancouver Island region are also assessed using specific runs as indicators of marine survival and adult escapement (DFO 2015a). Puget Sound Chinook Salmon are listed as threatened under the US ESA and are assessed regularly by NOAA/NMFS (National Marine Fisheries Service 2011a).
26	Identify and monitor natural and anthropogenic factors affecting Resident Killer Whale prey over the long term (e.g. climate change, Pacific Decadal Oscillation, El Niño).	High	Prey availability	Ongoing	DFO conducts annual reviews of factors affecting ocean ecosystems through the State of the Ocean series of seminars and related technical reports. An independent science panel review of the threats to Chinook salmon was conducted in 2013 as part of the Southern BC Chinook Integrated Strategic Planning Initiative (Riddell *et al.* 2013).
27	Form a transboundary working group of representatives from DFO, NOAA, as well as other technical experts to ensure that Resident Killer Whale needs are considered in the management of fisheries (e.g. Canada's Policy for Conservation of Wild Salmon, Pacific Salmon Treaty).	High	Prey availability	Underway	A series of workshops was held in 2011/2012 to assess the impacts of Chinook Salmon fisheries on SRKW recovery. The Independent Science Panel that conducted the review found strong evidence of SRKW dependence on Chinook during summer; however, they were skeptical that reduced Chinook salmon harvesting would have a large impact on the abundance of Chinook salmon available to SRKW. The panel recommended that future research focus on further exploring the relationship between SRKW and Chinook (Hilborn *et al.* 2012). A coordination meeting was held in March 2017 between NOAA and DFO Science to develop collaborations regarding future SRKW recovery actions, including monitoring of SRKW food requirements and prey availability.
28	Protect and preserve the freshwater habitat of important Resident Killer Whale	High	Prey availability	Ongoing	DFO's Wild Salmon Policy (2005) was designed to support efforts that could lead to rebuilding of stocks, including those in the salmon's freshwater habitat. The current draft

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	prey stocks.				Southern BC Chinook Strategic Planning Initiative provides strategic direction for addressing threats to southern BC Chinook.
29	Continue to implement and support salmon recovery plans (e.g. Canada's Policy for Conservation of Wild Pacific Salmon, Puget Sound Chinook Recovery Plan).	High	Prey availability	Ongoing	Such efforts are underway as part of the Southern BC Chinook Strategic Planning Initiative, the COSEWIC assessment (2017-18) and the Canadian Wild Salmon Policy (2005)
30	Continue to assess the potential impact of salmon enhancement and aquaculture operations on Resident Killer Whales, both directly and through effects on wild salmon populations, and develop actions to mitigate such effects, should impacts be detected.	Medium	Prey availability	Underway	Concerns have been expressed about potential risks to "wild" populations associated with high hatchery proportions in the enhanced populations, because it implies a correspondingly low proportion of wild salmon. There is also concern about the extensiveness of straying of hatchery fish into "wild" unenhanced populations all of which has implications for genetic diversity of wild chinook stocks. At this time, however, SRKWs appear to feed primarily on the following Fraser River stocks: the Middle-Upper Fraser River, Thompson River, and Lower Fraser CU groups. In these stocks, hatchery programs have been reduced to levels where risk is small. (Hilborn *et al.* 2013).
88	Use historical fishing records to identify potential Resident Killer Whale feeding areas.	Medium	Prey availability	Underway	Analyses of historic and recent Chinook fishing records relative to SRKW and NRKW distribution was initiated by DFO in 2017
89	Analyze historical data to identify environmental correlates with Chinook abundance and Resident Killer Whale mortality trends.	Medium	Prey availability	Underway	As noted in 88 above
10	Investigate the benefits of management actions (e.g. protected areas, fishery area boundary adjustments or closures) to protect important foraging and beach rubbing locations such as Robson Bight	High	Disturbance Noise pollution Prey availability	Underway	Study design has been initiated for assessment of fishing impacts in SRKW foraging locations and to assess disturbance responses of NRKWs at rubbing beaches. Field work to begin summer 2017. All results can be applied to SRKWs to provide insights into the effects of noise and

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	and other identified areas, and implement where appropriate.				physical disturbance on the population and may inform management actions.
11	Assess cumulative effects of potential anthropogenic impacts on Resident Killer Whales using an appropriate impact assessment framework for aquatic species.	High	Disturbance Noise pollution	Not started	
12	Develop and recommend implementation of best practices, guidelines, regulations, or other measures to minimize or eliminate physical and acoustic disturbance to Resident Killer Whales.	High	Disturbance Noise pollution	Ongoing	Amendments to the Canadian Marine Mammal Regulations have been drafted and are pending approval Tourism industry associations operate according to updated codes of conduct/Best Practices Guidelines (PWWA 2014). New vessel regulations around killer whales in the inland waters of Washington State were implemented in 2011 prohibit vessels from approaching within 200 yards of killer whales and from positioning within 400 yards of the path of killer whales (Protective Regulations for KW 2011)
13	Prioritize on-water enforcement efforts for compliance with legal protections for Resident Killer Whales and their habitat.	High	Disturbance Noise pollution Prey availability	Ongoing	Since 2003, there have been four successful convictions of individuals charged by DFO with disturbing killer whales under the Fisheries Act and the Species at Risk Act. Numerous warnings have already been issued to boaters found to be potentially in non-compliance with whale watching guidelines.
14	Support Resident Killer Whale recovery during the planning, development, and implementation of marine protected areas by contributing to prey availability and threat abatement.	Medium	Disturbance Noise pollution Prey availability	Underway	DFO Science has identified an area of special importance to SRKW off southwestern Vancouver Island and has recommended this area for designation and protection as additional critical habitat for SRKW (Ford *et al.* in press; DFO 2017).
15	Institute a communications plan around the Marine Mammal Regulations and ensure the message is transboundary.	Medium	Disturbance Noise pollution	Not started	(New Marine Mammal Regulations under the Fisheries Act have not yet been finalized)
31	Expand transboundary coverage of calibrated hydrophones to quantify ocean	High	Disturbance	Underway	Several initiatives are underway or completed, including:

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	noise budget throughout Resident Killer Whale range, giving priority to improving and utilizing existing hydrophone networks.		Noise pollution		Ocean noise workshop led by World Wildlife Fund (WWF) in 2012 with transboundary participation. Actions identified included establishing baseline ocean noise levels and scenarios of possible change, integrating hydrophone networks and informing the placement for further hydrophones, as well as providing policy recommendations for noise mitigation (Heise and Alidina 2012). The Vancouver Fraser Port Authority's ECHO program including its Acoustic Working Group has coordinated and supported expanded acoustic monitoring of SRKW habitat in Canadian and US waters MEOPAR-funded the NEMES (Noise Exposure to Marine Ecosystems from Ships) project at University of Victoria to assessing ambient noise in the Salish Sea A coordination meeting was held in March 2017 between NOAA and DFO Science to develop collaborations regarding future SRKW recovery actions, including the identification of efforts to monitor underwater noise in future.
32	Standardize protocols and methodologies for data analysis, data presentation, and archiving of acoustic information obtained from hydrophones in the Resident Killer Whale range.	High	Disturbance Noise pollution	Underway	Initial steps to address this were taken at the WWF workshop held in 2012 (Heise and Alidina 2012). More recent initiatives have included participations of partners such as ONC, ECHO, and JASCO.
33	Investigate Resident Killer Whale use of marine Navy ranges, geographically and temporally in order to help inform decisions around Naval exercise planning.	High	Disturbance Noise pollution	Underway	DFO Marine Mammal Research deploys hydrophones in the Strait of Georgia to monitor whale vocalization and anthropogenic noise, including naval operations. Particular focus is being applied to monitoring SRKW use of the Canadian Forces Maritime Experimental and Test Range (CFMETR) in central Strait of Georgia through on-water and acoustic monitoring.

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
34	Link hydrophone-detected noise events with vessel presence using the Automatic Identification System (AIS) for real time detection of acoustic disturbance in Resident Killer Whale critical habitat, and implement a response mechanism to mitigate potential impacts.	High	Disturbance Noise pollution	Underway	The Vancouver Fraser Port Authority's ECHO program has this as a goal and has made progress including setting up a system near the Port of Vancouver where the noise of individual ships can be monitored and linked to their AIS information. Similar efforts are also being undertaken through an Innovation Canada-funded pilot study involving Ocean Sonics Ltd and DFO Pacific Marine Mammal Management. This Whale Tracking Network (WTN) program involves development of a real-time detection system for SRKW in key areas within Canadian critical habitat. This will involve integration with AIS information on vessel presence and noise.
35	Undertake systematic monitoring of ambient noise records for non-vessel related acute acoustic events that may cause harm to Resident Killer Whales.	High	Disturbance Noise pollution	Not started	
36	Compile metadata on acoustic recordings from existing archives and current available sources (e.g. Navy, government agencies, individuals, consultants); identify format, calibration, temporal and spatial distribution, data gaps, and data collection protocols.	Medium	Disturbance Noise pollution	Underway	This measure was initiated by DFO in 2016 through collaboration with ONC and JASCO.
37	Undertake behavioural studies of Resident Killer Whales in the winter months.	High	Disturbance Noise pollution Prey availability	Ongoing	Studies are underway to collect these data using acoustic monitoring, by tracking of tagged whales and opportunistic boat-based encounters with SRKWs. (Ford e*t al*. in press; Hanson *et al.* 2013)
38	Utilize D-tag data to create a 3D model of the Resident Killer Whale's immediate (received) acoustic environment.	High	Disturbance Noise pollution	Underway	SMRU Canada modelled received noise levels from D-tag data collected by DFO from NRKW; results can be applied to the SRKWs as well.
39	Develop an acoustic model that incorporates effects of increasing ambient	High	Disturbance	Underway	

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	noise levels on communication signals of Resident Killer Whales.		Noise pollution		Several studies have estimated the effect of noise on SRKW communication space, vocal behaviour and echolocation masking (e.g. Erbe 2002; Au *et al.* 2004; Holt *et al.* 2009, 2011; Williams *et al.* 2014b).
40	Continue and expand existing behavioural monitoring programs involving vessel/whale interactions and increase support for data analysis and publication.	High	Disturbance Noise pollution	Underway	There have been a number of peer-reviewed publication completed that report on these studies (e.g. Lusseau *et al.* 2009; Noren *et al.* 2009). Further studies are underway.
41	Maintain and improve the existing 24 hour hotline (BCMMRN/ORR) for acoustic incidents as a mechanism for timely response.	Medium	Disturbance Noise pollution	Ongoing	The 24-hour hotline and BC Marine Mammal Response Network continues but has yet to receive resources for improvement.
42	Increase transboundary communication of research methods and objectives to address disturbance issues with counterpart agencies in the US.	Medium	Disturbance Noise pollution	Underway	A coordination meeting was held in March 2017 between NOAA and DFO Science to develop collaborations regarding future SRKW recovery actions, including research and management of disturbance issues.
43	Improve interagency communication and coordination to ensure that new activities, projects and developments that may impact Resident Killer Whales are identified, and appropriate mitigation measures are developed and implemented (e.g. Canadian Environmental Assessment Agency, Fisheries Protection Program).	High	Disturbance Noise pollution	Underway	The new Oceans Protection Program announced in late 2016 has facilitated communication and coordination between DFO, TC and other agencies related to the mitigation of impacts from industrial projects and developments.
44	Review operational impacts of existing activities, projects and developments that may have acute or cumulative impact on Resident Killer Whales and work with stakeholders to develop and apply appropriate mitigation measures.	High	Disturbance Noise pollution	Ongoing	The Vancouver Fraser Port Authority's ECHO program is contributing to this by supporting assessments of underwater shipping noise in the Salish Sea and its potential impacts, as well as potential means of mitigating noise exposure. ECHO involves representatives from DFO, TC, NOAA and various industry stakeholders and other agencies.

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
45	Encourage the development and use of methodologies that mitigate acoustic impacts (e.g. bubble curtains, ship quieting technologies).	High	Disturbance Noise pollution	Ongoing	The Vancouver Fraser Port Authority's ECHO program is contributing to this by supporting initiatives aimed at mitigating noise produced by shipping.
46	Review and improve 1) thresholds for disturbance and injury, and 2) measures to mitigate marine mammal impacts from acute noise (e.g. seismic surveys, sonar use, pile driving and at-sea detonation); and implement through inclusion in Standards and Statements of Practice (e.g. Naval Orders, Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment).	High	Disturbance Noise pollution	Underway	The Statement of Canadian Practices with respect to the Mitigation of Seismic Sound in the Marine Environment (DFO 2008) was reviewed in 2014 to determine its adequacy for avoiding prohibited impacts on SARA-listed cetacean species. Several recommendations were made for methods to increase the effectiveness of current mitigation measures (DFO 2015b). No changes to the SOCP have occurred as a result of these reviews. Acoustic threshold levels for avoiding temporary and permanent hearing threshold shifts were updated for marine mammals in American waters in 2013 (NOAA Fisheries 2013).
47	Develop a means to assess individual ship noise and determine response strategies as necessary.	High	Disturbance Noise pollution	Underway	The Vancouver Fraser Port Authority's ECHO program is focused on understanding and mitigating the impacts of commercial vessel activities on at-risk whales off the southern BC coast. Goals include identifying vessel source levels and developing mitigation measures such as voluntary slow zones (Port of Vancouver 2017).
48	Develop a communication strategy to inform foreign vessel operators of the Canadian legislation protecting marine mammals and Canadian acoustic mitigation protocols.	High	Disturbance Noise pollution	Underway	A Mariner's Guide recently developed in partnership between the Vancouver Fraser Port Authority, Prince Rupert Port and the Vancouver Aquarium is targeted at large vessel mariners and aims to inform them about the cetacean species along the B.C. coast, threats to these animals that may be associated with large vessels and shipping, and how mariners can minimize these threats (Mariner's Guide 2016).

