Synthesizing scientific knowledge about population dynamics and diet preferences of harbour seals, Steller sea lions and California sea lions, and their impacts on salmon in the Salish Sea Workshop 2: November 20-21, 2019, Bellingham, WA

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Abstract

Trzcinski, M.K. 2020. Synthesizing scientific knowledge about population dynamics and diet preferences of harbour seals, Steller sea lions and California sea lions, and their impacts on salmon in the Salish Sea Workshop 2: November 20-21, 2019, Bellingham, WA. Can. Tech. Rep. Fish. Aquat. Sci. 3403: x + 50 p.

In 2019, two bilateral Canada-U.S. workshops were held to outline the scientific knowledge about population dynamics and diet preferences of harbour seals, Steller sea lions and California sea lions, and their impacts on salmon in the Salish Sea. The 2nd was convened in Bellingham, Washington between 20-21 November. The 75 participants included representatives of First Nations, Tribes, stakeholders in the fishing industry and non-profit organizations, as well as scientists from local and federal regulatory agencies and universities. The workshop aimed to 1) provide concise summaries of the current state of scientific knowledge and uncertainties, 2) incorporate other relevant technical knowledge, outline management implications, and recommend possible next steps for science activities necessary to inform management considerations, and 3) asked participants to critique and provide feedback on four areas of action thought to possibly mitigate the impacts of pinnipeds on salmon: variation in hatchery production, enhanced fish survival, non-lethal removal of pinnipeds, and lethal removal of pinnipeds. There was wide variation among attendees on the interpretation of scientific results, the potential efficacy of proposed actions, the degree of risk of a given action, and the level of acceptable risk. This report summarizes the key points from the group discussions to provide focus for future science, management, and policy regarding the impacts of pinnipeds on salmon.

Résumé

Trzcinski, M.K. 2020. Synthesizing scientific knowledge about population dynamics and diet preferences of harbour seals, Steller sea lions and California sea lions, and their impacts on salmon in the Salish Sea Workshop 2: November 20-21, 2019, Bellingham, WA. Can. Tech. Rep. Fish. Aquat. Sci. 3403: x + 50 p.

En 2019, deux ateliers bilatéraux canado-américains ont été organisés afin d'exposer les connaissances scientifiques sur la dynamique des populations et les préférences alimentaires des phoques communs, des otaries de Steller et des otaries de Californie, ainsi que leurs répercussions sur le saumon de la mer des Salish. Le deuxième atelier, organisé à Bellingham, Washington, les 20 et 21 novembre, a accueilli 75 participants. Parmi ceux-ci se trouvaient des représentants des Premières Nations, de tribus, de parties prenantes de l'industrie de la pêche et d'organisations à but non lucratif, ainsi que des scientifiques provenant d'organismes de réglementation locaux et fédéraux, et d'universités. L'atelier visait à 1) présenter des résumés concis de l'état actuel des connaissances scientifiques et des incertitudes, 2) intégrer d'autres connaissances techniques pertinentes, décrire les répercussions sur la gestion et recommander les prochaines étapes possibles des activités scientifiques nécessaires pour éclairer les éléments à considérer en matière de gestion, et 3) demander aux participants de donner leur opinion et de fournir des commentaires sur quatre domaines d'action envisagés pour atténuer éventuellement les effets des pinnipèdes sur le saumon, notamment : la variation de la production des écloseries, l'amélioration de la survie des poissons, le retrait non létal des pinnipèdes et l'abattage des pinnipèdes. Les avis des participants étaient très partagés en ce qui concerne l'interprétation des résultats scientifiques, l'efficacité potentielle des mesures proposées, le degré de risque d'une mesure donnée ainsi que le niveau de risque acceptable. Ce rapport résume les points clés issus des discussions de groupe afin de fournir une orientation future pour les activités scientifiques, la gestion et l'élaboration de politiques concernant les répercussions des pinnipèdes sur le saumon.

Workshop Summary

In 2019, two bilateral Canada-U.S. workshops were held to understand the scientific knowledge about population dynamics and diet preferences of harbour seals, Steller sea lions and California sea lions, and their impacts on salmon in the Salish Sea.

The first workshop, held in May 2019, focused on the current state of knowledge of pinniped impacts, and attendance was limited to scientists. A summary of the findings and discussion was documented by Trites and Rosen (2019). Readers looking for more detailed explanations of the current state of knowledge are referred to this document.

The second workshop on the potential impacts of pinnipeds (harbour seals, Steller and California sea lions) on salmon in the Salish Sea was convened in Bellingham, Washington on 20-21 November, 2019. The goals of this second workshop were to engage a broader science audience along with managers and stakeholders with technical expertise to 1) share current knowledge about pinniped population sizes, population dynamics and diet composition, 2) identify current scientific knowledge gaps and uncertainties, particularly as they relate to pinniped predation on salmonids, salmon population drivers, and broader ecosystem factors, 3) discuss direction for future science activities that can inform potential management considerations.

This second workshop differed from the first in the following manner: i) it included a wider audience representing First Nations, Tribes, stakeholders in the fishing industry, and non-profit organizations, as well as scientists from local and federal regulatory agencies and universities, ii) it provided concise summaries of the current state of scientific knowledge, and iii) it asked participants to critique and provide feedback on four areas of action thought to possibly mitigate the impacts of pinnipeds on salmon: variation in hatchery production, enhanced fish survival, non-lethal removal of pinnipeds, lethal removal of pinnipeds.

There was wide variation among attendees on the interpretation of scientific results, the potential efficacy of proposed actions, the degree of risk of a given action, and the level of acceptable risk. This report summarizes the key points from the group discussions, but not all ideas or comments could be included in the report, nor are they attributed to particular participants.

Workshop Structure

The structure of this workshop was designed to generate discussion and critical thinking about the impacts of pinnipeds on salmon. Participants (Appendix A) were allotted to specific tables, with five to eight participants per table, so that there was a mix of scientists, Indigenous Peoples, and stakeholders to ensure small group discussions at each table benefited from a wide range of knowledge, experiences, and perspectives. Throughout the meeting, time was allotted for discussion and note-taking by rapporteurs. The first day was filled mostly by short presentations of the current state of scientific knowledge followed by discussion. The second day was mostly focused on discussions of four possible areas of action.

Goals

To engage a broader science audience along with managers and stakeholders with technical expertise to 1) share current knowledge about pinniped population sizes, population dynamics and diet composition, 2) identify current scientific knowledge gaps and uncertainties, particularly as they relate to pinniped predation on salmonids, salmon population drivers, and broader ecosystem factors, 3) discuss direction for future science activities that could inform potential management considerations. This also included discussion of uncertainties, risks and benefits of suggested actions.

Scope

The workshop focused on harbour seals, California sea lions and Steller sea lions, primarily within the Salish Sea, but where appropriate also included information for outer British

Columbia (BC) and Washington (WA) coasts. Scientists, First Nations, Tribes, government and others knowledgeable about pinnipeds, their prey, and predator-prey relationships participated.

Deliverables

The previous workshop in this 2-part series culminated in a report summarizing the scientific knowledge on the abundance and distribution, population dynamics, foraging behaviour, diet preferences and ecosystem impacts of pinnipeds (harbour seals, Steller sea lions and California sea lions), with a focus on pinniped predation on salmonids (Trites and Rosen 2019). The second workshop built on the first and aimed to incorporate other relevant technical knowledge and key knowledge gaps, outline management implications including ecosystem considerations, and to recommend possible next steps for science activities necessary to inform management considerations.

Participants

A wide audience representing stakeholders in the fishing industry, First Nations, Tribes, and non-profit organizations attended, as well as scientists from local and federal regulatory agencies and universities — many of whom attended the first workshop in May, 2019.

Agenda

The full agenda can be found in Appendix B. On the first day, the workshop alternated between presentations by scientists in their fields of expertise, and group discussions and review of the information presented. These included:

- Pinniped Science Review (e.g., abundance and distribution trends, diets, foraging)

- Factors affecting salmonids within an ecosystem context (both within the Salish Sea and beyond)
- Pinniped-Salmon Interactions (e.g., spatial-temporal variation in predation pressure)
- Ecosystem pathways between pinnipeds and salmon (e.g., effects of disease on predation)

The second day focused on presentations regarding the specific management frameworks for pinnipeds in Canadian and US jurisdictions. Following these presentations, participants rotated among four break-out groups to discuss considerations within broad categories of potential actions to mitigate pinniped predation on salmonids:

- Variation in hatchery production
- Enhanced fish survival
- Non-lethal removal of pinnipeds
- Lethal removal of pinnipeds.

These actions were not discussed within the context of specific management frameworks, but represent ideas that various participants felt worthwhile to consider. To reiterate, while not attributed to specific participants, the material under the section "Possible Actions to Mitigate Pinniped Predation on Salmonids" reflects solely the discussions during the workshop and not any external sources of information.

Background

Pinnipeds have a long history of interaction with Indigenous Peoples on the west coast, followed by large-scale predator control programs and harvests from the late 1800s to mid-1900s. In 1971, Canada protected marine mammals under the *Fisheries Act*, followed by the *Marine Mammal Protection Act* (MMPA) in 1972 in the US. These protections have resulted in increased abundance of pinnipeds throughout their ranges and in the Salish Sea. The increased abundance has led to a perceived negative correlation with decreases in salmon stocks among some stakeholders and scientists.

Marine survival of Pacific salmon (i.e. SAR: smolt to adult survival) is highly variable among stocks, but many stocks of Coho Salmon, Chinook Salmon and steelhead (anadromous Rainbow Trout) in the Salish Sea have shown significant declines since the 1980s. Further, there is debate on the concepts of additive and compensatory predation, that is, whether every source of mortality over the life history of an organism can be added up to equal total mortality, or whether if one source of mortality was removed would total mortality remain undiminished because mortality from another source would increase. Predation may not be additive, and the degree to which compensation exists may affect the outcome of management efforts. While important to keep in mind, many of the workshop participants acknowledged that it would be difficult scientifically to demonstrate if predation was additive or compensatory. It was also noted that while predation impacts on salmonids was the focus of the workshop, predation is just one of many hypotheses for the causes of salmon declines.

This report is divided into two major sections, summaries of the *Current State of Knowledge* (which includes a synopsis of pinniped population trends, diet estimates, and estimated changes in salmonid marine survival) and summaries of *Possible Actions to Reduce Pinniped Predation on Salmonids*.

There was no attempt in the breakout discussions to reach consensus, prioritize actions or concerns, or eliminate any action from the realm of possibility. Rather, a diversity of opinions was sought and encouraged. Furthermore, no consideration was given to costs, logistics or current policy/management frameworks. That being said, an important concept was how to evaluate and monitor the success or failure of a management action.

