COMMENTS ON DRAFT FINAL REPORT OF THE INDEPENDENT SCIENCE PANEL "THE EFFECTS OF SALMON FISHERIES ON SOUTHERN RESIDENT KILLER WHALES"

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I reviewed the 3 May 2012 SRKW report paying particular attention to ecosystem aspects. As background, I attended the 1st workshop, giving a presentation entitled "Orca Oceanography", but was unable to attend the 2nd workshop due to other work commitments. I have not viewed all the presentations from the 2nd workshop.

A large amount of excellent work went into this process, which is effectively summarised in the SRKW Report. The work had a fairly focused mandate, trying to answer the question "*To what extent are salmon fisheries affecting recovery of SRKW by reducing the abundance of their available prey, and what are the consequences to their survival and recovery?"*

The work carried out was not, nor was it intended to be, an ecosystem approach. In my view, this was unfortunate. The authors of the SRKW report seemed to agree.

The final recommendation of the report's abstract states that *"research in the near term should emphasize…. an ecosystem view of factors affecting SRKW."* Later in the report (line 327) the authors state "*The mechanistic approach used in the Biological Opinion essentially ignores all other ecosystem connections except Chinook salmon*." Beginning on line 399, they conclude *"Thus the panel would have liked to see more evaluation of ecosystem factors affecting killer whales, and recommend that future analysis explore a broad range of ecosystem factors. A first step would be to explore a range of indices of ocean productivity as alternatives to Chinook abundance."*

At the first workshop I recommended exploring ocean indices of productivity. I hypothesised that ocean productivity should be correlated with killer whale (and Chinook salmon) mortality & growth (with appropriate time lags). My thesis was essentially that ecosystem indicators may explain differential survival patterns of northern and southern resident killer whales. Mortality rates of these two groups co-vary much of the time but during 1979-1984 they did not.

We know that while the distribution of these two groups overlaps, northern residents tend to be northerly, although this may be less pronounced now than it was historically. I provided results showing different temporal patterns in ocean indicators (satellite-derived chlorophyll concentrations, duration and extent of upwelling-favourable (northwesterly) winds) between the coastal downwelling (Alaskan) and upwelling (California current) regions. I recommended a statistical examination of relationships between oceanic indicators such as these and killer whale survival and growth. Admittedly I am biased, but this is an example of ecosystem related work that could have been done.

At the 2nd workshop, Ian Perry and Dave Preikshot provided additional examples of ecosystem based work that could be undertaken.

In summary, a lot of excellent work is summarised in the SRKW report. Appropriate next steps would be to examine aspects of the ecosystem other than Chinook salmon. It would be surprising if Chinook salmon abundance were the only factor controlling SRKWs. If the spatial distributions of SRKW and NRKW differ, it should be possible to compare regional ecosystem indicators during periods that SRKW and NRKW survival/growth results covary, and when they do not. If we are not confident in differences between SRKW and NRKW, it would still be worth looking at time series of ecosystem indicators to see if they are correlated with killer whale and Chinook salmon time series.

Two other comments are: (1) it would have been interesting to compare terminal run sizes for Chinook populations of high accuracy and precision (e.g. Harrison/Chilliwack) with FRAM/CTC time series; and (2) an explicit breakdown of Chinook abundance data into ocean and stream type populations. Perhaps this work has been done and I am not aware of it.

Comments on draft manuscript: The Effects of Salmon Fisheries on Southern Resident Killer Whales: Final Report of the Independent Science Panel

By

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The Panel has done a great job digesting a wide variety of data on killer whale foraging ecology and population dynamics, and their relationship to Chinook fisheries. They've produced an excellent draft report that provides a well-developed and very useful synthesis of the data. The following are some specific comments:

Section 2: Summary

Lines 200-201: "It seems somewhat illogical that SRKW would forgo feeding on other species at time of low Chinook abundance"

I think it is important to recognize that foraging specializations appear to be fixed cultural traditions in killer whale ecotypes, and that the strength of these traditions may defy logic. As an example, a group of mammal-eating transient killer whales captured and held in a net pen in 1970 refused all fish offered to them for 67 days. All individuals became highly emaciated and one animal died from malnutrition. The survivors were subsequently released and returned to a marine mammal diet. Fish-eating resident killer whales typically consumed fish offered to them within a day or two of being captured.