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
49	Investigate area-specific shipping and boating guidelines and/or regulations (e.g., speed restrictions, vessel traffic routes and scheduling) that reduce acoustic impact as well as risk of collision in Resident Killer Whale habitat.	Medium	Disturbance Noise pollution Prey availability	Underway	The Vancouver Fraser Port Authority's ECHO program is focused on understanding and mitigating the impacts of commercial vessel activities on at-risk whales off the southern BC coast. Goals include identifying vessel source levels and developing mitigation measures such as voluntary slow zones (Port of Vancouver 2017).
50	Improve boater education and tourism programs using the latest marine mammal regulations and guidelines (e.g. boater courses; marine safety courses, fishing licenses, vessel registration and licensing courses).	Medium	Disturbance Noise pollution	Underway	An ENGO, Soundwatch, promotes Be Whale Wise guidelines though on-water boater education programs in northern Washington State waters. ENGOs conducted on-water boater education programs funded by DFO in Canadian waters of the SRKWs habitat 2001 to 2006 and then 2011 to 2014. DFO fisheries officers provide information about whale watching guidelines to stakeholders, members of the fishing industry, and members of the public
51	Promote awareness of, and compliance with, guidelines and regulations to reduce acoustic impacts and vessel interactions (e.g. Be Whale Wise guidelines, stewardship programs, on-the-water education).	Medium	Disturbance Noise pollution	Underway	An ENGO, Soundwatch, promotes Be Whale Wise guidelines though on-water boater education programs in northern Washington State waters. ENGOs conducted on-water boater education programs funded by DFO in Canadian waters of the SRKWs habitat 2001 to 2006 and then 2011 to 2014. DFO fisheries officers provide information about whale watching guidelines to stakeholders, members of the fishing industry, and members of the public.
52	Investigate new methodologies and technologies to aid in compliance and enforcement of Marine Mammal Regulations and SARA.	Medium	Disturbance Noise pollution	Underway	(New Marine Mammal Regulations under the Fisheries Act have not yet been finalized) Since 2014, DFO has collaborated on an Innovation Canada project to implement a whale-tracking network using hydrophones in southern B.C. waters. (P. Cottrell pers. comm. 2017).
53	Ensure that the development and delivery of SARA enforcement training for DFO	Medium	Disturbance	Uncertain	*Information available at the time of this review did not*

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	fishery officers includes content from whale experts.		Noise pollution		*allow determination of the status of this recovery measure*
54	Evaluate and revise whale watching guidelines and/or regulations to reflect most recent understanding of effects of chronic physical disturbance.	Medium	Disturbance Noise pollution	Not started	
55	Evaluate the efficacy of a license program and conditions for commercial whale watching as a means of mitigating potential disturbance (e.g. training standards for boat operators and naturalists, number and/or type of vessels, standard of practice).	Medium	Disturbance Noise pollution	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
56	Promote responsible advertising and documentaries that reflect the Be Whale Wise guidelines and demonstrate appropriate viewing practices.	Medium	Disturbance Noise pollution	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
90	Research the effects of other vessel-based impacts (e.g. fish finders, air quality issues related to engine exhaust, disposal of waste and bilge water).	Medium	Disturbance Noise pollution Environ. contaminant	Underway	Atmospheric dispersion modeling was used to estimate SRKW exposure to exhaust gases from whale watching vessels; threshold doses of these gases were estimated for SRKW. Results indicated that there are situations where the concentrations of pollutants inhaled by SRKW may be causing adverse health effects (Lachmuth *et al.* 2011).
91	Develop a means of differentiating nutritional vs. disturbance-induced stress (via hormone response and other methods).	Medium	Disturbance Noise pollution	Underway	Fecal thyroid and glucocorticoid hormone levels were tested from SRKW fecal samples to assess the threats of prey limitation and disturbance on this population. Declines in fecal thyroid levels were observed in summer months. These could reflect changes in nutritional status, as well as responses to stress, photoperiod and temperature (Matkin *et al.* 2017).
92	Expand the Whale Wise flag program to notify other mariners when whales have	Medium	Disturbance	Uncertain	*Information available at the time of this review did not*

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	been observed in order to reduce risk of collision and acoustic disturbance.		Noise pollution		*allow determination of the status of this recovery measure*
93	Improve public awareness of recovery activities for Resident Killer Whales through Parks Canada Agency's educational programs (e.g. the BC Ferries Coastal Naturalist Program).	Medium	Disturbance Noise pollution Prey availability	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
57	Investigate diseases in stranded Resident Killer Whales and identify those caused by biological pollution (e.g. viruses, bacteria, fungi, parasites).	High	Environ. contaminant	Ongoing	A review of pathology data of all Killer Whales that have stranded between 2002 and 2014 is underway, led by S. Raverty. Necropsy protocols for Killer Whales have been updated; goals of the revised protocols include improving understanding of disease in Killer Whales and of the effects of contaminants and heavy metals on Killer Whale health (Raverty *et al.* 2014).
58	Collate and summarize information on marine mammal necropsy and disease reports.	High	Environ. contaminant	Ongoing	In a review of Killer Whale strandings along the west coast of North America from 2005-2010, disease was not identified as the cause of death for any RKWs; however, two Killer Whales (one Offshore and one Transient) were diagnosed with bacterial infections (Gaydos and Raverty 2010).
59	Evaluate the type and level of risk of biological pollutants from agricultural runoff, sewage effluent, wildlife rehabilitation facilities and other sources.	High	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
60	Investigate and monitor priority pathogens of concern in marine mammals as a means to identify risk to Resident Killer Whales (e.g. *Morbillivirus* spp.).	Medium	Environ. contaminant	Ongoing	SRKW exhaled breath samples have been analyzed to identify normal microbial flora, as well as pathologies in the respiratory tracts of these whales (Raverty *et al.* 2017).

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
61	Conduct research in support of evaluating risks associated with disposal at sea operations in coastal waters (e.g. with a focus on emerging concerns such as PBDEs).	Medium	Environ. contaminant	Underway	Sediment samples collected from disposal at sea sites at Point Grey and Sand Heads in 2010 were analyzed for PCBs, PBDEs, PCDDs, PCDFs, providing a baseline for future assessments (Ross *et al.* 2011). Current Ocean Disposal Rejection/Screening Limits were evaluated to determine if they are sufficient to protect RKW critical habitat. Current CEPA Action Level exceeds the PCB levels recommended to protect RKWs from bioaccumulation of PCBs. A sediment concentration range was derived that would protect 95% of RKWs (Lachmuth *et al.* 2010). Results of the above study resulted in development of Standard Operation Procedures' by ECCC and DFO in order to address risk associated with dredging and disposal of sediment materials in SRKW critical habitat. PBDEs are not currently examined in ocean disposal assessments and should be because if even the current sediment quality guidelines available in Canada for PCBs are applied to PBDEs, it can be expected that PBDE concentrations in killer whales will exceed available toxicity reference values by a large margin (Alava et al 2016).
62	Quantify the background levels of natural and anthropogenic hydrocarbons to provide a baseline for assessing spill impacts in Resident Killer Whale habitat.	High	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
63	Identify and monitor contaminants of concern (e.g. flame retardants, pharmaceuticals and personal care	High	Environ. contaminant	Ongoing	Current and historical concentrations of PCBs and PBDEs were modeled in individual SRKW; future concentrations of these contaminants were predicted.

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	products, PBTs, hydrocarbons), and conduct a risk-based assessment of different chemicals of concern in Resident Killer Whales, their prey, and their habitat.				PCB concentrations not predicted to increase significantly over time, but PBDEs were predicted to increase over time and with age, with a doubling time of 3-4 years. J pod had highest predicted concentrations of both PCBs and PBDEs (Mongillo *et al.* 2012). POP concentrations in Chinook Salmon from British Columbia (BC) and WA were measured; the more southerly Chinook sampled had the highest concentrations of PCBs, PCDDs, PCDFs, and DDT. One of the four stocks sampled exceeded CCME tissue residue guidelines for the protection of mammalian wildlife consumers of aquatic biota, and another stock was approaching these guidelines (Cullon *et al.* 2009). In 2015, the Vancouver Aquarium initiated "PollutionTracker," a monitoring framework with 51 stations along the coast of B.C. to provide coast-wide information about contaminant levels, types of contaminants, and response to regulations. Contaminant data are collected from sediment and mussels and will be analyzed and reported on every three years (P. Ross, pers. comm. 2017).
64	Evaluate contaminant concentration trends in Resident Killer Whales, based on both published and new measurements of different contaminants.	High	Environ. contaminant	Ongoing	A peer-reviewed publication reviewed findings from analyses of SRKW biopsy samples and found that levels of some POPs were higher in juveniles than in adult males, and that almost all sampled SRKW exceeded the threshold for PCB-related health effects for marine mammals (Krahn *et al.* 2009). A series of workshops were conducted in 2013; topics

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
					included PBDE modeling in Puget Sound and the need to establish a PBDE toxicological threshold for SRKW. Knowledge gaps toward establishing this threshold were identified and recommendations were made for future research to address these gaps (Gockel and Mongillo 2013). The following is underway: http://www.dfo-mpo.gc.ca/science/rp-pr/ncag-gncc/projects-projets/014-eng.html. Health risk-based evaluation of emerging pollutants in killer whales (*Orcinus orca*): priority-setting in support of recovery.
65	Develop a monitoring program for pathogens and biological pollutants to evaluate long-term trends in Resident Killer Whales and their prey.	High	Environ. contaminant	Underway	A review of pathology data of all Killer Whales that have stranded between 2002 and 2014 is underway (Raverty pers. comm. 2015). Necropsy protocols for Killer Whales have been updated; goals of the revised protocols include improving understanding of disease in Killer Whales and of the effects of contaminants and heavy metals on Killer Whale health (Raverty *et al.* 2014).
66	Undertake a workshop to identify source of persistent bioaccumulative contaminants presenting a risk to Resident Killer Whales.	High	Environ. contaminant	Underway	A series of workshops hosted by NOAA and the EPA were conducted in 2013; topics included PBDE modeling in Puget Sound and the need to establish a PBDE toxicological threshold for SRKW. Knowledge gaps toward establishing this threshold were identified and recommendations were made for future research to address these gaps (Gockel and Mongillo 2013) The 2016–18 Biennial Science Work Plan of the Puget Sound Partnership Science Panel, includes numerous

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
					activities targeted at contaminants In marine, nearshore and Chinook salmon in Puget Sound
67	Undertake a workshop to identify source of biological pollutants presenting a risk to Resident Killer Whales.	High	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
68	Collate information on remediation efforts for land-based PCBs.	High	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
69	Work with the Federal Contaminated Sites Action Plan (FCSAP) to evaluate the potential contribution of persistent environmental contaminants to the contamination of Resident Killer Whale habitat.	High	Environ. contaminant	Not started	
70	Pursue an interagency contaminants working group to identify roles and responsibilities with respect to potential impacts of contaminants on Resident Killer Whales and their environment.	High	Environ. contaminant	Not started	
71	Incorporate knowledge of distribution, foraging behavior and contaminant bioaccumulation in Resident Killer Whales into pesticide and chemical regulation development and implementation overseen by provincial agencies, Health Canada and Environment and Climate Change Canada	High	Environ. contaminant	Ongoing	Although not specific to the Southern Resident Killer Whale or their prey, the potential for bioaccumulation in organisms is assessed for all pesticides (new and re-evaluation) and for industrial chemical risk assessments as required under existing policies and regulations.
72	Determine the efficacy of regulations for PBDEs under the Canadian Environmental Protection Act (CEPA) taking into account trends in indicator species in Resident	High	Environ. contaminant	Underway	DFO is supporting performance measurement through a health risk-based evaluation of emerging pollutants in killer