Each of the 4 actions described in *Possible Actions to Reduce Pinniped Predation on Salmonids* section has some history (to varying degrees) of implementation around the world and in the Pacific Northwest in particular. Respective experts and elders in the room were able to provide context in discussions. It was not the objective here to review those previous management activities or outline benefits and consequences. Rather, the objective was to gather and summarize the diversity of opinions on possible management actions. It should be noted that there was little discussion about fishing impacts, or whether harvest levels, fishing gear, or spatial-temporal fishing effort need to be changed to increase fish survival. There was also no discussion of salmon bycatch in other fisheries. These issues were considered outside the objectives of the meeting.

Summary of Current State of Knowledge

The first workshop focused on the current state of scientific knowledge and was summarized by Trites and Rosen (2019). Readers looking for more detailed explanations of the current state of knowledge are referred to this document. For this second meeting, general summaries of key areas were presented and are summarized below along with a few key figures.

Pinniped abundance, distribution, and foraging

The distribution and abundance of pinnipeds in the Salish Sea (Strait of Georgia and Puget Sound) have undergone large changes over the past 150 years. Currently, harbour seals and Steller sea lions are the most abundant species, while fur and elephant seals are rare, and California sea lions have become more frequent over-winter visitors in recent years.

Harbour seals are the smallest of the three pinnipeds considered in this workshop (i.e, harbour seals, Steller sea lions, and California sea lions) and range in weight from 50 kg to 150 kg for females and 70 kg to 170 kg for males. Population reconstructions of harbour seals in BC from harvest records indicate that numbers were brought to low levels after 35 years of commercial harvest between 1879 and 1914. The population rebounded in the 1920s and were brought low again following a commercial and bounty hunt in Canada from 1962 to 1968. In the Strait of Georgia, the population grew rapidly from ~3,000 in 1968 to ~30,000 in 1990 at which time the rate of increase started to slow. The population plateaued in 1995 at ~39,000 and has ranged from 35,000 to 43,000 to the present (Figure 1). Similar increases were observed from 1978 to 2000 in the inland waters of Washington (Figure 2). The most current estimate available (2008) of harbour seals throughout all of BC is 105,000 animals.

Steller sea lions are the largest of the three pinnipeds considered here averaging 270 kg for females and 1,000 kg for males. The Eastern population of Steller sea lions inhabits coastal and continental shelf regions of the North Pacific Ocean from central California north through British Columbia and Southeast Alaska. Relatively small numbers enter the Salish Sea from fall to spring. The vast majority (~80%) of animals are found in BC and Southeast Alaska. Population reconstructions have not been done for Steller sea lions, but they also sustained large-scale kills and were driven to a low population size. The population abundance in British Columbia increased exponentially from ~8,000 individuals in 1971 to 39,200 in 2013, and has not yet shown signs of stabilizing (Figure 3). Similar trends occurred in Washington, Oregon and California with combined counts less than 2000 in the 1970's to approximately 10,000 in 2015.

California sea lions range in weight from 50 kg to 110 kg for females and 200 kg to 400 kg for males. California sea lions breed in southern California and Baja Mexico and have steadily increased from 1975 to the present. The current population appears to have stabilized around 275,000 animals. The most recent population estimate was 257,600 animals in 2014. Males disperse from breeding areas with some portion of them making seasonal incursions into the coastal waters of Washington, Oregon, and BC including the Salish Sea. Counts in Washington waters were rare in 1972 to over 3,000 in 2018.

The increase in the abundance and presence of pinnipeds in the Salish Sea occurred at the same time as large changes in salmon populations. As pinniped populations were increasing in the 1960s 70s and 80s, Coho Salmon and Chinook Salmon catches remained high. In the 1990s

Coho Salmon and Chinook Salmon catches started to decline, while harbour seal numbers started to stabilize at ~39,000 individuals, and Steller sea lion abundance continued to grow. During the same period, other pinniped prey species, such as herring and hake, also went through large population fluctuations. Unfortunately, there were inconsistent collections of pinniped diet data from these early periods, thus validating key prey species over this time period is not possible.

Current estimates of diet are derived from pinniped fecal samples (scat) collected at haul-out sites, which are typically tidally washed away each day. These scat samples are processed and analysed using a dual approach: hard parts provide information about the species and size of fish consumed, while DNA metabarcoding provides discrete estimates of species presence and proportions in the diet. These data suffer from statistical issues associated with getting a spatial-temporal representative sample. Diet estimates of harbour seals from scat collected in Washington inland waters show that forage fish (herring and sand lance) and gadids (primarily hake) make up 25 to 95% of the diet, and that salmon make up 2 to 25% of the diet (Figure 4a). Seal diets vary widely across space and with season. In the Strait of Georgia, the percent salmon in the diet of seals feeding in estuaries increased from 2% in June to 65% in November, the majority (>95%) of which were chum salmon (Figure 4b). The relative contribution of juvenile and adult salmon also varies seasonally, spatially and across years. Steller sea lion diet in the Strait of Georgia in the winter was principally herring 35%, and salmon made up ~7% of the diet (Figure 5). In summary, diet data of pinnipeds are quite variable in space and time. Both harbour seals and Steller sea lions eat salmon, including Chinook Salmon and Coho Salmon, but the proportions depend on where and when samples are taken.

Pinniped prey abundance, trends, and availability

Pacific hake and Pacific herring constitute the greatest portion of Salish Sea pinniped diets. Groundfish (including hake) populations in Puget Sound have fluctuated over the past 60 years, without significant declines in the overall abundance. Herring populations have been stable in Puget Sound in recent years, however, some stocks declined while others increased leading to relatively consistent overall population size (averaging effect) with notable changes in distribution. In the Strait of Georgia, herring spawning biomass is at all-time high levels, but spawn distribution has changed over time. Anchovy, another important forage fish in pinniped diets, has increased in recent years.

Five Pacific salmon species, as well as steelhead trout, spend at least some portion of their marine life-history in the Salish Sea. Species, and stocks within species, exhibit differences in their duration of residence within the Salish Sea, their trends in abundance, and the available information needed to evaluate management actions or conservation status. Recent work on Chinook Salmon, Coho Salmon, and steelhead has shown declines in marine survival since the 1980s for many Salish Sea populations compared to coastal populations (Figure 6).

In the Strait of Georgia, Chinook Salmon numbers declined in the late 1970s, Coho Salmon in the late 1980s, and Sockeye Salmon in the late 1990s (see Trites and Rosen 2019). In general, salmon stocks that have shorter periods of freshwater residence, relatively smaller size at marine entry and longer periods of coastal residence, (e.g., sub-yearling Chinook Salmon, Chum Salmon and Pink Salmon) currently have relatively better marine survival in contrast to those with longer periods of freshwater residence, larger size at marine entry and reduced periods of coastal residence prior to moving offshore (i.e. yearling Chinook Salmon). In Puget Sound, hatchery-produced Coho Salmon are twice as abundant as naturally produced fish, and hatchery-reared Chinook Salmon are 10-times more numerically dominant than their wild counterparts. Resident Chinook Salmon and Coho Salmon that rear year-round in Puget Sound likely have greater exposure to pinniped predation than do those that leave the Sound for extensive offshore migrations; yet these more resident stocks are the ones that are doing well compared to the more migratory stocks. Marine survival of the coastal Coho Salmon populations appears to have improved.

Factors affecting salmonids within an ecosystem context

Many factors affect the population dynamics of salmonids, and evaluating the critical factors controlling their abundance has been elusive. A life-history where >90% of their offspring die before a fraction return to rivers to reproduce means that any reproductive adult had to survive a multitude of threats. These include the threats of disease, contaminants, high water temperatures, hatchery management (negative genetic effects), habitat loss, predation and fisheries. It is likely a combination of these effects, as well as food quantity and quality, that affect salmon returns. Salmon evolved under most of these threats, but increases in human harvest and impacts on the ocean as well as climate change pose unprecedented challenges to salmonid survival. Hatchery fish tend to show similar temporal trends in survival as wild salmonids but have lower relative survival .

There is some evidence that the natal and juvenile environments of salmon affect their survival. A proportion of Coho Salmon are once again remaining resident in the Strait of Georgia—a behaviour that has been absent for approximately 20 years. In contrast, Chinook Salmon have much more life-history variation. Those that spend at least one year in freshwater move quickly through the Salish Sea and travel offshore (called stream-type or yearling) – while those that only spend weeks to months in freshwater generally tend to rear in estuaries or nearshore coastal waters (called ocean-type or sub-yearling). Most of the Salish Sea populations of Chinook Salmon are ocean-type with some portion of individuals apparently remaining entirely resident in the Salish Sea, while others eventually make their way out to coastal waters of the open ocean. These smolt variants generally coincide with adult run timing, with stream-type returning during spring and ocean-type returning during fall. In recent years, numbers of adult Chinook Salmon returning to some east-coast Vancouver Island rivers have been increasing (ocean-type that rear in coastal marine waters), while the early arriving Fraser River spring Chinook Salmon have declined (stream-type that rear in freshwater and exhibit an extensive offshore ocean migration).

In Puget Sound, an analysis was undertaken to identify ecosystem indicators that correlate with marine survival of Chinook Salmon, Coho Salmon and steelhead. The study found that freshwater delivery was a poor explanatory variable, while factors related to predation, competition, and water quality explained more variance in marine survival (although only 30-40% for the best models). Seal abundance correlated negatively for all three species; however, seal abundance explained more variance in steelhead trout and Coho Salmon data (22% and 30%, respectively) than it did for Chinook Salmon (<8.6%). It is important to note that the methods for estimating marine survival (i.e. SAR; smolt-to-adult-returns) varied among the three species, which may account for some of the differences in observed relationships. Furthermore, survey catches of juvenile Chinook Salmon were 2–10 times greater in Puget Sound than in the

Strait of Georgia. Consequently, differences in habitat need to be considered when comparing predation risks posed by pinnipeds to different salmon stocks in different regions of the Salish Sea.

Throughout their range in the Northeast Pacific, the abundance and size-at-age of the oldest age classes of Chinook Salmon have declined. Possible explanations for the decline in size include size selective removals either from predation (killer whales and sea lions) or fisheries (sport and commercial), or changing hatchery practices and changes in the ocean environment affecting size and growth. It is currently difficult to separate these effects.