We have often been told that it is illogical that RKW would not feed on sockeye salmon during periods of super abundance in summer, yet predation on this species is rare. It is likely that RKW maintain their strong focus on Chinook throughout the year, and that this is supplemented with other prey species to greater or lesser extent depending on availability. To me, the question is not whether the whales increase predation rates on other species during periods of low Chinook abundance – they almost certainly do – but more importantly whether they can feed on alternative prey with sufficient profitability that it offsets nutritional stress.

Lines 202-203: "Other fish-eating killer whales in the North Pacific show a broader range of diet."

I'm not sure of the source for this statement and I do not believe it to be accurate. There are only three populations of fish-eating killer whales in the North Pacific for which there are good data on diet – SRKW, NRKW, and southern Alaska residents (SARKW). There is no good evidence that NRKW have a broader diet than SRKW,

and the known diet of SARKW is similar to these other RKW populations – Chinook, coho, and chum salmon. Not enough is known of the diet of fish-eating 'offshore'-type killer whales to assess diet breadth.

Lines 240-245: The fact that the larger NRKW population also showed very similar patterns of unexpectedly high mortality rates during the same period of low Chinook abundance in the late 1990s make a causative relationship more plausible than if just the SKRW is considered. I think this should be pointed out in this paragraph. Although a cause and effect relationship cannot be proven, the weight of evidence, in my opinion, strongly support this to dismiss it would not be precautionary.

Lines 373-378: I am confused by the statement "further contaminant work could establish the major Chinook stocks that contribute to SRKW diets". Our studies and those of Hanson et al. (2010) have already identified stocks of origin for Chinook consumed by SRKW using genetic analysis of prey remains. This work has shown the major stocks in SRKW diet for about half the year, and surely provide a much higher resolution of stock identity than could be provided by contaminants analysis. I assume this paragraph is meant to recommend that contaminants be used as a supplement to provide insight into major stocks of Chinook consumed by SRKW during periods of the year when genetic stock identification data are not available. Genetic stock identification (GSI) would certainly be a preferred means of identifying important Chinook stocks for SRKW and should be the recommended priority, in my opinion, supplemented as needed with contaminants analysis. Contaminant analyses to date show a 'California' signature for L and K pods and a higher PBDE/PCB ratio for J pod, suggesting they might feed more in urban areas such as Puget Sound and southern Strait of Georgia. We already know these differences in the ranging patterns of SRKW pods and I would be surprised if contaminants will provide more than a crude resolution of important Chinook stocks compared to GSI.

Lines 429-430: I'm concerned about the definitiveness of the statement: "A key point, occasionally overlooked by participants in both meetings, is that the Southern Resident population is not declining." Whether or not the SRKW population is judged to be increasing or decline depends on the time frame begin considered. One could argue that due to cropping prior to the mid 1970s, the SRKW population was depleted at the start of field studies in 1974, may have increased to *K* in 1996 (at 97 animals), and has since declined by 12% over the past 16 years (to 85 animals as of June 2012). It would be difficult to picture this as an increasing population.

Lines 533-534: "A skewed sex ratio at birth favors males in the Southern Resident population…."

We actually do not know what the sex ratio is at birth – it could easily be 50:50 or close to it, with female biased mortality in the period between parturition and when the animals' sex can be identified, which is usually around a year of age (sometimes

less, sometimes more). This is a period of high mortality. With such a small population, the sex ratio bias could be stochastic.

Lines 546-547: "…consisted of SRKW or of all killer whales in the Pacific."

Is this meant to include literally all killer whales – including other genetically distinct assemblages such as transient and offshore forms – and the entire Pacific Ocean (both north and south)? Perhaps some tighter bounds are needed.

Line 576: Frederick Sound is a little further north than SRKW have been seen (Pt Ellis, Chatham Strait). Chatham Strait would be more accurate.