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
	Killer Whale habitat, and develop additional source control strategies if warranted.				whales to help priority-setting in support of recovery: http://www.dfo-mpo.gc.ca/science/rp-pr/ncag-gncc/projects-projets/014-eng.html.
73	Identify and support programs that identify and mitigate small scale and/or chronic contaminant spills and leaks.	High	Environ. contaminant	Underway	Transport Canada/ECCC Marine Aerial Reconnaissance Team (MART), flies coastal regions of BC and uses high resolution visual monitoring equipment to detect and measure spills An oil spill response plan specific to Killer Whales was developed in the US during a workshop held in 2007; plan has now been adopted as part of the Northwest Area Contingency Plan (Region 10 Regional Response Team and Northwest Area Committee 2015).
74	Reduce the risk of lifetime contaminant exposure in Resident Killer Whales by incorporating knowledge of distribution, foraging behavior and their food web into assessment and remediation plans for contaminated sites.	High	Environ. contaminant	Underway	A PCB food web bioaccumulation model was developed that allowed for evaluation of current sediment quality criteria in BC; indicated that current standards are not protective of Killer Whales (Alava *et al.* 2012).
75	Work with other government departments, non-governmental organizations, and industry to promote best practices, green design, mitigation protocols and outreach efforts for the protection of Resident Killer Whales and their habitat from urban pollution (e.g. sewage treatment, source control, combined sewer overflows, runoff).	High	Environ. contaminant	Underway	The Puget Sound Partnership's Action Agenda includes targets for reducing the contaminants and toxic chemicals in fish and marine sediments in Puget Sound, as well as strategies to achieve these targets by 2020 (Puget Sound Partnership 2009). Outreach and stewardship programs, including Killer Whale Tales (http://killerwhaletales.org), school curricula and the Pacific Region Contaminants Atlas (http://www.pacifictoxics.ca) raise awareness of the threat of contaminants to Killer Whales, and provide members of the public with ways to reduce the introduction of

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
					pollutants into the marine environment. The Vancouver Aquarium established a new, independent, multidisciplinary, collaboration-based, institute to fill a major gap in understanding and managing our coastal ocean environments. The Ocean Pollution Research Program is a major new Vancouver Aquarium research initiative that will conduct international-caliber scientific research on ocean pollution.
76	Work with individuals, industries, agricultural operations, and other sectors in order to reduce the release of agricultural chemicals of concern into the habitat of Resident Killer Whales and their prey.	High	Environ. contaminant	Ongoing	Although not specific to the Killer Whale or their prey in coastal BC context, Pesticide Management Regulatory Agency (PMRA) decisions for registration of pesticides routinely include conditions of use (e.g. buffer zones, restrictions regarding aquatic habitats, etc.) to reduce agricultural run-offs in general.
77	Ensure that the protection of Resident Killer Whales and their habitat is included as a high priority in spill response and monitoring protocols within the Canadian Coast Guard's Incident Command Structure.	High	Environ. contaminant	Not started	
78	Prepare for oil or chemical spills to minimize impacts to Resident Killer Whales through the development of a spill response plan, including deterrence methods, training, drills and equipment.	High	Environ. contaminant	Not started	There is no marine mammal response plan in the event of an oil spill in Canada.
79	Review and, if appropriate, recommend refinement of policies and best management practices for ocean dredging and disposal at sea.	Medium	Environ. contaminant	Ongoing	Joint DFO-ECCC Standard Operating Procedures (SOP) were developed in keeping with Lachmuth et al (2010) for use by ECCC and DFO when reviewing any proposed dredging and/or disposal activities within SRKW Critical Habitat. In applying the SOPs, permits are only considered for disposal at sea within SRKW critical habitat (e.g., Sand Heads

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
					disposal site) under very limited circumstances. However, EPOD's Marine Programs Division continues to work with killer whale experts and DFO in addressing any emerging issues and new management approaches.
80	Refine and expand existing monitoring programs of municipal and industrial waste to minimize Resident Killer Whale exposure to legacy and emergent pollutants.	Medium	Environ. contaminant	Underway	ECCC has a national wastewater monitoring program under the Chemicals Management plan where legacy and emerging pollutants are measured. Under this program an examination of parameters affecting the occurrence and removal of PBDEs in 20 Canadian wastewater treatment facilities was undertaken (Kim et al. 2013).
81	Reduce the release of biological pollutants into the habitat of Resident Killer Whales and their prey by working with municipal, provincial and federal agencies tasked with domestic, agricultural and industrial discharges (including ballast water).	Medium	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
82	Mitigate the release of biological pollutants into the habitat of Resident Killer Whales and their prey by working with individuals, industries, agricultural operations, and other source sectors to develop or improve protocols and guidance.	Medium	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
94	Develop, evaluate, and apply new tools to assess the effects of contamination and pollution on the health of free-ranging Resident Killer Whales.	Medium	Environ. contaminant	Underway	Necropsy protocols for Killer Whales have been updated; goals of the revised protocols include improving understanding of disease in Killer Whales and of the effects of contaminants and heavy metals on Killer Whale health (Raverty *et al.* 2014). Atmospheric dispersion modeling was used to estimate SRKW exposure to exhaust gases from whale watching vessels; threshold doses of these gases were estimated for

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
					SRKW. Results indicated that there are situations where concentrations of pollutants inhaled by SRKW may be causing adverse health effects (Lachmuth *et al.* 2011). The following is underway: http://www.dfo-mpo.gc.ca/science/rp-pr/ncag-gncc/projects-projets/014-eng.html. Health risk-based evaluation of emerging pollutants in killer whales (*Orcinus orca*): priority-setting in support of recovery.
95	Quantify the current levels of contaminant concentrations in Resident Killer Whale prey and refine the analysis of contaminant intake by Resident Killer Whales using current information on their feeding ecology.	High	Environ. contaminant	Underway	POP concentrations in Chinook Salmon from British Columbia (BC) and WA were measured; the more southerly Chinook sampled had the highest concentrations of PCBs, PCDDs, PCDFs, and DDT. One of the four stocks sampled exceeded CCME tissue residue guidelines for the protection of mammalian wildlife consumers of aquatic biota, and another stock was approaching these guidelines (Cullon *et al.* 2009).
96	Evaluate the risks of bioaccumulation related to mercury (Hg) contamination in Resident Killer Whale food webs.	Medium	Environ. contaminant	Not started	
97	Support new, proposed, or existing bans on the use of pesticides for cosmetic purposes, and re-establish a comprehensive inventory of pesticide sales and use in British Columbia.	High	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*
98	Incorporate knowledge of Resident Killer Whale distribution, foraging behavior and contaminant bioaccumulation into federal technical reviews on chemicals of concern.	High	Environ. contaminant	Uncertain	*Information available at the time of this review did not allow determination of the status of this recovery measure*

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
16	Analyse new acoustic and sightings data to identify additional areas of habitat necessary for the survival and recovery of Resident Killer Whales.	High	Prey availability	Ongoing	DFO Science has identified an area of special importance to SRKW off southwestern Vancouver Island and has recommended this area for designation and protection as additional critical habitat for SRKW (Ford *et al.* in press; DFO 2017).
17	Review and assess project impacts on Resident Killer Whales and their habitat, and provide advice on avoidance and mitigation measures as required.	High	Disturbance Noise pollution	Ongoing	DFO's Fisheries Protection Program undertakes these reviews and requests advice from DFO Science which is delivered through DFO's Canadian Science Advisory Secretariat.
83	Continue to undertake research activities to identify areas of habitat necessary for the survival and recovery of Resident Killer Whales.	High	Prey availability Disturbance Noise pollution	Ongoing	DFO Marine Mammal Research program leads research involving photo-identification, acoustic monitoring and diet studies using focal follows etc. and has thus far contributed to the identification of current SRKW Critical Habitat (Ford 2006) and to new candidate areas (Ford *et al.* in press; DFO 2017). NOAA also leads work to complete surveys, identify prey, and assess distribution of SRKWs (e.g. Hanson *et al.* 2010a; Hanson *et al.* 2010b: NWFSC 2013b)
84	Identify and account for the likelihood that changes in the relative strength of major salmon stocks may cause corresponding shifts in the geographic location of critical habitat for Resident Killer Whales.	Medium	Prey availability	Ongoing	*During the time available for this review, it was not possible to determine specific information about this measure*
85	Refine understanding of the functions, features and attributes of Resident Killer Whale habitat and identify what may constitute critical habitat destruction.	Medium	Prey availability Disturbance Noise pollution	Ongoing	Salmon stock composition is included as one of the criteria for identification of additional habitats in Canada that are important to the survival and recovery of RKWs (e.g., Ford *et al.* 2017). DFO Marine Mammal Research program leads research involving photo-identification, acoustic monitoring and diet studies using focal follows to inform a better understanding

#	Recovery Measures	Priority	Threats	Status of activities	Achievements
					of functions, features and attributes of critical habitat.
86	Continue efforts outlined in Broad Strategy 3 to ensure disturbance from human activities does not prevent access of Resident Killer Whales to their critical habitat.	High	Disturbance Noise pollution	Underway	See various achievements on measures under Broad Strategy 3 above
87	Continue dialogue with the NOAA to encourage transboundary consistency of Southern Resident Killer Whale critical habitat protection.	High	Disturbance Noise pollution	Ongoing	A formal international agreement has not been implemented; however, NOAA and DFO have collaborated on several studies and workshops focused on RKW recovery including the workshops focused on assessing the effects of salmon fisheries on SRKW recovery in 2011/2012. A coordination meeting was held in March 2017 between NOAA and DFO Science to develop collaborations regarding future SRKW recovery actions, including critical habitat identification and protection.

6. Effectiveness of Recovery Measures

The following sections identify the primary threats to SRKW recovery, characterize the threats, and review the efficacy of measures undertaken to date aimed at mitigating the threats. It is evident from Table 2 that many Recovery Measures (32) involve research aimed at improving the understanding of how a particular threat affects this population. Although these Recovery Measures do not directly result in threat reduction, knowledge and understanding gained from research is often necessary to guide and inform the management options that can lead to the mitigation of threats.

6.1 Prey Availability

Characterization of the threat

SRKWs are highly specialized predators and prey primarily on Chinook salmon. This selectivity is particularly evident during the months of May through September in the Salish Sea, when they forage almost exclusively on Chinook salmon in Juan de Fuca Strait, Puget Sound, the southern Strait of Georgia and off southwest Vancouver Island (Ford *et al.* 1998; Ford and Ellis 2005, 2006; Ford *et al.* 2010b; Hanson *et al.* 2010b; M. Ford *et al.* 2016; J. Ford *et al. In Press*). During October and November, SRKWs increase their use of Puget Sound, and are likely to feed on migrating Chum salmon as well as Chinook (Osborne 1999). By December, most of the SRKW community have left their summer core areas in the Salish Sea. In particular K and L pods are mostly absent from December to May. Although much less is known of SRKW diet in winter and early spring, sightings and acoustic recordings indicate that they range widely along the mainland US coast and off the west coast of Vancouver Island (Wiles 2004; Zamon *et al.* 2007 Hanson *et al.* 2013; Ford *et al.* in press). Their occurrence off the mouth of the Columbia River and in Monterey Bay, California, appears to be associated with local concentrations of Chinook salmon (Wiles 2004; Zamon *et al.* 2007; Hanson *et al.* 2010b).

The survival and recovery of SRKW appears to be strongly linked to Chinook abundance. Ford *et al.* (2010b) showed that mortality rates of both SRKWs and NRKWs were negatively correlated with Chinook salmon abundance over a 25-year period, from 1979-2003. In particular, a sharp decline in Chinook salmon abundance that persisted for four years during the late 1990s was associated with mortality rates up to 2-3 times greater than expected and resulted in population declines in both Resident Killer Whale populations. Ward *et al.* (2009) demonstrated a significant association between Chinook salmon abundance and reproductive rates in the SRKW population.

Due to their relatively large size and high lipid content, Chinook salmon are highly profitable prey for SRKWs and provide a high caloric gain for the energy expenditure of foraging (Ford and Ellis 2005, 2006). They have also been, at least historically, a reliable prey source. Unlike many species of salmon that spend large portions of their lifecycle on the high seas only returning to coastal waters to spawn, Chinook are available year-round in coastal waters. Killer Whales appear to preferentially select four to five-year-old Chinook salmon, which have mean body masses of 8-13 kg (Ford and Ellis 2005). These Chinook are considerably larger than mature Chum salmon (4.0-5.5 kg), which become more prominent in the diet in the fall, and are more than double the size of a typical coho or pink salmon, which they seldom eat (Ford *et al.* 1998).

Chinook abundance

The abundance of Chinook salmon in both Canada (British Columbia) and the US (Washington, Oregon and California) has been greatly reduced from historic levels and many populations are in decline. As a consequence many stocks, including 10 of 17 Chinook stocks in Washington, Oregon and California, are listed as threatened or endangered under the US Endangered Species Act (ESA) (NWR 2004), or identified as stocks of conservation concern in Canada. Chinook abundance in B.C. dropped in the 1970s and 1980s, but escapements (number of fish entering the river to migrate to spawning areas) increased until the early 1990s in some rivers. This increase is primarily due to hatchery production and reduced harvest rates following implementation of the Pacific Salmon Treaty in 1985 (Beamish *et al.* 1997). However, several of those stocks have again decreased substantially in abundance over the last three generations (Riddell *et al.* 2013). Recently, seven Fraser River Chinook conservation units (CU) were designated as red (highest level of concern) and two others as amber (lower level of concern) in a process that applied the Wild Salmon Policy status categories based on various measures and indicators of status (DFO 2016b; Grant and Pestal 2013). Although there are 15 CUs recognized in the Fraser River system, only eleven had sufficient data for evaluation. The last 12 to 15 years have been a period during which most groups of Chinook within the Fraser River have declined in numbers, and the outlook for Chinook outside of the Fraser River has generally not shown sustained improvement since 1990 (DFO 2016b).