Marine survival has been correlated with smolt growth and condition in the first marine year. Years when Chinook Salmon grew faster in Puget Sound were years when they had higher marine survival rates. Catch per unit effort (CPUE) of Coho Salmon in the Strait of Georgia has increased from a low in 2008 to above average levels in 2012, 2013, 2015, and 2018. These high catch rates correlate with higher growth rates in Coho Salmon, providing some indication of an ecosystem shift which favors a greater production of high-quality prey. Juvenile Coho Salmon are now eating less fish and more energy rich crab and amphipod larvae. Further support for ecosystem changes and potential changes in bottom-up production were found in a similar diet shift (less fish and more energy rich crab and amphipod larvae) of juvenile Chinook Salmon in the Strait of Georgia.

Pinniped-salmon interactions

Predator-caused mortality has to be accurately estimated relative to total mortality to determine the impact of predators on prey populations. We know that seals eat salmon, and considerable effort is being directed to estimate the percent salmon in the diet, but what is needed is to put consumption estimates in the context of total natural mortality (i.e. impact). Statements like "harbour seals contribute xx% of total mortality" are more useful, as they provide some quantitative assessment of predator impact and set it in the context of mortality caused by fisheries and other (often unknown) causes. Scientists in eastern Canada working on grey and harp seal predation on Atlantic cod found that most of the uncertainty in estimates of consumption are due to uncertainty in the proportion of prey species consumed and how estimates vary by predator age, sex and feeding location. Ultimately, the impact that seals have on prey populations depends upon the population dynamics of the prey species, as well as the seasonal distribution of predators and prey. Notably, their conclusions depend on the spatial context of the population and its ecosystem. In the waters off eastern Newfoundland, predation by seals has not been found to significantly impact northern cod stock levels, whereas in the Gulf of St. Lawrence low cod population size coupled with high levels of grey seal predation appears to have created a predator pit, limiting the recovery of cod, hake and skate in those areas.

Predation rates and biomass consumed by harbour seals and Steller sea lions have been calculated at different spatial scales using different data sets and assumptions. The diversity of approaches and results represent, to some degree, both the diversity of scientific approaches and natural spatial-temporal variations in predators and prey. One study concluded that three lines of evidence point to seals as a potential cause of increases in first-ocean-year mortality rates:

correlative, diet, and seal behaviour. Increases in mortality rates of Coho Salmon correlate with increases in seal abundance, however, Chinook Salmon stocks show highly variable responses to seal abundance with the dominant lower Fraser (Harrison) Chinook Salmon showing about half the change in mortality rates seen in other Georgia Strait indicator stocks.

Because researchers are using bioenergetics models to estimate impacts, current estimates of numbers of Coho Salmon and Chinook Salmon consumed are sensitive to assumptions about the size of juvenile salmon being consumed, as well as the number of prey (hatchery and wild) that are available and vulnerable to seals after freshwater and post-release mortality has occurred. Predation rates (estimated proportion of total salmon smolts which entered the ocean which were then estimated to be consumed) for juvenile Chinook Salmon and Coho Salmon appear to be lower in Puget Sound than in the Strait of Georgia. It is important to note that there is high uncertainty and disagreement around these estimates, and they are subject to change as new data are incorporated and model assumptions refined.

Steller sea lions also consume salmon smolts. While smolts comprise a miniscule proportion of the diet in terms of biomass, consumption can represent a large number of smolts. However, the impact on Chinook Salmon stocks is probably minimal when viewed in the context of the number of smolts produced and the number of smolts dying before attaining adulthood. Preliminary analyses indicate that Steller sea lions are an important predator of adult Chinook Salmon in British Columbia. Total Chinook Salmon consumption, mainly by northern resident killer whales and Steller sea lions, has increased dramatically over the last four decades, while catches in the Chinook Salmon fishery have declined. Increased consumption of Chinook

Salmon by predators may help explain the declining exploitation rates in Chinook Salmon fisheries.

There are at least three different ecosystem models being built by different research teams that can be used to assess food web interactions and the potential consequence of reducing pinniped population sizes on ecosystem dynamics. Individual-based models, and spatially and temporally explicit ecosystem models that simulate the whole life cycle of modelled species have reproduced reasonable diet compositions and improved our understanding of pinniped impacts on prey species. The models are in development, and data limitations affect each model's ability to accurately model the system and consequently our ability to predict the effect of potential management actions and the potential risks of unintended consequences.

Possible Actions to Mitigate Pinniped Predation on Salmonids

Four possible actions to mitigate pinniped predation on salmonids were discussed at the workshop: vary hatchery production, enhance fish survival, non-lethal removals of pinnipeds, and lethal removals of pinnipeds. Participants were asked to consider five questions during deliberations.

1. What scientific findings are most relevant?
2. What are uncertainties that increase risk of unintended consequences and not having the desired result?
3. What are potential secondary effects and ecosystem risks?
4. What additional information do we need to have to make decisions?

5. What level of certainty is needed before testing various approaches?

It should be noted that the possible actions listed are by no means a complete or prioritized list of actions that can be assumed to improve the survival of salmon or forage fish from pinniped predation, but ones that were discussed during the workshop.

Vary hatchery production

Possible actions discussed by participants included:

- Modulate the number of fish produced. Hatcheries can release more fish to test whether marine survival stays constant or continues to decline, paying particular attention to the timing and location of releases. Hatcheries can also reduce releases to determine whether this leads to enhanced body growth, and survival of wild salmon - presumably through decreased competition for food.
- Modulate the timing of release. Hatcheries can release fish all at the same time, hoping to flood the predator field, or can spread releases out in time to reduce the potential for a pulse predation response. This can also be done to reflect a greater level of outmigration diversity patterns, more similar to wild fish populations.
- Modulate the location where fish are released. An evaluation of survival associated with release location can occur in rivers near high densities of pinnipeds and/or further away in order to test local predation effects on survival.
- Modulate the size of fish released. An evaluation of survival associated with release size can occur to determine if larger size smolts have a higher or lower survival rate.

It was recognized that varying hatchery production could potentially have positive or negative effects on salmon returns, and hatchery releases could be better designed to test the impact of predators on juvenile salmon survival.

Expected outcomes / uncertainties

While hatchery approaches in the US and Canada are different, it was felt that large hatchery releases would benefit from a broader ecosystem and experimental context. It was noted that First Nations and US Tribes have been manually diversifying salmon for centuries by moving fertilized eggs between streams, and that greater input and collaboration between hatcheries and First Nations/US tribes is necessary. Another suggestion was to use hatcheries in a comparable manner to salmon enhancement, as a means to bolster forage fish abundance (like herring) to provide ample alternate prey for pinnipeds. This may potentially relieve some of the predation pressure on salmon by pinnipeds.

Research

Using an experimental approach to address specific questions related to predation and marine survival with hatchery releases was encouraged. However, in some hatcheries the focus has been on releasing fish to contribute to fisheries, rather than designing release practices to answer specific questions — like predation effects. Leveraging stock differences, such as run timing, ocean type and spatial location would be important to consider when using hatchery releases to evaluate predation impacts.

Risk/level of certainty

Several participants made the case that the risk of further negative effects is low because hatcheries are already in operation. Others questioned whether there are any demonstrated benefits and whether more strategic investments in other areas could be made.

As with all the potential management actions, the level of certainty a participant needed before they felt an approach could be tested in the field was quite variable among group members. It is difficult to capture the diversity of the perceived risk of an action and the degree of certainty required before taking an action without conducting a survey (perhaps something to consider in future). In more general terms and in relation to the other categories of action, the level of certainty needed to implement a management action related to varying hatchery production was the second lowest (rank 3). In effect, it is currently occurring and largely assumed to be acceptable, although as noted above this view was not held by all who attended.

Enhance fish survival

<u>Possible actions discussed by participants included:</u>

- Improved protection of instream water flow during critical periods of salmon life history
- Improved effort and coordination on salmon habitat restoration and effectiveness monitoring (both freshwater and marine)
- Greater scientific and management effort on all salmon rivers, not just the most productive ones
- Reduce negative interactions with fish farms (e.g. potential disease transfer)
- Greater focus on enhancing forage fish production (e.g. habitat protection and enhancement)

- Greater collection and incorporation of Traditional Ecological Knowledge (TEK)

Fisheries management of salmonids has a long history of efforts aimed at increasing fish survival by improving freshwater habitat and fish passage.

Enhancing fish survival is a broad subject. Discussions considered attempts to directly affect Chinook Salmon or Coho Salmon survival, while recognizing that factors affecting juvenile survival are distinct from factors affecting adults returning to spawn. It was further noted that enhancing survival of other fish species, particularly forage fish, may be an avenue for increasing Chinook Salmon or Coho Salmon survival.

<u>Expected outcomes / uncertainties</u>

Periods of drought can have large impacts on salmon populations. Juvenile and adult salmon subjected to high temperatures and low water flow in rivers and streams have very high mortality rates. High water flow can damage habitat and salmonid survival as well.

Protecting water flow and temperature is directly related to watershed conservation and management. Examining the effects of forestry practices and a re-evaluation of current regulations is certainly one means to build resilience into freshwater ecosystems throughout the Salish Sea basin. Installing dams in certain watersheds to control hydrology to mitigate erratic flows might be another avenue, but that could come at a cost to fish passage. Protecting the diverse and unique life history and genetics of the fish living in particular watersheds needs to occur in conjunction with watershed conservation and management.

The diversity in the timing of outmigration, juvenile rearing, run and spawn timing all likely affect year-to-year variation in salmon production and survival. High among-river variation in environmental conditions and salmon production will make it difficult to estimate predation effects across the Salish Sea ecosystem.

There was some question about whether the focus of enhanced fish survival should be on the freshwater or marine environment, and obviously work needs to continue in both areas. Some evidence from tagging studies of steelhead was presented that showed that different freshwater rearing environments did not affect survival, suggesting that the marine component of the life history stages is more important for determining growth and survival than the freshwater component.

Some workshop participants expressed concern about disease transfer and escapes from fish farms, and suggested that information on year-to-year disease prevalence, salmon survival and effects on wild populations be clearly communicated. Most salmon farms along salmon migration corridors farm Atlantic salmon, which is non-native to the BC coast. There was some support, particularly by Indigenous Groups, for only using native species for fish farming.

Several participants suggested a shift in focus from Chinook Salmon or Coho Salmon-centric thinking to enhancing survival for forage fish in general. What would be good for forage fish species is also likely to be good for salmon. If forage species are doing well in general, then there is some indication that the ecosystem is healthy — with good zooplankton production and habitat structure, which provides juvenile salmon food and refuge from predators.