Lines 576-578: Acoustic monitoring provides far more evidence that SRKW are found on the other coast vs inside waters. This was described in presentations in both workshop 1 and 2.

Line 581: I am not familiar with any Hanson et al. 2005 document, and the reference is not provided in the Lit Cited. Perhaps it is meant to be 2010?

Section 4.0 Feeding Habits

Line 584: It is true that the data for winter Chinook indicate that the fish are younger (= smaller), but the sample size is small. Of 19 Chinook samples aged, 31% were 3 yr, 52% were 4 yr, and 16% were 5 yr. This compares to a summer/fall proportion of roughly 9%, 52%, and 34%, respectively, for May through October Chinook samples (Ford and Ellis 2006). I would defer to the Chinook specialists to advise on whether the age distribution of Chinook in winter should be significantly different from that in summer. If it is not, then the apparent shift to smaller Chinook in winter in our data is likely a sampling artifact.

Lines 657-658: "The small numbers of samples obtained during the winter suggest a greater reliance on chum salmon and on demersal species in this season."

This is true from Brad Hanson's samples in October to December, primarily collected in Puget Sound. It may not be the case outside of this area and in months after most chum have migrated into rivers. Our samples for 'winter' (i.e., December-April) show a continued reliance on Chinook similar to that seen in summer. Our salmonid prey tally for December-April, both SRKW and NRKW combined, is 83% Chinook, 12% chum, and 0.4% steelhead (n = 14 NR and 10 SR predation samples).

Lines 762–763: Satellite tagging is not the only nor is it necessarily the best method of determining winter foraging areas for SRKW. Much useful information has been collected on SRKW occurrence in winter through passive acoustic monitoring by both NOAA and DFO scientists, and this was summarized by B. Hanson and J. Ford, respectively, in workshop 2. I think it is important to include mention of this technique in this recommendation.

Section 5.0 Fisheries and Prey Availability

Line 991: "Comparisons of age composition in SRKW feces…"

To my knowledge, salmon age cannot be determined from fecal remains.

Lines 993-996: "(Note: Steve Latham. Pacific Salmon Commission, in his post-Workshop 2 comments, correctly observed that comparison of age composition of Chinook in SRKW samples with test fishery age composition is not appropriate due to size selectivity in the test fisheries themselves.)"

We did not make use of any age structure data from test fisheries in our age composition analyses. I addressed this misinterpretation of our analyses in my comments following the report on workshop 1. Our comparison of age structure of Chinook taken by killer whales was to the age structure estimated by the PSC Chinook Technical Committee as part of their development of the abundance index, for the area in which we sampled RKW predation (northern Vancouver Island). This is described in Ford and Ellis (2006). I cannot recall if NOAA researchers used test fishery age data in their comparisons.

Dear panel members,

I was impressed by your synthesis of presentations and communications, and I have provided specific comments on Sections 2, 4 and 5 that are intended to be helpful and constructive.

Chuck Parken

Specific Comments

Section 2.1

The section introduces the 2010 Biological Opinion, but to my knowledge it is a U.S. document, and was not developed bilaterally. Thus some clarification can be provided here and subsequently where appropriate. Perhaps the document could be referred to as the 2010 U.S. Biological Opinion. Please double check this.

Section 2.2

Line 176. Figure 3-3 suggests there is much uncertainty for the population growth rate Lambda over 1979-2011 and that there is a meaningful chance that Lambda is less than 1 for SRKW. Lambda less than 1 identifies a decreasing population. Perhaps the uncertainty in the rate can communicated or the caption for Figure 3 can be expanded to improve communication.