In Washington, hatchery fish now account for about 75% of all harvested Chinook, which is a concern for genetic diversity and productivity of Chinook populations (Mahnken *et al.* 1998 in Wiles 2004). Declines in abundance of spring-run Chinook salmon have been particularly evident in California's Central Valley, in the Columbia River (interior spring Chinook salmon), and in Puget Sound. Associated with the declines in abundance, there have also been shifts in age structure of many populations toward younger ages and smaller adults. In addition to reduced Chinook abundance, the size and thus nutritional value of individual fish appears to have declined over recent decades. Between 1975 and 1993, up to a 45% decline in the average mass of Chinook salmon was observed in nine populations from British Columbia to California (Bigler *et al.* 1996). Thus, the nutritional yield of each Chinook salmon is significantly less today than it was in past years and negatively impacting the overall foraging energetics of SRKW (Krahn *et al.* 2004, 2002).

Genetic identification of prey samples indicates that SRKW foraging in the Salish Sea and off the west coast of Vancouver Island are feeding primarily on Fraser River system Chinook, but also some Puget Sound and southeast Vancouver Island stocks (Ford *et al.* 2010b; Hanson *et al.* 2010b). The Fraser River system contains the largest spawning populations of Chinook on the west coast of North America. Diet studies of SRKW indicate that Chinook from different stocks appear in the diet roughly in proportion to their relative abundance (Ford *et al.* 2010b; Ford *et al. In Press*; Hanson *et al.* 2010b).

A 2013, photogrammetry study assessed SRKW body condition in 43 SRKWs and demonstrated a decline in body condition of 11 animals including 7 prime-age females compared to their condition in 2008 when 43 animals were also assessed. In the 2013 study, twelve SRKWs were identified as pregnant, based on breadth measurements from these aerial photos. However, only two of these animals were subsequently seen with a calf, suggesting that poor body condition is a likely factor (Fearnbach et al 2015).

In 2017, a review of recent research on SRKW was undertaken to detect evidence of poor body condition in the population (Matkin *et al.* 2017). This review examined evidence from sightings data (photo-identification and mortality), aerial photogrammetry, necropsy data, and fecal hormone analyses. The independent science panel that conducted the review concluded that there were multiple lines of evidence that indicated the presence of poor body condition in SRKW, and that this was associated with loss of fetuses, calves and adults.

Recovery Measures to address this threat

<u>*Chinook abundance*</u>

In 2011 and 2012, DFO collaborated with the National Oceanic and Atmospheric Administration (NOAA) in a series of three scientific workshops that rigorously reviewed the available information on SRKW, their feeding habits, and the potential effects of salmon fisheries on SRKW through reductions in prey abundance. A panel of independent scientists was selected to oversee and participate in the process and produce a report documenting its findings (Hilborn *et al.* 2012). The report acknowledged the large body of scientific research on population effects of reduced prey availability, but concluded that caution was warranted in assigning a causative relationship to the correlation between the coast wide Chinook salmon abundance index and SRKW survival. In addition, the panel noted that reductions in coast-wide Chinook harvest would not necessarily lead directly to a greater availability for SRKWs. This was based on the reliance of SRKWs on Fraser River stocks and some Puget Sound stocks of Chinook salmon such that a coast wide closure of Chinook salmon fisheries (which is a mixed stock fishery) would not necessarily lead to direct increases in Chinook salmon from these stocks becoming available to SRKWs. They also noted that increases in abundance in Chinook salmon that may result from coast wide closures could be negated by competition from Northern Resident Killer Whales, seals and sea lions.

Hilborn et al. (2012) provided a series of recommendations for future work which were included as Recovery Measures in the Action Plan. Their recommendations emphasised the value of ongoing assessments of body condition as an indicator of reduced prey availability as well as a need for greater effort to identify their winter diet (Hilborn *et al.* 2012).

In 2005, DFO introduced the Wild Salmon Policy (WSP) to guide conservation and management of Pacific salmon species. The WSP set out an approach involving the identification and assessment of the biological status of conservation units of Chinook salmon. The conservation units were ranked according to their biological status and the rankings were used to target subsequent research and management actions. For, example, numerous Chinook conservation units from the Fraser River system, as well as many others in southern BC, were assessed with biological status in the “red zone” indicating a high level of concern, and triggering a requirement under the WSP for “*immediate consideration for ways to protect fish, increase abundance and reduce the risk of loss*” (DFO 2016b).

Chinook salmon stocks in southern BC are caught not only in coastal BC fisheries but also in Washington State and Alaska fisheries. The Pacific Salmon Treaty (PST) commits Canada and the U.S. to carry out fisheries and enhancement programs and includes provision for bilateral cooperation to limit harvest that would be beneficial for conservation of important stocks. Compared with the 1990 PST, its renewal in 2009 included a 15% reduction in the harvest of Chinook salmon in the Southeast Alaska (SEAK), and a 30% reduction in the west coast of Vancouver Island (WCVI) aggregate abundance based management (AABM) Chinook fisheries. As part of the 10 year renegotiation cycle, the current provisions of the Chinook salmon fishery chapter are being renegotiated by the two countries and continuation of the existing fishery reductions and other adjustments are a key area of discussion. The Pacific Salmon Commission's (PSC) Chinook Technical Committee, which evaluates the management regime, has noted deficiencies in data on numerous stocks that have impacted evaluations of the effectiveness of the management regime (PSC 2016). While these management actions and the development and implementation of the WSP are underway, it is not clear whether they have resulted in a positive effect for SRKWs. However, it is worth considering that the availability of prey for SRKWs could be an even greater threat were these actions and efforts not in place.

DFO has compiled two data reports to support the current COSEWIC assessment of southern BC Chinook salmon. In addition, in 2012, DFO entered into a bilateral planning process with First Nations and other collaborators called the *Southern BC Chinook Strategic Planning Initiative*. The overall goal of this initiative is to develop a strategic plan that will address the challenges facing these stocks, such as depressed and/or declining spawner abundance, reduced and variable freshwater and marine survival rates, pressures on freshwater habitat, total mortalities associated with harvest, increased predation, and ecosystem effects from climate changes. The draft strategic plan includes six biological objectives, one of which is particularly relevant to SRKWs and offers considerable potential to ensure prey availability for this population. Specifically, under the objective: "Sustain salmon contribution to ecosystem health", there are two specific sub-objectives: 1) ensure that there are sufficient Chinook salmon post-harvest to sustain Chinook-dependent predators and 2) ensure that Chinook salmon harvests are not harming Resident Killer Whale populations. The indicator and performance measures listed are: 1) sensitivity of fecundity and population growth rate of SRKWs to current harvest rates of Chinook salmon; and 2) changes in the relationship between SRKW metrics and Chinook salmon abundance indicators. While the document is still in draft, the inclusion of these objectives, indicators and performance measures demonstrates a consideration of the relationship between Chinook salmon abundance and Recovery Measures for SRKWs (Table 2).

Only two of the 98 Recovery Measures in the Action Plan (#28 and 29) are specifically directed to the recovery of Chinook salmon stocks in Canada. There are a number of efforts underway that align with these measures (Table 2). There are at least four additional Recovery Measures (#3, 9, 25, and 26) that relate to research that could support implementation of improved fisheries management actions (Table 2). Implementation of these latter measures has been initiated or is ongoing and requires strong collaboration between personnel conducting salmon stock assessment and marine mammal researchers to ensure needed information is available for incorporation.

Chinook Availability

Initial efforts to address the threat of reduced prey availability focused on demonstrating a causal relationship between the coast-wide Chinook abundance index and SRKW mortality, with the intent of informing Chinook management actions. As discussed above, there is limited evidence to suggest a coast wide closure of the Chinook salmon fishery would address the issue of prey abundance for SRKWs; however more targeted reductions in Chinook salmon harvest will likely be beneficial and measures to address the threat of reduced prey availability in key foraging areas are currently being investigated.

There are a number of activities that have been recently implemented in DFO that have potential to deliver measurable outcomes for Recovery Measures # 6, 7, 8, 10, 27 which relate to the consideration of SRKW prey requirements in fisheries management decisions. Identification of SRKW foraging areas has already been completed, and pressures from fishing activities in these areas is under assessment. Assessment results will provide managers with the opportunity to consider strategic salmon fishery planning approaches and management actions that have the greatest likelihood of increasing the availability of Chinook salmon for SRKW in the locations and at the times that foraging is most likely to occur. Considerations such as reductions in Chinook salmon removals through fishery area boundary adjustments or closures, or changes to retention limits will be focused on foraging grounds, and subsequent evaluation of the effectiveness of these management measures will be implemented.

In support of these measures, information about SRKWs, their reliance on Chinook salmon, and the threats to their survival were included in the Integrated Fisheries Management Plan for 2016/17 (IFMP 2016). As such, this IFMP which sets out the management plans for salmon fisheries in B.C. represents an important step towards incorporating consideration of SRKW needs in Chinook salmon fisheries management (Table 2), although it does not propose specific fishery management actions

Effectiveness of Actions

Much of the research described above related to characterization of the importance of Chinook salmon availability to SRKW has occurred since 2003. Results to date confirm this species as the dominant prey for at least half of the year, and demonstrate a correlation between SRKW health and prey availability and have prompted an evaluation of management options to support recovery. Research on these topics is ongoing (and captured in one of 13 Recovery Measures in Table 2 and as new findings emerge they will continue to inform and guide management-based Recovery Measures.

Management measures taken by DFO to reduce harvest pressure on Chinook salmon on the B.C. south coast aimed at conserving key Fraser River Chinook stocks should be of benefit to SRKWs. There is, however, little evidence that management actions that would directly support Chinook salmon availability for SRKWs in key foraging locations have been implemented. The NOAA-led transboundary workshop (Hilborn *et al.* 2012) as well as several CSAS research documents that assess the Chinook salmon needs of SRKWs (e.g. Ford *et al.* 2010b; Vélez-Espino *et al.* 2014a; 2014b) aim to inform management actions, but to date, have not led to specific fishery management actions. However, the recent shift in approach from focusing on Chinook abundance, to supporting Chinook availability in

SRKW foraging grounds has led to the initiation of science-based advice in support of strategic salmon fishery approaches and management actions to reduce the competition SRKWs experience from Chinook fishing. In addition, the inclusion of objectives regarding SRKW's prey requirements in the Integrated Strategic Plan for Southern BC Chinook, and the description of their needs in the salmon IFMP represents some progress.

6.2 Acoustic and physical disturbance

Characterization of the threat

Acoustic disturbance and physical disturbance are considered together here because it is often not clear whether it is physical presence (e.g., boats getting in the way of whales) or acoustic impacts (underwater noise created by vessels or other anthropogenic activities that mask communication and echolocation signalling) together or separately that are negatively affecting whales.

Killer whales use sound for communication, prey detection, and to acquire information about their environment. These animals produce a variety of sounds including echolocation clicks for foraging and navigation and pulsed calls and whistles during social interactions. Call production is believed to serve important roles in the social dynamics of groups that travel and forage together (Ford 1989). Resident killer whales appear to make extensive use of echolocation to locate and capture prey, though vision may also play a role at close ranges (Ford 1989; Barrett-Lennard *et al.* 1996). Studies of echolocation click structure and the sound energy content of the clicks in NRKWs suggest that they should be able to detect Chinook salmon at ranges of about 100 m in average conditions, and less so as ambient underwater noise increases (Au *et al.* 2004).

It is estimated that ambient (background) underwater noise levels have increased an average of 15 dB (note a 3dB increase represents a doubling of noise levels) in the past 50 years throughout the world's oceans (NRC 2003). Shipping noise is the dominant source of ambient noise between 10 to 200 Hz but, ships also produce significant amounts of higher frequency noise in the audible range (600Hz to 114kHZ with the greatest sensitivity in the range of 5kHz to 81kHz, Branstetter *et al.* 2017) of killer whales. Noise received from ships at ranges less than 3 km in the relatively narrow passage of Haro Strait, an area frequented by SRKWs, extend upward into frequencies used by SRKWs (Veirs *et al.* 2015). It is widely recognized that commercial shipping has increased dramatically in recent years. Currently in the Salish Sea one large ship transits the area, on average, every hour of every day of every year, with three transits per hour observed at the busiest times (Erbe *et al.* 2012 Williams *et al.* 2014a). Within the Salish Sea, commercial shipping is the dominant source of overall sound energy, but smaller craft (recreational, fishing, whale watching boats) are a substantive contribution in certain sub-areas of the Salish Sea (ECHO 2016). In Puget Sound one year of ship traffic data was paired with hydrophone recordings to assess ambient noise and quantify contribution of vessel traffic. Commercial vessel traffic accounted for more than 90% of the sound energy budget, with container ships as the greatest contributor (Bassett *et al.* 2012).

Whale watching and recreational boating activity has also increased as a result of increasing interest in ecotourism, and a growing human population around the Salish Sea. Commercial whale watching in the Canadian and U.S. portions of the Salish Sea increased from a few boats in the 1970s to about 80 boats in 2003 and in 2016 to 100 boats; this estimate does not include the recreational boaters (Holt 2017). Non–commercial boats include kayaks, sailboats and powerboats. Whale watching activities have the potential to disturb marine mammals through both the physical presence and activity of all types of watercraft, as well as the increased underwater noise levels that boat engines generate (DFO 2011).

Trends in acute noise from such activities as dredging, drilling, or blasting in SRKW habitat are not reviewed here due to the time frame available to complete this review.