Reducing quotas for herring might increase herring population levels and thereby relieve some of the predation pressure on salmon. However, an increase in adult herring may lead to an increase in pinniped abundance and create added pressure on salmon. Juvenile Chinook Salmon and Coho Salmon feed on juvenile herring. A reduction in adult herring catch may not increase the abundance of juvenile herring, and consequently may not have the intended effects of increasing food supply for juvenile salmon. One suggestion was to determine whether the herring stocks that serve as prey for Chinook Salmon are the same herring stocks that serve as prey for seals. In addition, a specific habitat-related action which may enhance fish survival is to increase the protection of kelp beds and to restore kelp in areas where they have been reduced or lost. Increases in kelp would provide more breeding habitat for herring and refuge for juvenile salmon.

Research

There were many suggestions on areas for further inquiry and research. There were notably more suggestions for research on the effects of the marine ecosystem, rather than the freshwater ecosystem, on salmon health and productivity. To some degree, all ecosystems are affected by the amount of energy entering into the food web. If the Salish Sea ecosystem is partly driven by primary productivity, then are there ways to increase primary productivity?

It was felt that more work could be done to compare stocks that are doing poorly with stocks that are doing well, and relating this variation to the marine environment and salmon residency. A lot of salmon stocks are doing well, particularly Pink Salmon and Chum Salmon populations. One area for focus could be to determine if there are life history characteristics specific to current healthy salmon stocks that thrive under the current ocean conditions.

Further questions arose about the timing and magnitude of the phytoplankton bloom and how that affects the feeding and survival of juvenile fish. There seems to be information in this area that could be analyzed and interpreted to answer these questions.

There also was interest in determining if fish condition and health have declined or have remained stable. If fish condition and health have declined, then there could be increased susceptibility to predation. However, if condition has remained the same, then decreases in survival are more likely to be related to increased predation pressure.

There is some evidence that feeding conditions have improved in the Strait of Georgia and Chinook Salmon and Coho Salmon are bigger and fatter (length-weight condition index), which likely leads to higher survival. However, the increase in condition coincides with a higher proportion of residency, which means greater exposure to pinniped predation and possibly lower survival. Condition of Chinook Salmon and Coho Salmon improved in 2008, providing some evidence for a regime shift.

An increase in survival after 2008 in the face of predation pressure remaining relatively constant would provide some support for bottom-up effects on salmon survival. In the past two years, the condition index has been high for Coho Salmon caught in juvenile surveys in the Strait of Georgia, leading some to predict high survival and returns of Coho Salmon over the next two years. Changes in fish condition, particularly juvenile condition, and a potential correlation between condition and survival indicates that more work needs to be done on the factors controlling ecosystem production and salmon diet.

While most of the focus has been on Chinook Salmon and Coho Salmon and their survival, several participants suggested looking for correlations between pinniped abundance and the abundance of alternative prey such as herring and pollock. Questions were raised about whether the survival rates of herring and pollock have decreased. There also were questions about at what stage salmon populations were being regulated (i.e., adults, juveniles, or some combination of the two). Further research on ways to mitigate bycatch and catch-and-release mortality was suggested. There is also little available information on year-to-year disease prevalence and any interactions with salmon survival and population dynamics.

Although the focus of this workshop has been on the impacts of pinnipeds on salmonids, some participants questioned how predation of salmon by pinnipeds compare to that caused by other predators such as birds and bears? Similarly, in the broader ecosystem-level context, how has the increase in toothed and baleen whales affected salmon populations directly and indirectly?

Risk/level of certainty

There was little perceived risk in efforts to enhance fish survival in either the freshwater or marine environment. In relation to the other categories of action, the level of certainty needed in order to continue with this action is the lowest (rank 4). The discussion was more about which activity would have a greater positive impact, rather than which activity risks harm to salmon stocks or to the ecosystem. There were also few impediments to implementing these activities, aside from funding and interest.

Non-lethal removal of pinnipeds

<u>Possible actions discussed by participants included:</u>

- Harassing pinnipeds at critical places and times
- Discouraging the use of haul-out sites near productive salmon rivers
- Relocating or removing temporary haul-out sites (e.g. log booms)
- Requiring marine installations and infrastructure (e.g. marinas) to have appropriate pinniped deterrents
- Using contraceptives for population control

<u>Expected outcomes / uncertainties</u>

The non-lethal removal or displacement of pinnipeds tends to be localized and specific to individuals or small groups. These include scaring or harassing pinnipeds at critical places and times, such as at estuaries during salmon outmigration and when salmon return to rivers. Harassing could also coincide with hatchery releases, to give salmon a better chance of survival.

Human-made haul-out sites were also seen as a key element in facilitating interactions with salmon. In particular, areas where seals are hauled out on log booms or marinas adjacent to salmon rivers could be the focus of pinniped harassment. In the case of log booms, they could be moved. Potential pinniped use could be considered when granting permits for new marinas, and requiring structures which discourage pinniped use could be a condition of granting permits.

These suggested non-lethal removal activities raised questions about whether there are regulatory standards allowing or limiting the harassment of marine mammals, and if harassment of pinnipeds is allowed, who might have the jurisdictional authority to authorize activities such as moving log booms or allowing harassment activities at existing marinas. This may be different from state to state and between Countries.

There seemed, however, to be little enthusiasm for pinniped harassment activities amongst participants, as they would require a lot of sustained effort and the impact is expected to be low and variable at best. As with all potential activities, it would also be essential to have a monitoring program in place to measure the impact of pinniped harassment activities.

Previous experience of harassment in the Columbia River system was noted to have had limited success over the medium to long term; animals quickly became habituated, particularly if efforts were not sustained and continuous.

The playing of predator calls was discussed as a means to displace harbour seals. Previous experience, albeit limited, with resident killer whale (salmon-eating) calls showed little or no effect on harbour seal distribution. Transient killer whales (marine mammal-eating) do not vocalize until after a kill, so their calls are expected to be ineffective. Overall, it was expected that predator calls as a means to harass and displace pinnipeds would not be effective, but this could be further tested. One obvious consequence of pinniped displacement is increased impact in other areas, potentially affecting other salmon stocks and/or other endangered species.

The use of contraceptives to reduce pinniped numbers was thought to be an interesting potential non-lethal action. Among meeting participants, there was some familiarity with a trial contraception vaccine used on grey seals in the 1990s. Although it was thought to be effective in the sample sizes implicated, a single injection was thought to have only lasted 3 to 4 years. Currently, injection of a contraception vaccine cannot be administered remotely, thus animals have to be handled. Given the size of harbour seal and sea lion populations, a large number of animals would presumably have to be handled repeatedly to impact population size, making this approach too complex and unmanageable. The details of how a contraception program could be implemented along with its expected cost would need to be known before a full evaluation of this action could be made. Given the life history of harbour seals, participants speculated that a program would entail inoculating 10,000 seals over 10 years to detect impacts on the seal population and subsequently impacts on salmon. A contraception program for sea lions seems even more difficult and less likely due to their size and the need to handle them. Injection of the contraception into pups could lead to sterilization, but this is currently conjecture. A control (unaffected) area would also be needed to evaluate the effectiveness of a contraception program. The potential negative effects and unintended consequences of contraceptives in the Salish Sea ecosystem was of some concern. There is already a high level of contraceptive chemicals entering the Salish Sea from human use and effluent, and the consequences of releasing a chemical or vaccine into the Salish Sea environment would need to be evaluated. Workshop participants were also unaware of any instance where contraceptives were effective in controlling any other wildlife population. Consequently, non-lethal actions, like a contraception program and harassing pinnipeds, bear some risk (and thus, these possible actions were ranked with the second highest relative risk ranking).

Lethal removal of pinnipeds

Possible actions

- A large and sustained cull or hunt of pinnipeds
- Localized hunts and killing of pinnipeds

When discussing lethal removals of pinnipeds, it is important to note the differences in the definitions of a “hunt” and a “cull”. A hunt is where the animal being killed is used for food or other human purposes. A cull is the killing of animals for the sole purpose of reducing impacts on something else, such as reducing impacts on another animal species. The implementation and legal regulations for the two are quite different. Both harbour seals and Steller sea lions eat salmon. However, there is considerable debate among scientists about whether salmon populations are being limited by pinniped consumption. Some argue that this can only be answered by running an experiment or perturbation (i.e., by conducting a large and sustained cull and seeing if salmon populations rebound). This approach could be a “before-after” type of ecosystem perturbation. Several participants suggested that a spatial ‘control’, or an area where pinnipeds were not culled and both pinnipeds and salmon populations were monitored, would also be necessary to determine a cull's effectiveness.

Large sustained removals

Some preliminary modelling results presented at the first workshop indicated that harbor seals would need to be initially reduced by 50% (~20,000 individuals) throughout the Salish Sea to effect a strong enough decrease in predation pressure to thereby increase Chinook Salmon and Coho Salmon survival enough to lead to population recovery. When the target harbor seal population size is reached, an additional ~3,000 animals per year would need to be killed to maintain a stable population. It was suggested that these efforts would likely have to be sustained for 8 to 10 years (several salmon generations) before the effectiveness of the cull could be evaluated.

It was suggested that Steller sea lions numbers would also need to be significantly reduced, as they too are predators of salmon.

Localized removals

Other suggestions for lethal removals were less extensive. Pinnipeds are already being removed in rivers near dams where salmon congregate in Oregon and Washington. Some Indigenous Peoples in western Canada harvest pinnipeds for social and ceremonial purposes, but these are in small numbers.

One advantage of localized removals is that there can be a geographic focus. For example, localized hunts and/or culls in rivers and estuaries could be used to test if salmon survival increases. Several participants countered this suggestion by pointing out that any salmon would have to pass through a very large and diverse predator field on both the trip out to the ocean and back to their natal river, making it difficult to detect the effect of localized removals. Many urged that more be learned and reported from localized removal activities.

Expected outcomes / uncertainties

Several participants noted the potential for other non-pinniped predators (e.g., herons, mergansers, otters, raccoons, trout, sculpins, etc.) to compensate for decreases in harbour seal abundance and eat more salmon – so they too may require some removals to achieve the goal of increasing salmon survival. Although there is no current evidence that compensation by non-pinniped predators would happen, the situation would need to be monitored.

One participant noted that there were an estimated 28 million links between predator and prey in a study of the Benguela ecosystem, and suggested that complexity in the Salish Sea ecosystem is also high, and along with it, the possibility of unintended consequences. A participant suggested one possible ecosystem response: if pinnipeds were culled in the Salish Sea, their primary prey, hake, could increase and thereby increase predation pressure on herring and cause their decrease — with potentially large consequences to other components of the ecosystem including salmon. This statement was countered with the observation that large hake are currently rare in the Salish Sea ecosystem.

The response of the participants to such statements of ecosystem effects and unintended consequences were divided into two categories, i) the risk of unintended negative consequences is too large to take, or ii) the current situation for salmon is dire and we cannot afford to not take the risk. Whatever the position one takes, we would only know if unintended negative effects predominate after a cull was implemented. If they did, then the next question would be, are those negative effects reversible? The resiliency of the Salish Sea pinniped populations has already been demonstrated, so it is expected that they would rebound over many decades if lethal removals were stopped. Pinniped recovery, presumably, would then reverse the unintended negative effects of a cull. Although this scenario seems likely, populations of northern fur seals did not rebound after a cull. With the added complication of climate change, and changing environmental conditions there is no guarantee that pinniped populations would rebound.

Management Context

Presentations were provided on the legal framework and management context of pinniped removals in Canada and the United States and are summarized below.

Canadian Management of pinnipeds-context and approach

Context

- Pinnipeds are protected and managed under the *Fisheries Act*, and depending on the species, can also fall under the purview of the Species at Risk Act (SARA)
- DFO views pinniped management from an ecosystem perspective, considering their overall role in the environment

- First Nation's Food, Social, and Ceremonial access to pinniped harvest takes precedence over commercial pinniped harvest
- US MMPA marine mammal targeted removal or by-catch comparability standard requirements apply to Canadian commercial seafood exports to the US

Approach

- Marine mammals are protected and managed under the *Marine Mammal Regulations* under the *Fisheries Act* which outlines
  - Conservation and protection of marine mammals
  - Management and control of fishing for marine mammals
- *Marine Mammal Regulations* provide the framework for the issuance of:
  - Seal license – personal and commercial
    - In BC, there are currently no personal or commercial pinniped fisheries unlike other regions
    - Indigenous Peoples harvest seals for Food, Social and Ceremonial purposes
  - Nuisance seal license
    - Authorizes holders to hunt nuisance seals if deterrence efforts have not been successful
    - In BC, nuisance seal licenses are rarely issued and only under exceptional circumstances
- In BC post 1970, targeted removals have been rare and only in special circumstances

US Management of pinnipeds-context and approach

Context

Pinnipeds are managed under the *Marine Mammal Protection Act* and in some cases the Endangered Species Act.

Goals:

- To maintain the optimum sustainable population (OSP) and ecosystem function of marine mammal stocks
- To restore depleted stocks to their optimum sustainable population levels
- To reduce mortality and serious injury (bycatch) of marine mammals incidental to commercial fishing operations to insignificant levels approaching a zero mortality and serious injury rate.

Approach

The relevant legal sections for pinniped takings are found in:

MMPA Pinniped Management Options—Takings

- Section 101(a)(3)(A) (Waiver – Moratorium on Taking of Marine Mammals)
  - Rule-Making (Section 103)
  - Take Permit (Section 104)
- Section 109(a) (Transfer of Management Authority to States)
- Section 120 and Section 120(f) (Pinniped Removal Authority)

Figure 8 provides an example of the Features and Considerations required to support management decisions related to marine mammal removal.

Research

Transient killer whale numbers throughout the Pacific west coast have increased following the trajectory of most marine mammal populations with protection. Transient killer whales feed primarily on pinnipeds. So how would reductions in pinnipeds affect transient killer whale populations? If there were fewer pinnipeds, would transient killer whales shift their diet? Would other species potentially be put at risk from increased predation from transient killer whales? More data and scientific work on these other ecosystem components are needed to shed some light on these questions.

It was felt that any lethal removals of pinnipeds, large scale or localized, through a cull or hunt, would require clear and measurable objectives (e.g., % increase in Chinook Salmon survival) to evaluate the degree of success, while at the same time having strong monitoring programs for pinnipeds, salmon and other ecosystem components (e.g. hake, herring, resident and transient killer whales). Given the range of uncertainty and variation in opinion on the topic of lethal removals, building scientific consensus on whether to implement this option will be difficult.

If lethal removals were to occur, then concerns about humane killing, and the proper and safe handling and disposal of carcasses would need to be addressed.

Risk/level of certainty

Uncertainty and risk involved with lethal removal of pinnipeds in order to positively affect salmon populations can be classified into two categories: scientific, and socio-economic.

The scientific uncertainty associated with a direct linkage between lethal pinniped removals and increasing salmon abundance is large, as are uncertainties around unintended consequence of lethal removals and the reversibility of this action. Given this level of uncertainly, participants discussed at what level of risk does lethal removals become acceptable, what level of certainty is required before testing various approaches, and what additional information is required to make decisions.

The risk participants were willing to accept in the probability of success of a lethal removal program ranged from 20% to 100% depending on whether their tolerance for risk was based on socio-economic considerations (high risk tolerance; accepting lower probability of success) , or ecological considerations for maintaining the integrity of an ecosystem (lower risk tolerance; accepting higher probability of success), or ethical and animal welfare considerations (lowest risk tolerance; only accepting certainly of success).

To illustrate the variability in perception of risk expressed in discussions, the following are offered as specific examples. One participant suggested that an 80 to 85% agreement between different models would be enough to make a decision. Another thought that only a 50% chance of lethal removals having a positive effect on salmon was sufficient, and suggested that with milestones identified and an effective monitoring system in place, the decision could be re-evaluated after a period of time (e.g., 3 to 5 years). Another participant suggested that if economics is the only consideration, then only a 20% chance of success is enough to accept the risk of lethal removals. One participant wanted 100% certainty in success to endorse lethal removals.

In relation to the other categories of action, the level of certainty needed among participants to implement lethal removal is the highest (rank 1). When considering risk, one has to also consider who bears the cost of implementation, the benefits of success, and the costs of failure — financial or otherwise. This question applies both to human socio-economic constructs as well as to the Salish Sea ecosystem.

Summary

There were several themes to the discussion about possible actions.

- Would the proposed action be effective in increasing salmon survival?
    - There was wide variation among participants in the perceived effectiveness of *any* action
- How would the effectiveness of an action be measured? Over what time period?
    - Although discussed, no specific measures of effectiveness were proposed
- What is the risk of unintended negative consequences to salmon or the ecosystem?
    - This was widely discussed and little consensus was reached on the risk of unintended consequences

Trends in pinniped population sizes and changes in marine survival were summarized in Trites and Rosen (2019) and in the first part of this report, *Summary of Current State of Knowledge*. A negative correlation between declines in marine survival of some salmonid populations and increasing abundance of some seal and sea lion populations provides some indication that predation could be a potential contributing factor. Although, as noted earlier, a compilation of alternative hypotheses remains plausible and one should be cautious of treating correlations as causative mechanisms.

A more nuanced approach to resolving whether pinnipeds are impeding recovery of some salmon populations would test if variation in marine survival can be further explained by spatial-temporal differences in pinniped density. It is already known that some salmon species and runs are more susceptible to predation due to the spatial location or timing of a run relative to the distribution and abundance of pinnipeds. Teasing apart the effects of spatial location and residency time of salmon in relation to pinniped density will be important in estimating predation impacts.

Several recommendations were made to gather more data to help better understand the current situation and the potential effects of pinnipeds.

- Continued estimation of pinniped population trends
- Better understanding of pinniped distribution and "hot spots"
- Better spatial and temporal data on pinniped diet
- More data on Chinook Salmon and Coho Salmon early life history and fish distribution
- Data on instream survival as a function of environmental conditions
- Research on the interrelationship between freshwater rearing conditions and marine survival
- Studies of multiple stressors on salmon and their interactions

<u>Socio-political</u>

In addition to science and ecosystem concerns, it was recognized that there are many social and cultural issues surrounding the lethal removal of pinnipeds. The regulatory and political structure in which lethal removals would occur is complicated Action may require a range of decision points involving the Canadian and US federal governments, state and provincial governments, the governments of individual First Nations and Tribes, and possibly municipal governments. So, a full socio-economic evaluation would be necessary.

In Canada, consultations would need to occur with First Nations, and Indigenous Knowledge (IK) and oral history would need to be incorporated into any decision — this is also true for any of the other categories of action as well. Several questions would need to be answered, such as: What is the current public sentiment for a pinniped hunt or cull? What would be some of the political consequences to trade or other industries? What are some of the anticipated legal consequences and costs? Are there markets for animal products such as pelts? Could a market be developed? What other products could be marketed? If a hunt or cull is implemented in one jurisdiction and not in another, could the objectives still be achieved?

Several participants called for a greater collection of IK and a greater effort in incorporating IK into understanding of ecosystem change and balance. One example presented was the experience of harvesting kelp on Haida Gwaii, where First Nations experienced extremely good and extremely bad years. In some core areas, First Nations have seen very little change in kelp, in other areas they have seen *skaii* (little snails) that eat and kill kelp. How can this information be better used? In another example, a participant suggested that if anonymity is assured, some First

Nations and Tribes would have information on results of seals killed in small systems. How can we work together to use this knowledge?

Many possible actions were discussed during this workshop. Undoubtedly, there are other actions which should be considered, and it is hoped that this report helps bring them forth. It should be recognized that ‘no action’ or ‘status quo’ is also a management option. Further progress may be gained by encouraging a more nuanced approach to the possibilities. Next steps might consider actions tabled in the form of documents, rather than open-ended discussions. Many of the specifics of the supporting science and implementation are important for a more in-depth evaluation. Any action plan requires:

1. A clear set of objectives, including
    a. the size of the perturbation
    b. the duration
    c. the expected consequences
    d. potential unintended consequences
    e. milestones and stopping points
    f. defined measures of success and failure
2. A full and detailed summary of the state of science
3. An effective ecosystem monitoring program
4. A detailed explanation of implementation including logistical procedures
5. A socio-economic evaluation
6. Consultation with Indigenous Communities and stakeholders
7. A budget estimating costs