Anthropogenic noise, either chronic (e.g. shipping noise) or acute (e.g. pile driving, blasting, seismic surveys and other types of hydro-acoustic related surveying and navigation), can interfere with the ability of SRKWs to conduct their life processes. Such disruptions are associated with decreased foraging success, displacement of animals from preferred feeding habitats, displacement of prey, impaired hearing, either temporarily or permanently (Barrett-Lennard *et al.* 1996; Erbe 2002, Bain 2002, NRC 2003, Au *et al.* 2004).

Studying the effects of noise on cetaceans involves complex modelling of sound propagation and information on the auditory hearing sensitivity of a species. Erbe (2002) modelled the noise of whale-oriented boat traffic in the vicinity of SRKWs and showed that the noise of fast boats could mask their calls within 14 km, could elicit a behavioural response within 200 m, and could cause a temporary threshold shift (TTS) in hearing of 5 dB after 30–50 min within 450 m. Boat speed was a significant factor in determining the amount of noise generated. Slowing speed, which results in less noise, masked signals at 1km from the boat. However, there are typically many boats in the vicinity of SRKWs, so modelled noise levels associated with a number of boats around the whales were found to be close to the critical noise threshold assumed to cause a permanent hearing loss over prolonged exposure.

Numerous studies since 2002 have demonstrated behavioural response and changes in acoustic signalling by SRKWs living and foraging in the Salish Sea that strongly suggest an energetic cost and potential stress to SRKWs associated with the increased noise levels. Specifically, SRKWs significantly increased the duration of their calls when boats were present and increased the amplitude of their calls as background noise level increased as a result of the number of vessels nearby (Foote *et al.* 2004; Holt *et al.* 2009; 2011).

SRKWs were observed to be within 400 m of a vessel most of the time during daylight hours from May through September, largely as a result of whale-watching oriented vessels approaching and following them. Studies of SRKW behaviour in the vicinity of whale-watching oriented vessels in the Salish Sea showed that SRKWs were significantly less likely to be foraging and significantly more likely to be traveling when boats were around and were displaced short distances by the presence of vessels (Lusseau *et al.* 2009). Behavioural responses to close approaches of boats include an increase in surface active behaviour which may have increased energetic costs (Noren *et al.* 2009).

The response of SRKWs to vessels is likely a result of acoustic disturbance and in the case of small vessels that may approach them, due to physical disturbance as well. Williams *et al. (*2014b) estimate that in the noisiest sites in Canadian Pacific waters, SRKWs will lose up to 97% of their acoustic communication space in the frequencies used for social communication calls.

A Killer Whale-Noise-Exposure simulation model based on sound propagation modelling, a behavioural dose response model (SMRU Consulting Canada 2014), and published audiograms of killer whales indicate that noise from vessels regionally in the Canadian portion of the Salish Sea is likely impacting SRKW's ability to forage successfully. Time lost from foraging across all vessels types is estimated at 20-23% of each whale day. Two-thirds of this lost time is considered to be due to behavioural responses which are caused predominantly by large ships (generally vessels of 500 tons or more), although whale watching boats (small vessels) are predominantly responsible for the remaining high sound frequency click masking noise (RBT2 2013).

Recovery Measures to address this threat

There are at least 12 Recovery Measures in the Action Plan that are relatively immediate actions aimed at mitigating noise levels in the Salish Sea, assessing cumulative effects of development projects and other human activities, and reducing noise and disturbance from largely whale-watching oriented boat traffic through education, enforcement and whale watching guidelines (Table 2; e.g. Recovery Measures # 12, 31, 34, 35, 41, 10, 11, 13, 47, 49, 50, and 53).

Among these there are six Recovery Measures (# 31, 34, 47, 49, 48, 43) aimed at addressing the problem of increasing ambient noise from shipping in the Salish Sea which have had some recent achievements. In 2012 the World Wildlife Fund organized a workshop to further the understanding and management of ocean noise on the Pacific coast. The workshop identified actions including establishing baseline ocean noise levels and scenarios of possible change, integrating hydrophone networks and informing placement for further hydrophones, and providing policy recommendations for noise mitigation (Heise and Alidina 2012). Since then, DFO undertook a coast-wide inventory of hydrophone installations as a first step to developing a network of calibrated hydrophones in Canadian waters. This is an identified Recovery Measure.

Analysis of acoustic data from the Canadian portion of the Salish Sea has been undertaken to determine the vessel sectors that contribute different levels of noise in the various sub-regions**.** The purpose of this on-going effort is to identify sub-regions where noise mitigation is needed for SRKWs to guide mitigation efforts (ECHO 2016).

The Vancouver Fraser Port Authority has led an initiative aimed at better understanding and managing the impact of shipping activities on at-risk whales, in particular SRKWs throughout the southern coast of British Columbia. The initiative is called Enhancing Cetacean Habitat and Observation (ECHO). The long term goal of the ECHO Program is to develop mitigation measures that will lead to a quantifiable reduction in potential threats to whales as a result of shipping activities. Approaches include identifying vessel noise source levels and developing mitigation measures such as voluntary slow zones, hull cleaning or incentives to adopt quietening technology (e.g. reduced port fees) (Port Vancouver 2017). To guide the program, there are advisory groups and technical working groups that include DFO membership.

The Vancouver Fraser Port Authority also established a Technical Advisory Group (TAG) to enhance the relevance, quality, and rigour of the Environmental Assessment studies that would be needed for the Roberts Bank Terminal 2 proposed development. The focus of the TAG was on SRKWs. The work of the TAG led, in part, to the estimate of lost foraging time and a SRKW dose response curve for behavioural effects to noise (SMRU Consulting Canada 2014; ECHO 2016; RBT2 2013).

DFO maintains a 24-hour hotline (BCMMRN/ORR) to report incidents involving whales. NOAA has a similar system as well as on-line reporting. In Canada, promotion of whale watching guidelines, on-the-water voluntary compliance programs, and enforcement efforts are underway. There have been four successful prosecutions of individuals for causing disturbance to resident killer whales in Canada since 2003. In the US, whale watching regulations are also enforced. Regulations implemented in 2011 in Washington State prohibit vessels from approaching within 200 yards of killer whales and from positioning within 400 yards of the path of killer whales. In Canada the *Be Whale Wise Guidelines* ask that people operating vessels stay 100m away from whales and slow their speeds within 400m of whales, travel parallel to them, and avoid approaching within 400m of the path of the whales. New regulations that would enforce these guidelines in Canada under the Fisheries Act are in development.

Effectiveness of actions

The research referenced in the characterization of the threat section above has largely occurred since 2003. Although the state of knowledge in 2003 included some behavioural studies on Northern Resident Killer Whales (Williams *et al.* 2002a; 2002b) and acoustic modelling (Erbe 2002), it is clear that the research since then has led to a demonstrably better understanding of this threat, which will continue to inform and guide management-based Recovery Measures.

Recovery Measures that aim to modify the behaviour of recreational and whale watching vessels through voluntary restrictions and disturbance charges leading to conviction (Canada), regulated restrictions about minimum whale watching viewing distances (U.S.), and education and outreach activities have increased in recent years. Collectively these implemented measures have likely had a positive effect on altering the behaviour of people in small boats on the water, thereby likely reducing acoustic and physical disturbance from small boats. However their collective effectiveness, in terms of measurable reductions in noise or disturbance is uncertain. Effectiveness could be inferred from an estimate of the number of boats within a certain distance of whales during summer annually, but this statistic was not found in time for this this review. Completion and formulation of Canada's Marine Mammal regulations under the Fisheries Act would make an enforceable contribution.

Underwater noise from vessels in the Salish Sea is high, but a quantitative time series was not available at the time of this review demonstrating an increase in underwater noise levels since 2003 or over a longer time period. However, it can be inferred that increases in whale watching boats, shipping traffic and further projected increases in shipping activity have led to increases in the underwater noise since

2003. Recovery actions aimed at mitigating noise in the Salish Sea from shipping have advanced significantly in recent times and were nonexistent in 2003. Collectively these activities, primarily since 2012, have further advanced the understanding of the threat. Efforts by the Vancouver Fraser Port Authority and their ECHO program have brought together expertise from different areas (DFO, academia, research and development companies, and shipping industry etc.; Table 2) to identify and refine mitigation options for reducing shipping noise in SRKW habitat. However no specific mitigation actions have been implemented yet.

6.3 Environmental Contaminants

Characterization of the threat

The threat of environmental contaminants encompasses chemical, particularly bio-accumulating chemical contaminants and biological pollutants. These later contaminants may be pathogens that enter SRKW habitat from coastal runoff and through wastewater from urban and agricultural areas and possibly through airborne transport. These two categories are discussed separately below. The Salish Sea is surrounded by increasing urban development and industrialization. There are local regional and global inputs of contamination. The issue is also made more complex because Canada and the U.S. have different regulations to address this transboundary threat and an effective solution will require greater collaboration and harmonization.

Chemical contamination

Killer whales are vulnerable to accumulating high concentrations of Persistent Organic Pollutants (POPs) because they are long-lived animals that feed high in the food chain (Ross *et al.* 2000, 2002, Rayne *et al.* 2004; Ross 2006). POPs are persistent, they bio-accumulate in fatty tissues, and are toxic. Resident killer whale prey, primarily Chinook salmon, feed in the upper trophic levels in the food web too and several stocks of importance to SRWKs reside in Salish Sea and in other coastal marine areas for a considerable amount of their life cycle.

POPs include 'legacy' contaminants such as the polychlorinated biphenyls (PCBs), and the organochlorine pesticide DDT, which are no longer widely used in industrialized countries, but remain persistent in the environment. The so-called 'dirty dozen' POPs are encompassed under the terms of the Stockholm Convention which aims to phase out use of chemicals of global concern. Additional contaminants of 'current concern' include flame retardants such as polybrominated diphenylethers (PBDEs) as well as currently used pesticides.

<u>*PCBs*</u>

Mean total PCB concentrations in SRKW sampled 1993-96, greatly exceeded those measured in the highly contaminated St. Lawrence beluga whales, *Delphinapterus leucas* (Ross 2000). The PCB concentrations in SRKWs at that time were well above levels associated with toxic effects in harbour seals and indicate that SRKWs are at risk of adverse health effects including immunotoxicity, reproductive impairment and endocrine disruption (Ross *et al.* 1996). Total PCBs in SRKWs tissues in 2004 and 2006 appeared to have decreased from 1993-96 however the levels still exceeded the threshold associated with health effects in harbour seals (Krahn et al. 2007). Blubber biopsy samples from NRKW obtained in 2003 to 2007 were analyzed to consider the effects of PCBs on mRNA transcripts related to KW health and found PCB-related increases in the expression of five of these gene targets. These results indicate there are on-going adverse physiological effects of PCBs in NRKWs and thus this is undoubtedly true in SRKWs as well (Buckman *et al.* 2011).

PBDEs

Fire retardants (PBDEs) are a significant and emerging concern for SRKWs (Ross 2006). Three main types of PBDEs are used in consumer products: Penta-BDE, Octa-BDE and Deca-BDE. Moderate levels of total PBDEs were observed in 39 biopsy samples collected from SRKWs in the years 1993-1996. Concentrations in the environment increased exponentially in the 2000s. The endocrine-disrupting potential (negative effects on reproduction, early development etc.) of PBDEs has been established in laboratory animals, fish and in seals. PBDEs are being introduced to the marine environment by wastewater discharges and atmospheric deposition (Rayne *et al.* 2004; Ross *et al.* 2008; Ross *et al.* 2009).

Current and historical concentrations of PCBs and PBDEs were modeled in individual SRKWs. Total PCB concentrations were predicted not to increase significantly over time, but PBDEs were predicted to have increased with time and with age, with a doubling time of 3-4 years. J pod, which spends the most time in the Salish Sea was predicted to have the highest concentrations of both PCBs and PBDEs (Mongillo *et al.* 2012).

Chemical Contaminant levels in Chinook salmon

Unlike other salmon, many populations of Chinook salmon remain in nearshore waters during the ocean phase of their life cycle and they are relatively long-lived compared to other salmon species. As a result they are more vulnerable to pollution through prolonged exposure. Chinook salmon generally have higher concentrations of persistent bioaccumulating toxins than other Pacific salmon species (Mongillo *et al.* 2016).

For example, 97 to 99% of PCBs, polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), DDT, and hexachlorocyclohexane (HCH) in returning adult Chinook salmon in southern BC were acquired during their time at sea, which, in the case of ocean-type Chinook salmon includes coastal marine waters rather than high seas habitat. Highest POP concentrations (including PCBs, PCDDs, PCDFs, and DDT) and lowest lipids were observed in returning adult Chinook salmon sampled near the Lower Fraser River and in Puget Sound near rivers of destination. It is known that Chinook salmon experience migration-related loss of lipid content as they approach their natal rivers because they stop feeding during this time. The lower lipid content of Chinook salmon as they near their natal rivers in southern BC may cause SRKWs to increase their salmon consumption, relative to NRKWs by as much as 50% to obtain sufficient caloric value, thereby increasing their exposure to POPs (Cullon *et al.* 2009).