8. A full evaluation of uncertainty and risks.

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Figures

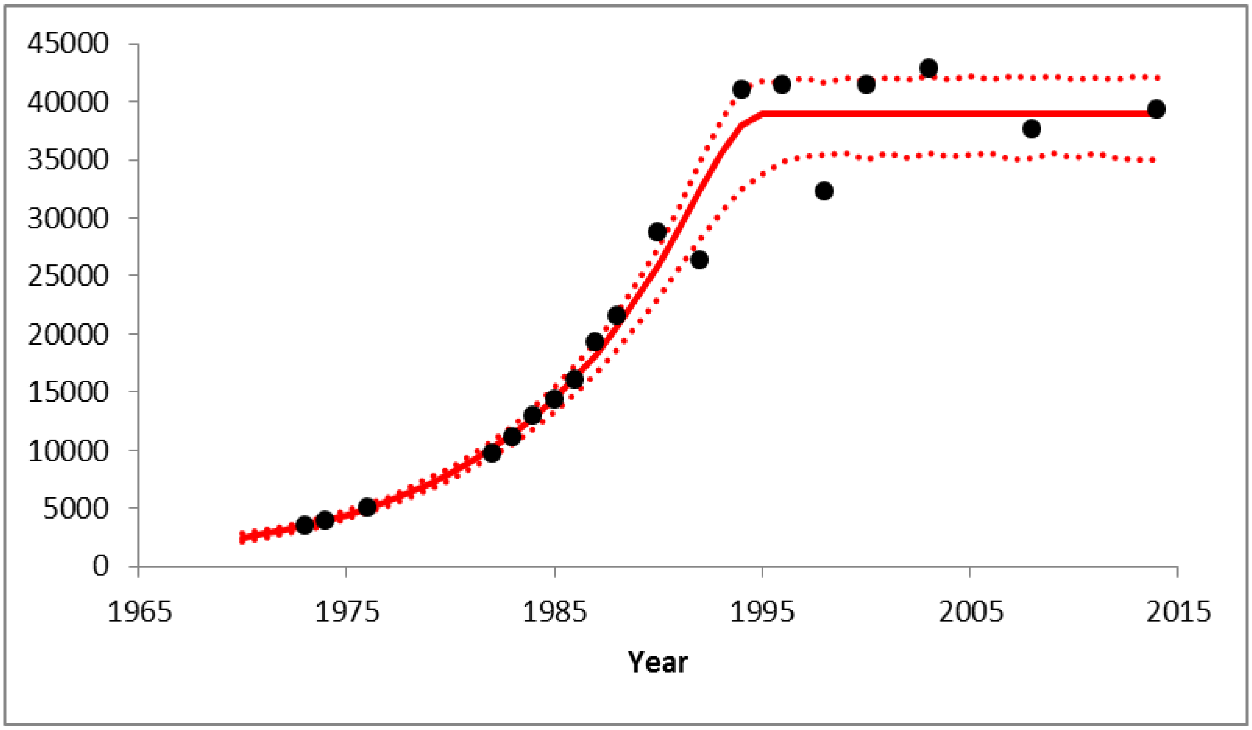

Figure 1. Harbour seal abundance in the Strait of Georgia (reprinted from Majewski and Ellis 2016).

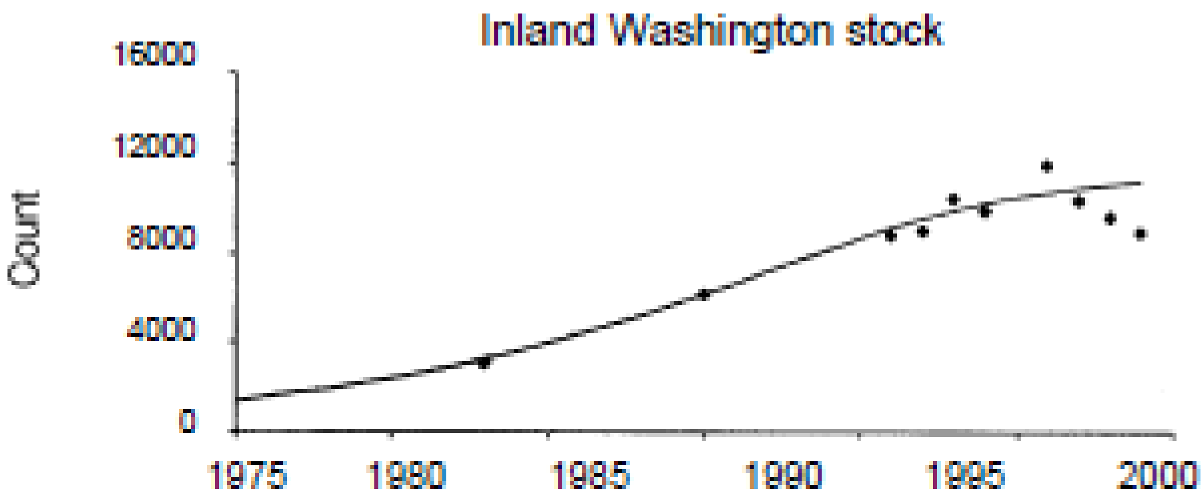

Figure 2. Harbour seal abundance in inland waters of Washington, USA (reprinted from Jeffries et al. 2003).

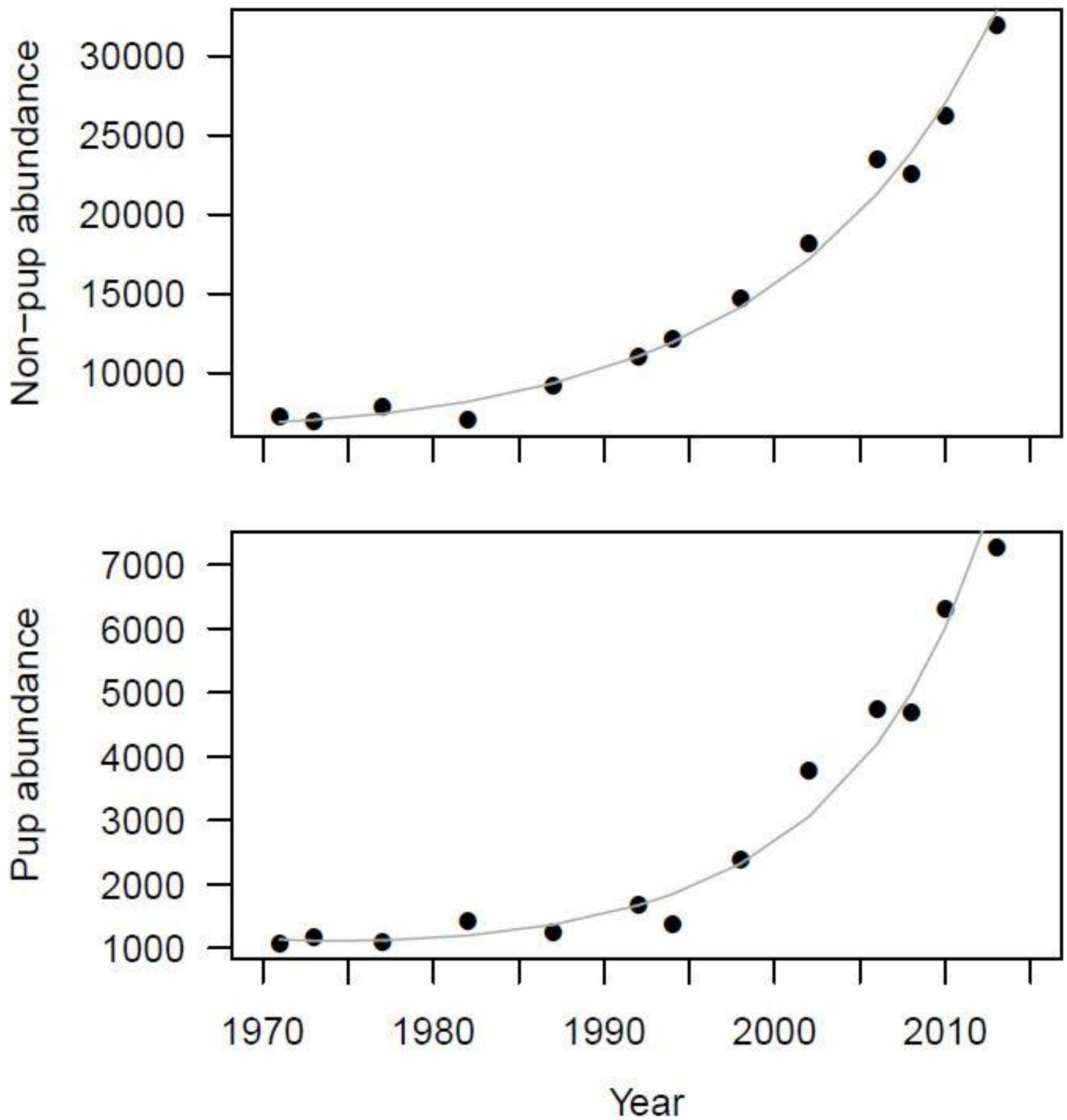

Figure 3. Steller sea lion abundance of a) non-pups (age 1+), and pups (age <1) (Adapted from Olesiuk 2018).

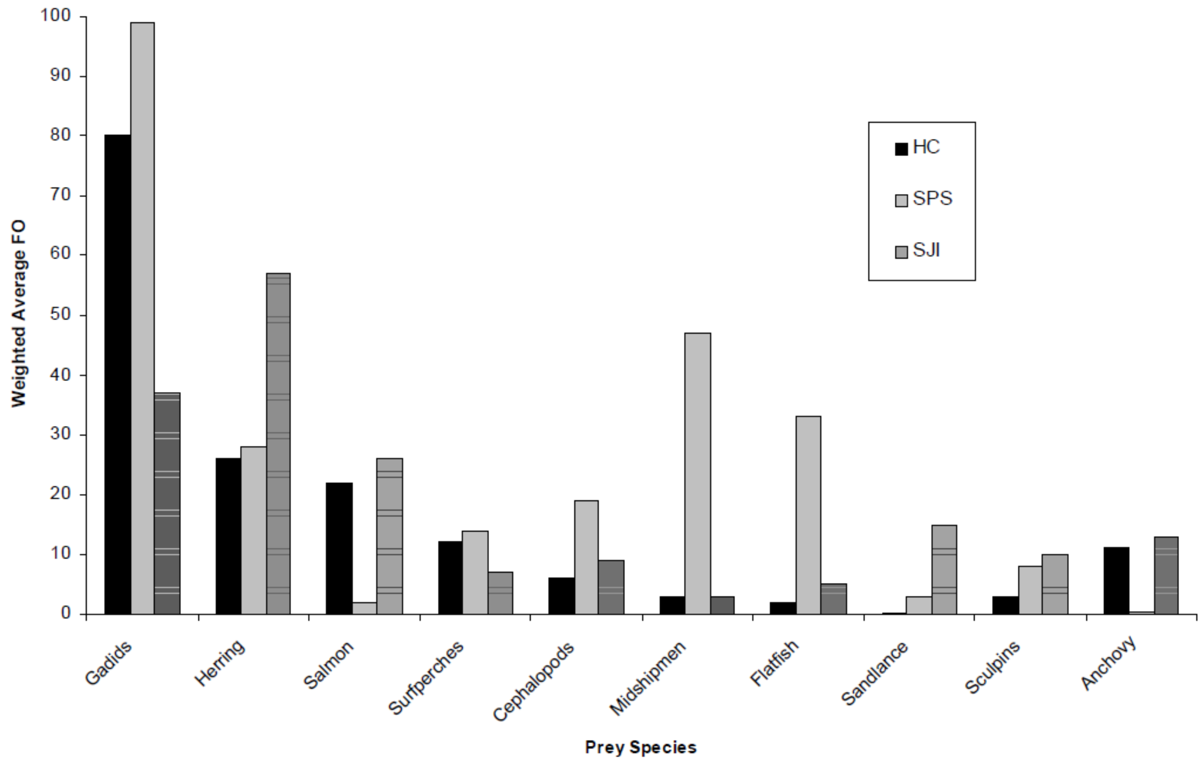

Figure 4a. Overall weighted average of primary (>10%) prey species in the diets of harbour seals for all seasons and years combined in Hood Canal (HC), south Puget Sound (SPS) and the San Juan Islands (SJI) (reprinted from Lance and Jeffries 2009).