It has been suggested that exposure and accumulation of POPs may exacerbate mortality of SRKWs during periods of reduced Chinook salmon abundance resulting in nutritional shortages (Lundin *et al.* 2016). Under such conditions SRKWs would likely need to gain energy by mobilizing their fat stores (blubber) which would also release PCBs to be metabolized. This could lead to elevated liver enzymes that are related to deleterious effects on reproduction and immune function.

Recovery measures to address this threat

There are a number of Recovery Measures that could result in a relatively immediate reduction to the threat (e.g., Recovery Measures 73, 74, 79, 80). Some measures to address this threat have been initiated while others have not.

The Government of Canada has taken multiple actions to reduce the releases of some contaminants. Regulatory bans on certain chemicals, updates to regulations regarding disposal and new regulations for wastewater effluent have been put in place, some prior to 2003, others after 2003. These are discussed below and include activities that align with most of the listed Recovery Measures associated with this threat.

For example, DDT was widely restricted in both Canada and the U.S. in the 1970s and entirely banned from use by the 1980s. PCB production was banned in North America in the 1970s, although they are still used industrially and commercially in closed applications (e.g. in transformers and capacitors); however, this is tightly regulated throughout North America (Grant and Ross 2002).

The manufacture, use, and import of many contaminants of concern, including polybrominated diphenyl ethers (with the exemption of manufactured items), polybrominated biphenyls, perfluorooctane sulfonate, short-chained chlorinated alkanes, tributyltins, polychlorinated naphthalines, and polychlorinated terphenyls are prohibited in Canada under the *Prohibition of Certain Toxic Substances Regulations, 2012*.

For dioxins and furans, polycyclic aromatic hydrocarbons, mercury, lead, cadmium, and copper, the Government of Canada has put in place a number of measures aimed at reducing emissions of these contaminants.

Regarding nonylphenol and its ethoxylates, the Government of Canada published a Pollution Prevention Planning Notice for textile mills and manufacturers and importers of cleaning products which resulted in a reduction of nonylphenol and its ethoxylates by 99.99% and 96% in these sectors, respectively.

Although some of these actions occurred well before 2003, given the persistent nature of many these substances, improvements will continue to occur with the passage of time.

Internationally the Government of Canada has been working with other countries to minimize exposure to contaminants from foreign sources. This includes work under the Stockholm Convention which aims to prohibit POPs, many of which are outlined in Appendix 2 of the Recovery Strategy (DFO 2011) and work under the Minimata Convention (Canada ratified in 2017) on mercury which aims to protect human health and the environment from the adverse effects of mercury. Canada ratified the Stockholm Convention in 2001; however, the work under the convention is ongoing to address Persistent Organic Pollutants.

Within Canada**,** Environment and Climate Change Canada (ECCC) and Health Canada (HC) are each responsible for evaluating regulatory performance to determine the efficacy of regulations. For example, under the Canadian Environmental Protection Act, 1999 (CEPA 1999), two to three million tonnes of material are disposed of at dedicated sites in the marine environment. The CEPA Action Level for disposal of potentially contaminated material at sea was found to be too high to protect killer whales due to the bio-accumulative nature of PCBs (Lachmuth *et al.* 2010). As a consequence in 2011-12, ECCC developed Standard Operating Procedures with DFO in order to address any additional risks associated with dredging/disposal in the Critical Habitat of resident killer whales. More restrictive PCB limits on sediment concentrations were subsequently introduced, based on modelling which took into account bioaccumulation (Alava et al. 2012). Because PCBs have largely been banned for the past 40 years, levels in sediment are slowly degrading or becoming buried by sediment deposition. Thus, the more restrictive limits as well as burying of contaminant sediment with cleaner sediment can serve to lower exposure to legacy sources of PCBs (Lachmuth *et al.* 2010).

Improvements to water quality protection were introduced in Canada in 2012 through the *Wastewater System Effluent Regulations* (WSER) (Government of Canada 2012). The WSER sets minimum regulatory effluent quality standards to be achieved through secondary wastewater treatment. The higher standard required will lead to removal of over 95% of the total mass of conventional pollutants in wastewater. Significant amounts of non-conventional pollutants and bacteria that may be present will also be removed through such treatment. The WSER sets out the timeline by which wastewater treatment facilities must meet the new standards. Wastewater systems considered of high risk to contaminate the environment are required to meet the effluent quality standards by the end of 2020, medium risk facilities by the end of 2030, and low risk facilities by the end of 2040.

Research to support the WSER included a study that analyzed PBDE congeners and levels in 20 wastewater treatment plants in Canada. The resulting profile of PBDE congeners in the influent provided a reference point for future PBDE monitoring in wastewater against which to evaluate the effectiveness of the 2012 regulation. The results of the study also provided operational recommendations to achieve higher percentages of PBDE removal from waste water (Kim *et al.* 2013).

DFO’s National Contaminants Advisory Group has contracted for the following study which will provide key information on contaminant levels in SRKWs and health effects using genomic techniques:

> Health risk-based evaluation of emerging pollutants in killer whales (*Orcinus orca*): priority-setting in support of recovery. Led by Frank Gobas and Peter Ross

In Washington State, the Department of Ecology undertook an assessment and identified the major sources of several chemical pollutants in Puget Sound, including PCBs, as a key step towards reduction of this threat (Ecology and King County 2011).

Washington's PBDE Law of 2008 (RCW 70.76) placed restrictions on the use of PBDEs in products sold in Washington. Manufacturers of Penta-BDE, Octa-BDE voluntarily ceased production beginning in 2004. Deca-BDE manufacturers agreed to discontinue the manufacture, import, and sales of Deca-BDE at the end of 2012. By 2013 USA companies were required to phase out the production and use of Deca-BDEs (USEPA, 2010a). Deca-BDE was banned in the US from televisions, computers, and residential upholstered furniture beginning January 1, 2011

A series of workshops hosted by NOAA and the EPA were conducted in 2013; topics included PBDE modeling in Puget Sound and the need to establish a PBDE toxicological threshold for SRKW. Knowledge gaps toward establishing this threshold were identified and recommendations were made for future research (Gockel and Mongillo 2013).

Effectiveness of actions

The actions presented above indicate collectively positive steps to abate the threat of at least some chemical contaminants in the marine environment and most of these actions align with many of the Recovery Measures associated with this threat. While the ban on DDTs and PCBs appears to have been similar in both countries and has been effective at reducing these contaminants in the environment generally, the restriction on PBDEs appears to differ between Canada and the U.S. Nonetheless, overall the regulations have probably reduced at least some PBDEs from accumulating in the marine environment. In 2008, Canada prohibited the manufacture (but not the use) of all PBDE congeners and also prohibited the use, sale, offer for sale, or import of certain PBDEs, as well as mixtures, polymers and resins containing them. In 2016, the prohibition on PBDEs was expanded to include the manufacture, use, sale, offer for sale, or import of all PBDEs and products containing PBDEs with an exemption for manufactured items. In contrast the US appears to have focussed on prohibiting the manufacture of three PBDE congeners and taken further steps to prohibit the use of one of these congeners, DECA-BDE by 2013.

PBDEs are thought to make their way into the marine environment primarily through wastewater and run off. In Puget Sound, for example, PBDEs are found in significant amounts in wastewater discharges (~ 25-38% of total PBDE loading into Puget Sound (Gockel and Mongillo 2013)). Although Canada has not prohibited all uses of PBDEs, its wastewater regulations set standards for wastewater quality that are required to be implemented by 2020 for high risk facilities, 2030 for medium risk facilities, and by 2040 for low risk facilities. As wastewater systems are upgraded to achieve these standards in the coming decades, reductions of PBDEs entering the marine environment are anticipated. However it is important to note that full compliance is not expected for over 20 years.

There are a number of Recovery Measures that would support reduction of chemical pollutants (e.g., Recovery Measures # 66, 68, 69, 70, 71, 75, 76, 77, 78, 97) but little appears to have been initiated in Canada (Table 2). In particular, there is, as yet, no oil spill response plan in Canada specifically for marine mammals including SRKWs or their habitat. However, adjacent, Washington State has developed and adopted such a plan. In the U.S. there have been some efforts to identify sources of POPs that are of concern for SRKWs and to try to develop toxicological thresholds for PBDE levels in SRKWs, (see Ecology and King County 2011 and Gockel and Mongillo 2013).

Ultimately a measure of effectiveness is reduction in the level of contaminants in marine food webs. SRKWs are long lived animals and thus declines in body burden of bioaccumulating POPs are not to be expected over a period of decades in the same cohort of animals. Hickie *et al.* (2007) modelled estimates of PCB concentrations in SRKW from 1930 to 2030 and estimated that the PCB concentrations in SRKWs would not fall below the threshold concentration associated with onset of toxic effects (17 mg/kg) in marine mammals until at least 2063. They concluded that despite adoption of regulations and source controls for PCBs in the 1970s these long-lived aquatic mammals are not protected by current Canadian or U.S. PCB dietary residue guidelines, because PCB concentrations in Chinook salmon would also have to drop. Contaminant levels, however, in shorter-lived top predators such as the harbour seal will reveal recent trends in contamination of the food chain. PCB concentrations in harbour seals, in the Salish Sea were found to have declined by 81% between 1984 and 2003, a not unexpected finding given the earlier ban on PCBs. Total PBDE concentrations which doubled every 3.1 years between 1984 and 2003, appeared to drop in 2009 possibly reflecting the withdrawal of the penta- and octa-BDEs from the market in the U.S. in 2004, with consequent reductions in their release into coastal waters (Ross *et al.* 2013).

Thus it appears there has been some reduction of PCBs in the marine food chain of SRKW habitat largely as a result of actions prior to 2003. Changes to ocean disposal guidelines in 2011 in Canada with respect to PCBs, are also expected to have a positive effect, although at the time of this review it is not clear if there is evidence of a further declining trend. Actions to restrict PBDEs that started as early as 2004 in the U.S. and came into force in Canada in 2008 and 2012 are expected to have a reduction effect but at the time of this review, it is not certain whether declining trends reported by Ross *et al.* (2013) are continuing.

Biological pollutants

Characterization of the threat

Biological pollutants, including pathogens and antibiotic-resistant bacteria resulting from human activities, may threaten the health of SRKWs, their habitat or their prey. Due to the small size of the southern resident killer whale population and the gregarious social nature of these animals, introduction of a highly virulent and transmissible pathogen has the potential to catastrophically affect the long-term viability of the population through reduced reproductive success and survival (Gaydos *et al.* 2004). Furthermore, although age may be a confounding factor, it has been suggested that there is an association between cetacean exposure to PCBs and mortality due to infectious diseases (O'Hara and O'Shea, 2001). Pathogens and antibiotic-resistant bacteria can enter the marine environment by means of coastal run-off and wastewater discharges.

A number of Recovery Measures have been proposed that involve reducing or mitigating the release of biological pollutants into the habitat, some are underway, others are not, (e.g., Recovery Measures 67, 81, 82, 59, 65) (Table 2). Canada's *Wastewater System Effluent Regulations* (WSER) of 2012 will require all wastewater facilities to meet the effluent quality standards by 2040. This would be expected to significantly reduce the release of biological pollutants, which is one of the recovery measures listed in the Action Plan. Highest risk facilities must be compliant by 2020.

Several measures that involve monitoring and identifying biological pollutant trends in SRKW are underway as part of ongoing long term programs. Presently most efforts are focussed on monitoring for pathogens and disease related mortality in stranded SRKWs and other marine mammals that inhabit the same region. The emergence of novel pathogens will be detected as part of these efforts. Standardized necropsy protocols and disease testing has been developed for BC and WA. This monitoring will also help to detect biological pollutants.

Effectiveness of actions

At the time of this review there is no indication that the threat of biological pollutants has been reduced, however it seems that biological pollutants are not as significant a concern as chemical pollutants. Nonetheless, compliance by Canadian wastewater treatment facilities may help reduce this threat when they come fully into force. Continued health monitoring via necropsies of dead SRKWs will continue to be important to detect emerging biological pollutants.

6.4 Ship Strike

Fast moving large vessels can pose a strike risk for whales, even killer whales. The recent mortality of J34, a prime age male found to have died from large blunt force trauma, highlights this threat. The very small size of the SRKW population and the low numbers of prime age males and females that support the reproductive potential and genetic diversity of the population means that a threat that could remove one animal will have significant consequences. There are no specific Recovery Measures to address this threat, because it was not identified as a threat during the recovery planning; related recommendations are contained in section 8 of this review.

7. Effectiveness of Recovery Measures related to Critical Habitat

Identification of the habitat necessary for the survival and recovery of a SARA-listed threatened or endangered population (termed “critical habitat”) is a requirement under SARA. The identification and protection of Critical Habitat for any aquatic species at risk does not directly reduce a specific threat to that species but once identified and published in a recovery strategy, legal protection of the critical habitat is required. In 2009, identification and protection of SRKW critical habitat was undertaken, and encompasses the Canadian portion of the Salish Sea, specifically the transboundary areas of southern British Columbia and Washington State, including Haro Strait and Boundary Pass and adjoining areas in the Strait of Georgia and the Strait of Juan de Fuca (see Figure 4 in DFO 2011). The U.S. portion of the Salish Sea was identified as Critical Habitat under the U.S. ESA in 2006 (DFO 2011; Ford 2006; NMFS 2006). In Canada under SARA, this has added a higher level of scrutiny of human activities that could destroy the habitat. The SARA protects critical habitat from destruction (destruction would result if part of the critical habitat were degraded, either permanently or temporarily, such that it would not serve its function when needed by the species) (Table 2).