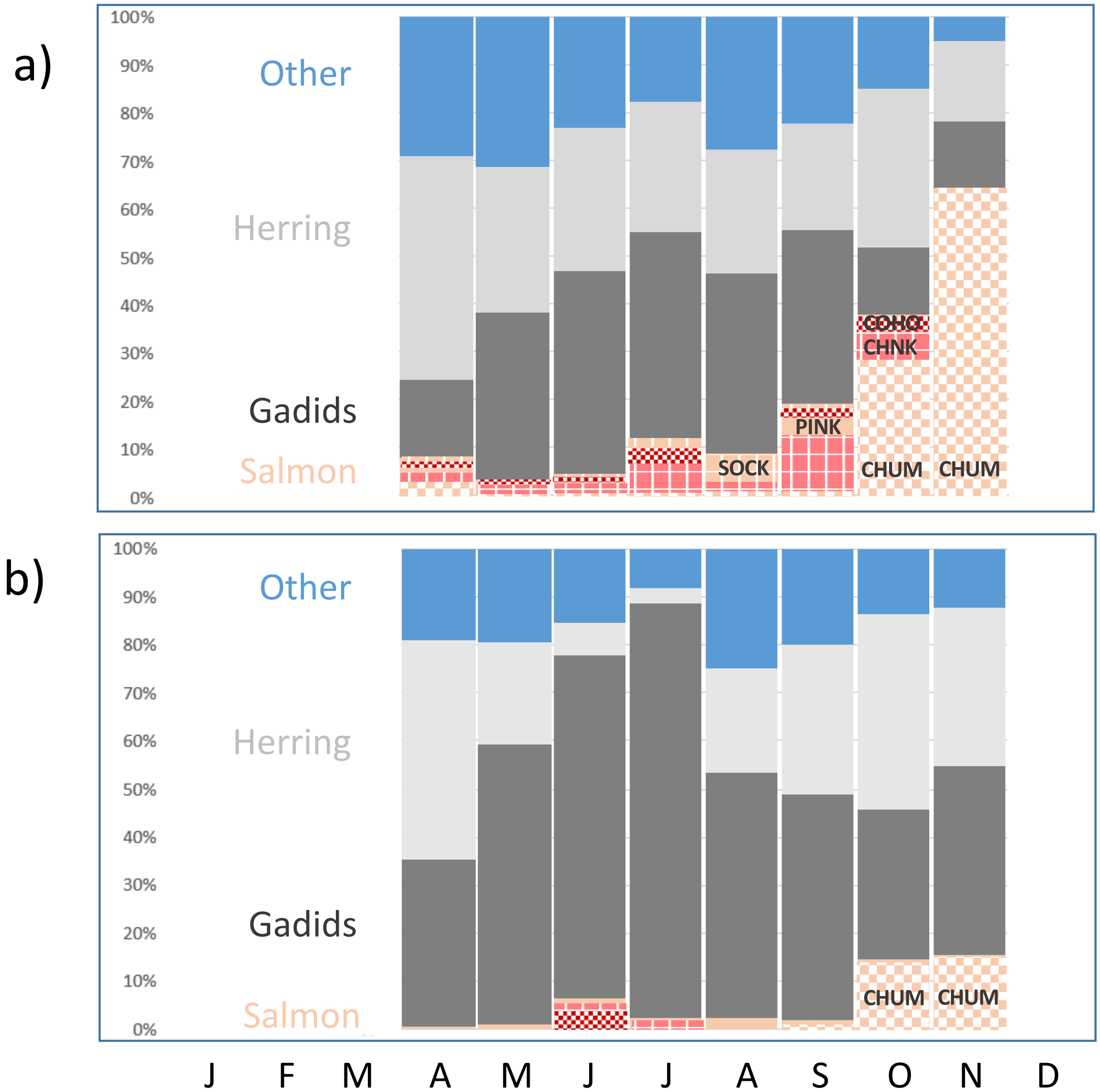

Figure 4b. Percent species in the diets of harbour seals by month in a) estuaries, and b) non-estuaries calculated from scats sampled in the 2010s (Trites unpublished data; Tucker unpublished data).

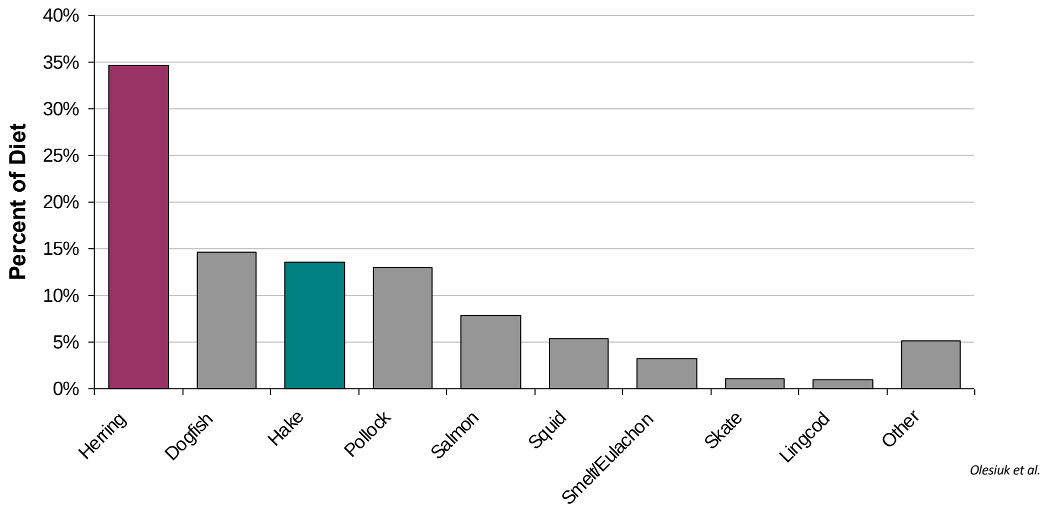

Figure 5. Steller sea lion winter diet in the Strait of Georgia (1982-2009) (Olesiuk unpublished data)

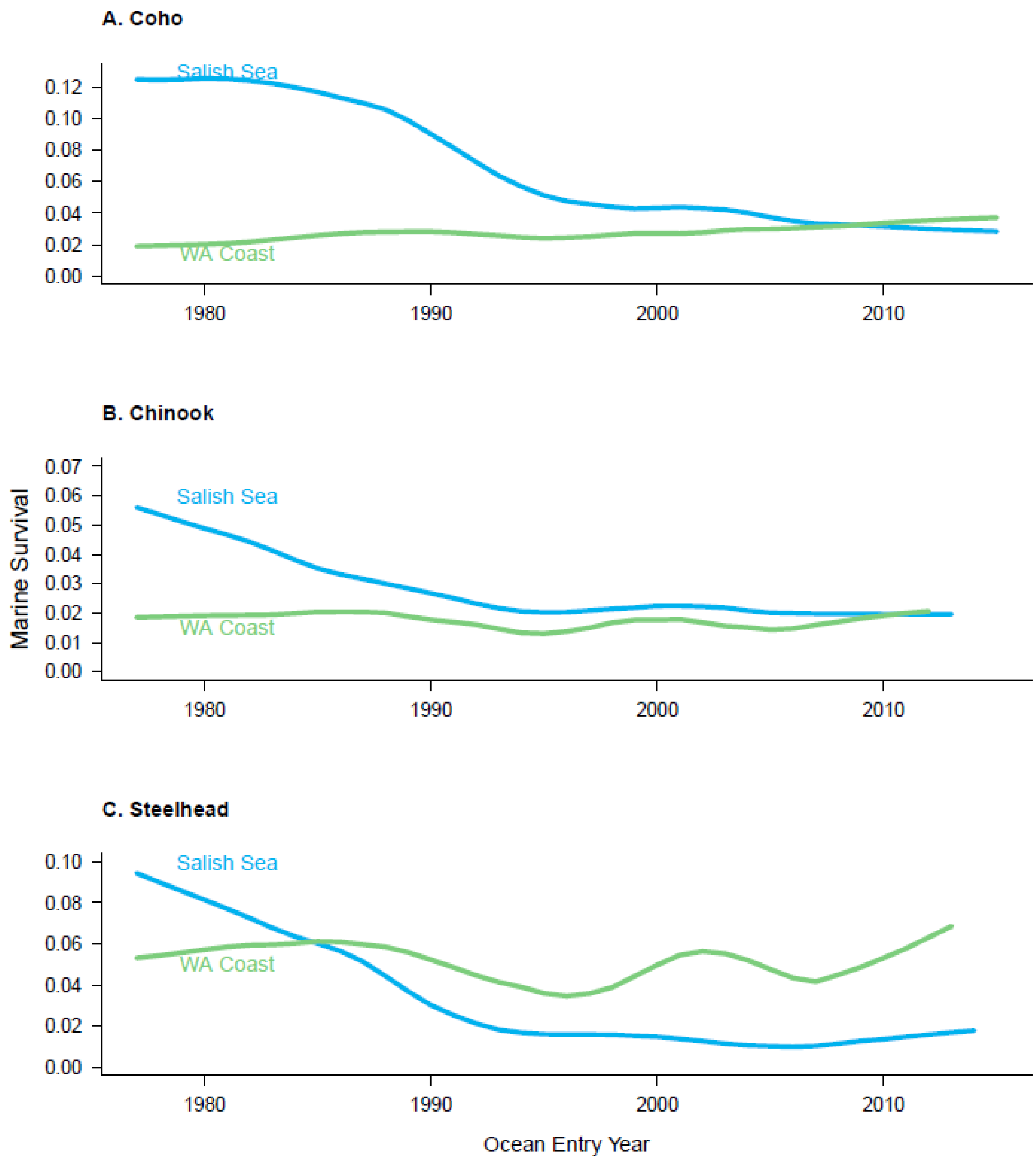

Figure 6. Changes in marine survival for three salmonids for Washington coastal (green line) and Salish Sea (blue line) populations. Figure created by Long Live the Kings using datasets assessed in Zimmerman et al. 2015, Ruff et al. 2017, Kendall et al. 2017.

MMPA Pinniped Management Options for Lethal Take

- Section 120(f)—Pinniped Removal Authority: Temporary Marine Mammal Removal Authority on the Waters of the Columbia River or its Tributaries (Endangered Salmon Predation Prevention Act of 2018)

Public Law 115-329, the Endangered Salmon Predation Prevention Act of 2018, amended Public Law 103-238, the MMPA Amendments of 1994, by replacing section 120, subsection (f) of the MMPA with a new subsection (f): Temporary Marine Mammal Removal Authority on the Waters of the Columbia River or its Tributaries. Allows states, tribes (select), and the MMPA section 120(f)(6)(D) Committee to request removal authority pursuant to section 120(f) of the MMPA.

Feature	Considerations
Allows Lethal Take	CSL and SSL (specified area in the Columbia River Basin)
Authorization	MMPA Authorization
Criteria	Population trends, specific problem to be addressed, past (non-lethal) efforts, whether marine mammals pose a threat to public safety, injury/imbalance to fish and ecosystems (no individually identifiable pinnipeds and significant negative impact via statutory exception)
Process: Timeline	15 days (sufficient evidence, est. Pinniped Fishery-Interaction Task Force) + 60 days publication in Federal Register + 60 days Task Force review and recommendations + 30 days to approve
Process: Committees	Task Force PFITF appointed, reviews and recommends approval
Process: Hearings/Publications	Notice and opportunity for public comment, public meetings
Geographic Area	Columbia River (RM 112-RM292 and tributaries in WA/OR below RM 292)
Limitations	No depleted, listed or strategic stocks/populations, CSL and SSL
Requirements	MMPA, NEPA, ESA
Applicant	Eligible entities

NOAA FISHERIES

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Figure 8. A slide from Robert Anderson's presentation at the workshop providing an example of the Features and Considerations necessary for management decisions of pinniped removal under the US MMPA. This example specifically relates to temporary removal of marine mammals on the waters of the Columbia and its tributaries..

Appendix A: Participants

Name	Representing
Christine Abraham	DFO, National Capital Region
Alejandro Acevedo	Western Washington University
Liz Allyn	Makah Tribe
Joe Anderson	WDFW
Robert Anderson	NOAA, NMFS
Heidi Arthur	DFO, Pacific Region
Jenny Atkinson	The Whale Museum
Ashley Bagley	Long Live the Kings
Dick Beamish	DFO Emeritus, Pacific Region
Penny Becker	WDFW
Barry Berejiken	NOAA, NMFS
Zed Blue	WA Commercial Fisherman
Laura Boggard	Oceans Initiative
Ginny Broadhurst	Western Washington University, Salish Sea Inst
Wendell Bunch	Puget Sound Anglers
Kelsey Campbell	Atlegay Fisheries
Paul Cottrell	DFO, Pacific Region
Barry Curie	Area B, BC
*Neil Davis	DFO, Pacific Region
Lero Deardorff	Lummi Nation
Jeff Dickson	Squaxin Island Tribe
Devin Flaud	Lummi Nation
Nicole Frederickson	Island Marine Aquatic Working Group
Caihong Fu	DFO, Pacific Region
Jeff Grout	DFO, Pacific Region
Mike Hammill	DFO, Quebec Region
Richard Harry	Aboriginal Aquaculture Association, BC
Merle Herrett	Puget Sound Anglers
Kim Hughes	WDFW
Kirt Hughes	WDFW
Chris Hunt	U.S. Navy, NAVFAC
Anabel Jarry	Nuchatlaht Tribe
Chris James	NWIFC
Merle Jefferson	Lummi Nation
Steven Jeffries	WDFW
Larry Johnson	Maanulth Fisheries Committee
Lisa Jones	DFO, Pacific Region
Chief Roy Jones Jr.	Pacific Balance Marine Management

Iris Kemp	Long Live the Kings
Eddy Kennedy	DFO, Pacific Region
Tim Kulchyski	Cowichan Tribes
Martin Louis	Musqueam Fisheries
Wilf Luedke	DFO, Pacific Region
Julia Mackenzie	DFO, Pacific Region
Sheena Majewski	DFO, Pacific Region
Moses Martin	Tla-O-Qui-Aht First Nations
Mike McCulloch	BC Ministry, FLNRO
Casey McLean	SR^3 Sealife Response+Rehab+Research
Nora Nickum	Seattle Aquarium
Ben Nelson	Long Live the Kings, and Univ. of British Columbia
Chrys Neville	DFO, Pacific Region
Ken Pearce	Pacific Balance Pinniped Society
Isobel Pearsall	Pacific Salmon Foundation
Scott Pearson	WDFW
David Rosen	Univ. of British Columbia
Scott Redman	PS Partnership
Kim Sager-Franklin	Lower Elwha Klallan Tribe
Michael Schmidt	Long Live the Kings
Alyssa Scott	The Whale Museum
Thomas Sewid	Pacific Balance Marine Management
Monika Wieland Shields	Orca Behaviour Institute
Ben Starkhouse	Lummi Nation
Philip Thorson	U. S. Navy
Andrew Trites	Univ. of British Columbia
Strahan Tucker	DFO, Pacific Region
Marc Trudel	DFO, Pacific Region
Kurt Trzcinski	Contractor
Scott Wallace	David Suzuki Foundation
Carl Walters	Univ. of British Columbia
Eric Ward	NOAA, NMFS
Julie Watson	WDFW
Rob Williams	Oceans Initiative
Lisa Wilson	Lummi Nation
Derek Vilar	Lummi Nation

* did not attend, but gave presentation remotely

Appendix B: Agenda

Agenda

Synthesizing scientific knowledge about population dynamics and diet preferences of Harbour Seals, Steller Sea Lions and California Sea Lions, and their impacts on salmon in the Salish Sea
Workshop 2

Sheraton Four Points, Bellingham, WA
November 20-21, 2019

GOALS, SCOPE, & DELIVERABLES

Goals - To engage a broader science audience along with managers and stakeholders with technical expertise to 1) share current knowledge about pinniped population sizes, population dynamics and diet composition, 2) identify current scientific knowledge gaps and uncertainties, particularly as they relate to pinniped predation on salmonids, salmon population drivers, and broader ecosystem factors, 3) discuss direction for future science activities that can inform potential management considerations.

Scope - The workshop will focus on Harbour Seals, California Sea Lions and Steller Sea Lions, primarily within the Salish Sea, but where appropriate will also include information for outer BC and WA coasts. Scientists, First Nations, Tribes, government and others knowledgeable about pinnipeds, their prey, and predator-prey relationships will participate.

Deliverables - The previous workshop in this 2-part workshop series is culminated in a report summarizing the scientific knowledge on population dynamics and diet preferences of pinnipeds (Harbour Seals, Steller Sea Lions and California Sea Lions), with a focus on pinniped predation on salmonids. This second workshop will build on the first workshop report and will aim to incorporate other relevant technical knowledge and key knowledge gaps, outline management implications - including ecosystem considerations, and recommend possible next steps for science activities necessary to inform management considerations.

DAY 1	
9:00	**Arrive/Coffee**
9:15	**Welcome, Overview of Workshop Objectives, Introductions**
9:45	**Pinniped Science Review** ● Pinniped abundance, distribution, sex and age composition, seasonal movements, and foraging behaviour ● Pinniped prey abundance, trends and availability to pinnipeds in Salish Sea
10:15	Small group discussions: ● Most important take home message from presentations? ● What do we think our priorities are for moving forward? ● Identification of hotspots of increased pinniped presence?
11:00	**Break**
11:15	Conclusions from the discussion - what is agreed upon and what is outstanding

12:00	**Lunch**
1:00	Factors affecting salmonids within an ecosystem context ● Big Ocean context ● Salish Sea context ● Q and A
1:50	Pinniped-Salmon Interactions ● Size selectivity, and spatial and temporal differences in predation pressure on salmonids ● Rates of predation on salmon and steelhead, and amounts consumed by pinnipeds in Salish Sea
2:15	Small group discussions following presentation: ● Most important take home message from presentations? ● Was anything unclear? ● What do we think our priorities are for moving forward?
2:45	**Break**
3:00	Conclusions from the discussion - what is agreed upon and what is outstanding
3:30	Pinniped-Salmon Interactions - Continued ● Factors that affect pinniped predation of salmonids ○ Forage fish abundance, barriers, artificial haulouts, hatchery management ○ Species interactions (forage fish, marine mammal predators, etc.)
3:45	Small group discussions following presentation: ● Most important take home message from presentations? ● Was anything unclear? ● What do we think our priorities are for moving forward?
4:15	Conclusions from the discussion - what is agreed upon and what is outstanding
4:45	Plenary ● Day 1 reflections ● Summary of emerging key priority research areas ● Overview of Day 2 program
5:30	**Adjourn for the day**
DAY 2	
8:30	**Arrive/Coffee**
9:00	Recap of Day 1
9:30	Considerations of pinniped predation on salmonids ● Ecosystem pathways between pinnipeds and salmon, effects of disease on predation rates, and questions surrounding additive and compensatory mortality
9:50	Small group discussions following presentation: ● Most important take home message from presentations? ● Was anything unclear? ● What do we think our priorities are for moving forward?
10:00	Conclusions from the discussion - what is agreed upon and what is outstanding

10:15	**Break**
10:30	Management approaches and scientific considerations around mitigating impacts: implications and efficacy ● Canadian management approaches and their scientific considerations ● US: What are some of the requirements, challenges and implications around management? ● Theoretical approaches to mitigation - direct and indirect
11:45	**Lunch**
12:45	Small group facilitated exercise: Continued discussion on theoretical approaches to mitigation. ● What scientific findings are most relevant? ● What are uncertainties that increase risk of unintended consequences and not having the desired result? ● What are potential secondary effects and ecosystem risks? ● What additional information do we need to have to make decisions? What level of certainty is needed before testing various approaches?
2:15	Break
2:30	Continue small group exercise
3:00	Conclusions from the discussion - what is agreed upon and what is outstanding
4:15	Plenary ● Final reflections ● Summary of key priority research areas
4:45	**Adjourn**