For example, underwater noise is very high in SRKW habitat in the Salish Sea, compared to elsewhere in coastal BC. Underwater noise has resulted in masking of communication, leading to alterations in foraging behaviour. Furthermore, since shipping noise is identified as an activity likely to destroy Critical Habitat (DFO 2011), any temporary loss of function should warrant very high priority for management action to reduce this threat particularly as it may be considered destruction under the SARA (DFO 2017c).

Two Recovery Measures (16 and 83) are focussed on further identification of important habitat. It is recognized that the entire critical habitat in the Canadian range of this population has not been identified, and further research is required to complete the identification of all the habitat necessary to support survival and recovery. Science advice regarding an additional area of SRKW important habitat off southwestern Vancouver Island has been developed and peer reviewed (DFO 2017b).

One Recovery Measure (85) is focussed on refining our understanding of the functions, features and attributes of critical habitat. This measure is important because improved understanding of the features and attributes that support the identified function can help to clarify what would constitute destruction under SARA. This measure is important although it is very difficult to determine thresholds or measures of habitat quality.

One Recovery Measure (17) on the review and assessment of proposed development project impacts is currently underway. DFO’s Fisheries Protection Program is responsible for project review and seeks advice from DFO Science regarding project impacts to SRKW, and provision of advice on, or review of proposed mitigation measures.

Effectiveness of actions

The action to review and assess proposed development projects to determine if they could lead to destruction of Critical Habitat, as defined and protected under SARA, has the potential to be effective at reducing any one of the major threats, as well as the new threat of ship strike in Critical Habitat. Indeed, while not a direct reduction of a threat, it is because of Critical Habitat designation that recent scrutiny of proposed development projects in SRKW habitat have led to a technical advisory teams to advise on the environmental assessment on the effects of noise and knowledge of killer whale acoustic signalling (SMRU Consulting Canada 2014). However, it has not yet resulted in implementation of actions that reduce underwater noise. In addition, review of proposed development projects that have the potential to result in increased vessel traffic have provided significant opportunity to engage with stakeholders and contributed to the initiation of the Port of Vancouver's ECHO program, which has a number of proposed acoustic mitigation measures slated for implementation in the summer of 2017.

8. Recommendations about Priority of Recovery Measures

Based on data from the long term population census program and genetic studies examining paternity patterns in the population, there is no evidence that the SRKW population is recovering. Annual population assessments since 1974 have shown that the number of SRKWs has fluctuated from a low of 71 animals in 1974, to a high of 96 in 1996. As of late 2016, there are 78 animals.

The following sections present recommendations about high priority actions to be taken to address the main threats to the population. These recommendations were made within a limited time frame and a limited review process, and therefore may be further refined in the future.

Recommendations about Prey Availability

A recent review of research to detect poor body condition in the SRKW population concluded that poor body condition is prevalent in some years and that it is associated with subsequent reproductive loss through loss of fetuses as well as mortality of calves. Poor body condition was also associated with mortality of adults, including prime reproductive age females.

In two specific instances, females that died were not only foraging to feed themselves but also to provision calves or orphaned young. The loss of these individuals may increase the risk of mortality for the individuals they provisioned. Both 2013 and 2016 had relatively low catch-per-unit-effort for Chinook salmon returns to the Fraser River, and in both of these years a number of animals in poor body condition died, or if pregnant, did not subsequently produce calves. In most wild populations, food availability is the most common cause of poor body condition (Matkin *et al.* 2017). Recovery Measures that aim to increase prey availability should be of paramount importance (Table 3). Longer term Recovery Measures that include rebuilding of Chinook stocks should be implemented, and to do so will require integration between Chinook salmon population recovery efforts and DFO Science and Management specifically related to SRKWs. It seems likely that with more focussed attention on possible actions to rebuild Chinook stocks, additional Recovery Measures beyond those identified will become apparent.

Near-term Recovery Measures that aim to provide improved foraging conditions to enhance SRKW foraging success on the existing available Chinook salmon include those that may lead decreased direct competition for prey, or reductions in acoustic impacts on the foraging grounds from vessel traffic. Such areas could provide undisturbed access and space for SRKWs to forage. Strategic fishery planning approaches and Chinook management actions in key SRKW foraging locations could reduce competition with fishers for Chinook in these hot spots. The primary SRKW foraging areas in the Salish Sea have been identified, although less is known of their foraging hotspots in winter areas such as northern Strait of Georgia (Hauser *et al.* 2007; Hanson *et al.* 2010a). Examples of approaches to identifying potential areas for restriction of fishing activity and other human activities are available (Hauser *et al.* 2007; Ashe *et al.* 2010). More recently, ECHO has applied acoustic mapping and SRKW distribution data to identify areas of high SRKW use that could be targeted for mitigation of acoustic and physical disturbance, which are also important considerations for foraging success. Monitoring and research needed to assess the effectiveness of these actions include trends in the nutritional status of SRKWs, their foraging success, habitat use and ultimately their population size.

Presently NOAA is considering a petition to establish a Whale Protection Zones that would extend 1.2 kilometres offshore of the west side of San Juan Island. The proposed protected area would encompass approximately 26 to 31 square kilometres (about 0.5% of the currently designated US portion of Critical Habitat) and is an area in which SRKWs are estimated to be three times more likely to be engaged in foraging than elsewhere (Ashe *et al.* 2009; NOAA 2016). Efforts to create areas of reduced acoustic and physical disturbance as well as reduced competition should also be a priority in Canadian waters.

In light of fluctuating herring stocks and changes in ecosystem structure and dynamics, a new management measure has been recommended in support of recovering Chinook salmon by considering Chinook foraging needs. Pacific herring and sand lance constitute an important part of the diet of Chinook in most areas (Healey 1991). DFO has a forage fish policy that could be implemented to consider the ecosystem role of these fish species and their potential importance to the rebuilding of not only Chinook stocks, but ultimately the SRKW population.

Table 3 - Suggested high priority recovery measures aimed at abating the threat of reduced prey availability and activities to monitor the effectiveness of these measures.

The rank for implementing measures is determined based on whether the scope of the measure or the benefits to the population with regards to abating the threat is large or small, and whether its impact in terms of threat abatement is direct or indirect. Timing can be 'immediate' (within 1 year), 'short-term (1-5 years), medium-term (5-10 years) or longer-term (10 + years), and represents the horizon for acquiring the scientific information necessary to implement the measure and for the effects of implementation to become evident, either in terms of a reduction of threat level or benefits to the population. A rank of 1 is given to measures that directly abate most effects from a threat; a rank of 2 is given to measures with a large scope, but with indirect impacts on the threat. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed.

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
Plan and manage salmon fisheries in ways that will reduce anthropogenic competition for SRKW prey in important foraging areas during key times (e.g., create protected areas; implement fishery area boundary adjustments and/or closures) or when there are indications of population nutritional stress. Among other things, this will require the formation and formalization of a transboundary working group of science and management representatives from DFO, NOAA, and other technical experts to ensure that SRKW prey needs are incorporated consistently in the management of salmon fisheries for transboundary stocks (e.g. Canada's Policy for Conservation of Wild Salmon, Pacific Salmon Treaty).	Large	Direct	Immediate	Short-term	1
During years of poor Chinook returns, implement a more conservative management approach than would be used in typical years to further reduce or eliminate anthropogenic competition for Chinook and other important prey in key SRKW foraging areas during key times.	Large	Direct	Immediate	Short-term	1
Protect and preserve the freshwater habitat of important SRKW prey stocks.	Large	Indirect	Short-term	medium-term	2
Implement fisheries management measures that will foster healthy and abundant populations of herring and sand lance to support greater availability of Chinook	Large	Indirect	Short-term	Medium-term	2
Data gaps and needs for monitoring					
Undertake a catch per unit effort assessment of SRKW foraging effort and success rate to provide information on the efficacy of management actions aimed at reducing prey competition and increasing prey availability in known			Short-term		

key foraging areas, and monitor over time.					
Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Assess seasonal and inter-annual changes in body condition and growth of SRKWs to further refine the relationship between nutritional status and prey abundance and/or foraging success to inform management actions aimed at increasing prey availability to SRKWs.			Short-term		
Continue to refine knowledge of SRKW prey preferences and prey distribution throughout their range and among seasons using methods including acoustic monitoring and dedicated vessel surveys.			Short-term		
Assess the impacts of disturbance and prey competition from fisheries on foraging success of SRKWs in foraging areas.			Short-term		
Continue to perform a population census each year on the SRKW* **Note: this research-based activity supports adaptive management of ALL threats and provides an ultimate gauge of the collective efficacy of management actions (i.e., population size and structure), but it only appears in this recommendation table for simplicity.*			Immediate		

Recommendations about Acoustic and Physical Disturbance

Underwater noise is a significant threat to SRKWs, discussed in section 6.2. Under existing conditions, underwater noise from shipping in SRKW habitat in the Salish Sea is already causing a reduction in foraging opportunities for SRKWs and there are expected impacts of this noise on SRKW communication space and on other life processes, (e.g., reproduction, resting, socializing). Further reductions to foraging opportunities are anticipated with future increases in shipping.

The Vancouver Fraser Port Authorities' ECHO program states as the following objective: "to evaluate vessel underwater noise reduction options, this could be used to incentivize ship owners to reduce their vessel noise outputs". This activity should be prioritized to address acoustic disturbance and lost foraging opportunities because it may lead to one of several mitigation options that could and should be employed simultaneously and as soon as possible. A new recommended measure is the coordination of underwater noise evaluation and reduction options between Canadian and US ports and industries to support the regional success of actions to reduce acoustic disturbance to SRKWs in the Salish Sea.

Recovery Measures that aim to identify and then set aside areas that are refuges from noise for SRKWs should be made a priority. Such mitigation options might include slow down zones for vessels, no-go zones for vessels, rerouting shipping traffic, and/or scheduling shipping traffic movements to allow for periods of quiet in important foraging habitat for killer whales. Monitoring and research needed to assess the effectiveness of these actions include determination of trends in nutritional status, foraging success, habitat use and ultimately population size.

To more effectively manage the impacts of anthropogenic disturbance to SRKWs in the Salish Sea, in particular, a rigorous assessment of cumulative effects of existing and planned developments and activities should be undertaken (e.g. Lawson and Lesage 2012). This is already identified as a Recovery Measure in the Action Plan. To support this, Recovery Measures related to monitoring ambient noise in the Salish Sea should continue to be priority activities.

Table 4 - Suggested priority recovery measures aimed at abating the threat of acoustic and physical disturbance and activities to monitor the effectiveness of these measures.

The rank for implementing measures is determined based on whether the scope of the measure or the benefits to the population with regards to abating the threat is large or small, and whether its impact in terms of threat abatement is direct or indirect. Timing can be 'immediate' (within 1 year), 'short-term (1-5 years), medium-term (5-10 years) or longer-term (10 + years), and represents the horizon for acquiring the scientific information necessary to implement the measure and for the effects of implementation to become evident, either in terms of a reduction of threat level or benefits to the population. A rank of 1 is given to measures that directly abate most effects from a threat; a rank of 2 is given to measures with a large scope, but with indirect impacts on the threat. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed. Management-based measures denoted by an asterisk also address the threat of ship strikes (discussed in a later section).

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
*Implement area-specific vessel regulations and/or guidelines (e.g., speed restriction zones, rerouting vessel traffic, altering vessel traffic scheduling to create convoys) that reduce the overall acoustic impact on SRKWs in their habitat, particularly in the Salish Sea.	Large	Direct	Immediate	Short-term	1
Implement incentive programs and regulations that result in reduced acoustic footprints of the vessels habitually travelling in and near important SRKW habitat (e.g., through changes in vessel maintenance, application of quieting technologies) and the elimination of the noisiest vessels.	Large	Direct	Immediate	Immediate	1
*Identify candidate acoustic refuge areas within foraging and other key areas of SRKW habitat, and undertake actions for their creation	Large	Direct	Immediate	Short-term	1
*Increase the distance between SRKWs and pleasure crafts and whale-watching vessels	Large	Direct	Immediate	Immediate	1
Establish a transboundary committee to ensure consistency among U.S. and Canadian management actions aimed at reducing shipping noise in the Salish Sea.	Large	Indirect	Immediate	Medium-term	2
*Maintain and improve the existing 24 hour hotline (BCMMRN/ORR) for the reporting of acoustic or physical disturbance incidents to ensure timely response and enforcement of whale watching guidelines.	Small	Indirect	Immediate	Short-term	2
Data gaps and needs for monitoring					
Assess cumulative effects of physical and acoustic disturbance from projects already on-going and those proposed on SRKWs. Do so using an appropriate			Short-term		

impact assessment framework for aquatic species.					
Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Develop a noise monitoring system to assess the noise production from individual ships to support the assessment of effectiveness of incentive programs for ship owners and enable enforcement.			Short-term		
Model existing acoustic data to estimate efficacy of potential noise reduction measures such as alteration of shipping lanes, varying ship speed, and coordinating vessel transits by convoy. Validate acoustic modelling efforts by deploying autonomous recorders and comparing measurements with model outputs.			Short-term		
Continue to monitor ambient ocean noise in the Salish Sea and expand the transboundary coverage of calibrated hydrophones to quantify ocean noise throughout the SRKW range			Short-term		
Quantify the impacts of vessel-related physical disturbance and anthropogenic noise and echolocation masking on SRKW foraging success, and compare to areas where mitigation measures have been implemented to assess the effectiveness of those measures and support their adaptation as needed.			Short-term		

Recommendations regarding environmental contaminants

Chemical Pollutants

Because the SRKWs frequent the industrialized waters of southern British Columbia and northern Washington State, mitigation efforts such as the removal or capping of contaminated sediments in that region, accelerating the rate of compliance with wastewater effluent regulations, and the continued regulation and restrictions on POPs in this region should be priorities. Of the three main threats to SRKWs, the positive effects of reducing the quantity and variety of chemical contaminants entering SRKWs and their habitat, will likely take longest to detect because of the bio-accumulating nature of POPs and the long life span of these animals. Therefore a high priority should be set on implementing and prioritizing management actions in the near term.

While the Canadian *Wastewater System Effluent Regulation* (2012) is a positive step, as it requires wastewater systems discharging untreated and under-treated wastewater to upgrade to at least a secondary level of wastewater treatment, it is not clear at the time of this review when all facilities that border the Salish Sea in Canada will be required to be compliant. Under the WSER, wastewater systems, such as those in Victoria and Vancouver have upgrade timelines of the end of 2020 and 2030, respectively. Early compliance with the regulations would be beneficial. The transboundary contaminant working group could be used to connect this effort in Canada with regulatory authorities in the US and support the development of consistent mitigation protocols to reduce entry of contaminants into the environment.

Temporal trends (1993–2006) for PBDEs observed in SRKWs showed a doubling time of ˜5 years. PBDEs are not currently examined in ocean disposal assessments but they should be because if even the current sediment quality guidelines available in Canada for PCBs are applied to PBDEs, it can be expected that PBDE concentrations in killer whales will exceed available toxicity reference values by a large margin (Alava *et al.* 2016).

Efforts to better understand the fate transport, and bioaccumulation of PBDE in the ecosystem and establishment of a PBDE toxicological threshold level in marine mammals and threshold levels for mixtures containing PBDEs and other persistent pollutants, would enable targeted remediation and regulations. There have been some efforts towards this in Puget Sound (see section 6.3); however there does not appear to be a similar process or coordination of effort in Canada. Such efforts will be necessary to assess the effectiveness of actions aimed at reducing contaminants in SRKWs, their prey and their habitat. In that regard it is advisable that an Interdepartmental Regional Advisory Committee and even a transboundary committee be established to set priorities and targets for reduction of chemical contaminants.

Canada does not have an oil spill response plan for marine mammals and their habitat, including SRKWs. Development of such a plan should be a priority.

Biological Pollutants

Health monitoring supported by an effective marine mammal stranding response and reporting network will continue to be important to enable monitoring of health through necropsy and disease testing. While this will not reduce the threat it will continue to inform our understanding of the threat and it could provide a measure of effectiveness of regulations or other management measures that ultimately aim to reduce releases of biological pollutants into the marine environment.

Table 5 - Suggested priority recovery measures aimed at abating the threat of chemical and biological pollutants and activities to monitor the effectiveness of these measures.

The rank for implementing measures is determined based on whether the scope of the measure or the benefits to the population with regards to abating the threat is large or small, and whether its impact in terms of threat abatement is direct or indirect. Timing can be 'immediate' (within 1 year), 'short-term (1-5 years), medium-term (5-10 years) or longer-term (10 + years), and represents the horizon for acquiring the scientific information necessary to implement the measure and for the effects of implementation to become evident, either in terms of a reduction of threat level or benefits to the population. A rank of 1 is given to measures that directly abate most effects from a threat; a rank of 2 is given to measures with a large scope, but with indirect impacts on the threat. Measures to fill data gaps or provide a monitoring function are not assigned scope, impact, timing for improvements, or rank, as they collectively support the implementation of the management-based measures listed.

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Management-based					
Adequately enforce existing, and/or newly added or expanded, Canadian regulations aimed at reducing toxic chemical compound discharges at the source.	Large	Direct	immediate	Longer-term	1
Accelerate the rate of compliance with the Canadian Wastewater System Effluent Regulation (2012) in wastewater treatment facilities that border the Salish Sea	Large	Direct	Short-term	Medium-term	1
Use best currently available knowledge of SRKW distribution, foraging behavior, and their food web to ensure that assessment and remediation plans for contaminated sites will reduce the risk of lifetime contaminant exposure in SRKWs.	Small	Indirect	immediate	Longer-term	2
Review policies and best management practices for ocean dredging and disposal at sea and modify them to include an examination of PBDEs, as well as any other necessary modifications, to minimize SRKW contaminant exposure.	Large	Direct	immediate	Longer-term	1
Identify programs that mitigate small scale and/or chronic contaminant spills and leaks and provide support to them (e.g., financially, in-kind). If none exist, design and implement an ongoing program that focuses on mitigating small scale and/or chronic spills and leaks in SRKW habitat.	Small - Large	Direct	Short-term	Short-term	1
Develop a spill response plan including training, equipment, and deterrence methods and ensure that the protection of SRKWs and their habitat is made a high priority in spill response and monitoring protocols in Canada.	Large	Indirect	Short-term	Short-term	2
Form an interagency contaminants working group to identify roles and	Large	Indirect	Short-term	Longer-term	2

Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
responsibilities for actions to reduce the impacts of contaminants on SRKWs and their environment. The group should also set targets for reduction of chemical contaminants (e.g., PBDEs) and the priorities and timelines for reaching those targets.					
Recovery Measures	Anticipated effectiveness		Anticipated timing		Rank
	Scope	Impact	Initiate implementation	Improvements	
Data gaps and needs for monitoring					
Quantify current contaminant concentrations in SRKW prey and refine the analysis of contaminant intake by SRKWs using current information on their feeding ecology.			Short-term		
Conduct a risk assessment of different chemical contaminants of concern in SRKWs, their prey, and their habitat.			immediate		
Identify and monitor contaminants of concern (e.g. flame retardants, pharmaceuticals and personal care products, PBTs, hydrocarbons) in SRKWs, their prey, and their habitat.			Short-term		
Conduct a pathway-based risk assessment to assess the risk of biological pollutants from various pathways of introduction, such as agricultural runoff, sewage effluent, and wildlife rehabilitation facilities.			Short-term		
Determine the efficacy of the new regulations for PBDEs under the Canadian Environmental Protection Act (CEPA) by monitoring PBDE trends in indicator species in SRKW habitat.			Short-term		
Establish a PBDE toxicological threshold level in marine mammals to support regulations and the prioritization of targeted remediation efforts.			Longer-term		
Establish a monitoring program for pathogens and biological pollutants to evaluate long-term trends in SRKWs and their prey. This would include maintaining an effective marine mammal stranding response and necropsy network*. **Note: this research-based activity supports the monitoring of ALL threats over time which can guide threat mitigation efforts and enable assessment of the collective efficacy of management actions over time, but it only appears in this recommendation table for simplicity.*			Short-term		

Recommendations regarding Ship Strikes

Two measures are recommended that aim to reduce and detect the threat of ship strikes. First, candidate ship slow down zones should be developed and tested, which would primarily be aimed at reducing underwater noise in SRKW habitat, but which could secondarily serve to reduce ship strike risk (see Table 4). Other measures could include slow down zones on known routes of scheduled large vessel movement (e.g. ferry routes), or development of a mariner alert system based on visual and/or acoustic identification of whales in an area. The efficacy of such measures to avoid collisions with killer whales is not certain at this time, but they should be piloted and monitored to determine their efficacy. Concurrently, performing necropsies consistently and the maintenance of an effective stranding and reporting network are vital to be able to document ship strike incidents resulting from this threat (see recommendation in Table 5) – this is in fact the mechanism through which the recent incident that resulted in the death of J34 came to light. Often carcasses are not found and therefore causes of mortality of missing animals cannot be determined. Continued support and improvement to a stranding and reporting network and necropsies should be a priority as it helps detect and track the impact of the ship strike threat, as well as other threats such as biological pollutants.

9. Conclusions

The SRKW population is not recovering and in fact continues to decline. Some actions have been taken to date that have contributed to partially abating some of the threats to this population, but collectively they have not been sufficient to prevent a continued decline in the population trajectory. Positive steps taken to reducing threats to SRKWs include the development of whale watching guidelines in Canada and enforcement of whale watching regulations in the US, improved ocean disposal of sediment guidelines in Canada for PCBs, and bans on certain contaminants and restrictions on others in both countries. However, thus far no recovery measures have been implemented that directly aim to reduce shipping noise or improve prey availability for SRKWs. Some actions have been taken to reduce the input of contaminants into the marine environment, but more is clearly needed.

Going forward, concrete management-based measures to abate the threats of prey availability and acoustic disturbance should be paramount, and provide the best chance at seeing positive progress in the near term. Research and monitoring efforts to support potential management actions to reduce impacts from shipping are currently underway and have resulted in monitoring and acoustic modelling advances that could support mitigation of acoustic disturbance (e.g. work being coordinated by ECHO and undertaken by SMRU Consulting Canada, JASCO Applied Science, Oceans Network Canada and others). Progress in the abatement of the contaminant threat and resultant positive changes in the population will only become evident over much longer timeframes given the long life span of these animals, the high contaminant burdens they presently carry and the bio-accumulating nature of some contaminants. This highlights the need to begin the implementation of management based measures aimed at reducing contaminants as soon as possible.

Salmon management actions to address concerns about conservation of Fraser River Chinook have been implemented, though not specifically to address the needs of SRKWs, and measures to specifically address concerns about prey availability for SRKW in their key foraging habitats appear to be lacking or at best are in early stages of development. It is critical that SRKW be provided greater access to prey in their key foraging areas, either by increasing the abundance of the prey, by reducing underwater noise so they more effectively forage from the existing prey base, or a combination of both, because indicators of nutritional stress (links between body condition and subsequent mortality) are compelling (Matkin *et al.* 2017). Recovery Measures aligned with efforts to rebuild Chinook salmon stocks appear to be well captured in the draft Southern BC Chinook Strategic Plan. In the immediate future, however, Recovery Measures aimed at providing access to Chinook salmon through reduced competition from fishers and reductions in physical and acoustic disturbance should be of high priority to allow SRKWs to forage with greater efficiency in order to meet their energetic requirements with the available Chinook population abundance. To provide improved access to Chinook salmon, areas should be identified that can be set aside for periods of time for access by SRKWs to forage. Field research will be needed to measure foraging success rates (catch per unit effort) to be able to assess functioning of such reserves. Measures of increased prey availability (reduction of threat) could be inferred by regular monitoring of body condition and annual surveys. Surveys to monitor trends in survival and reproduction in the population should continue.

This review has also provided an opportunity to highlight a newly emerged threat (ship strikes) that was not recognized in the Recovery Strategy or Action Plan, as well as the identification of some modified and additional measures that should be implemented in the near term.

The identification of Critical Habitat for SRKW was an important achievement, although Critical Habitat identification alone does not necessarily result in direct reductions of threats. In order for threats to be reduced, Critical Habitat requirements need to be adequately enforced. Critical Habitat identification has brought greater scrutiny to development projects that are planned or approved in the Canadian portion of the Salish Sea, although there remains a need to assess their cumulative effects. The identification has also served to catalyze efforts to manage shipping noise and impacts on marine mammals, particularly SRKWs (Vancouver Port 2017). Additional important habitat off the southwest coast of Vancouver Island that adjoins the currently identified SRKW Critical Habitat has recently been identified. Designation and enforcement of this additional area should be implemented as soon as possible (DFO 2017b); however, challenges remain to effectively protect critical habitat from being destroyed.

Almost half of the Recovery Measures in the action plan (40 of 98) are related to addressing knowledge gaps to better understand impacts of threats to SRKW through research, modelling or monitoring, rather than directly reducing a threat. While these research-based activities have not directly reduced threats, they have and will continue to play a crucial role in informing management decisions and to help monitor the effectiveness of management actions. Some management decisions may be controversial or have socio-economic implications that may be weighed heavily. In such cases having a detailed understanding of the threats to SRKWs can help support decisions.

Management-based recovery actions often seem challenging to implement as there are typically trade-offs to reducing anthropogenic threats (otherwise we would have reduced or eliminated the threat already). To make progress on management-based Recovery Measures, there needs to be a commitment within the federal government to integrate across sectors within DFO (e.g. Fisheries Management and Science) to ensure these actions are incorporated and that measurable advances become requirements. This is also true, and perhaps more challenging, when the management-based Recovery Measure involves other government agencies with whom DFO would need to cooperate and collaborate. These other agencies would ideally need to commit to making progress on recovery of a SRKW through implementation of specific Recovery Measures.

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Appendix 1

Acronym definitions:

DFO	Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
ECHO	Enhanced Cetacean Habitats and Observations
EPA	Environmental Protection Agency (US)
NOAA	National Oceanic and Atmospheric Administration
SMRU	SMRU Consulting Canada
SFU	Simon Fraser University
TC	Transport Canada
VFPA	Vancouver Fraser Port Authority