Line 184. The delisting criterion is a U.S. one. Suggest editing to "*….that the existing U.S. delisting criterion…*"

Lines 200-203. I think there are a couple of things occurring here to consider. The SRKW essentially leave the southern entrance to the Salish Sea during October-November and return in May, or at least they infrequently use the Critical Habitat in the winter compared their usage during May-October. During Nov-Apr, Chinook abundance is much less than during May-Sep. If the SRKW were ecological generalists and switch prey when salmon abundance declines, then one would expect them to remain in the Southern Entrance area. There are lots of other fish species such as steelhead, herring, rockfish, lingcod, flatfish, hake, stickleback, etc. to switch to, but the whales don't stay in the in the area and subsist on other fish—they emigrate and go to other areas presumably for feeding. It seems plausible that the food resources are not sufficient in the southern entrance during Nov-Apr, or perhaps they migrate for other non-feeding reasons. In the May-October period the SRKW are concentrating their predation in areas where Chinook and later chum salmon become more concentrated, such as the bottleneck and funnel areas that exist at the Southern Entrance and along the southern Gulf Islands, such as San Juan Island. The Parken et al. presentation at workshop 1 showed figures to communicate the predation pattern that occurred for the SRKW in the southern entrance and for the NRKW at the northern entrance to the Salish Sea. It also presented the concept of bottlenecks where SRKW predation is concentrated where the Chinook salmon migration becomes concentrated.

Parken, C., J. Candy, G. Ellis, J. Ford, and A. Velez-Espino. 2011. Relative importance of Chinook salmon stocks to resident Killer Whales in Northern Haida Gwaii and the Salish Sea entrances. Presentation at workshop 1.

Line 201. Suggested clarification

"*.....and there is not enough* <u>*annual*</u> *data to determine….*"

Lines 23-236. It would be informative to readers to define what the Parken-Kope index is. My understanding is that it is a subset of the time series for the 20 stock groups reported by Kope and Parken at Workshop 1. Selection of the stocks has a statistical basis that Erick Ward can clarify, or perhaps that was done in the Ward et al. presentation for Workshop 2. I think this is needed because some people may interpret the Parken-Kope index as something that was generated and recommended by Parken-Kope, which isn't the case. We produced time series for many stocks from California through to Northern BC, but the selection of stocks was done by Ward with the coauthors describing for each stock characteristics such as run timing and ocean distribution. Further, it may also help to clarify what ages were included for the time series: age-3 and older for ocean-type stocks and age-4 and older for stream-type stocks. This better aligns with the ages found in SRKW diet sampling, where the younger fish for each life history were virtually absent.

Line 253. Comment.
…if SRKW are consuming a very high proportion of available Chinook.

I agree with this statement if it is qualified to 'in Critical Habitats" as extrapolation to areas outside of them is very data limited. Also, within the spatial context of Critical Habitats, I don't think its significance was clearly communicated at either workshop, or that its basis may have been reviewed sufficiently.

In the Parken et al. presentation at workshop 1 the average terminal run of Chinook stock return to rivers around the Salish Sea was ~672,000 and perhaps half (336,00) use the southern entrance. On lines 1014-1015, the panel describes the potential SRKW consumption from Ford et al. 2009 and his presentation at Workshop 1. If SRKW eat 67,000-81,000 while in critical habitats during July and August when 90% of the diet is Chinook then roughly another 26,000-64,000 Chinook area eaten per month for May, June, Sep. and Oct when one assumes that about 70% of the SRKW diet is Chinook (this may be too high given that the entire SRKW population may not be present in the Critical Habitat area for 100% of the time and switching to chum during Sep -Nov). This rough calculation suggests SRKW would eat 171,000-337,000 during May-Sep, and implies SRKW may eat about **34%-50%** of the adult Chinook migration. The rates could be refined by adding in fishery catch, by changing the diversion rate assumptions, by stratifying by month to accurately represent the percentage of SRKW diet that is Chinook, and by varying SRKW feeding efficiency with Chinook abundance. My main comment here is that I don't think your summary point received the attention that it deserves during either workshop. It would be helpful to have feedback about whether the estimates are sensible. The range for the rate seems very high to me.

P. 8 Footnote 2
Please double check the citation. I think the author is J. Carlile and not J. Clark.

Line 264. Another reason that the assumption may not be true is that the SRKW cannot eat 100% of the adult Chinook that may be passed through fisheries and to the southern entrance to the Salish Sea. The comments and rough analysis for Line 253 above suggest a SRKW 'harvest

rate' of about 34-50%, so perhaps ½ to 2/3 of mature fished saved by fishery reductions would be passed to the terminal area. This means that fishery reductions would not be a complete economic loss for fisheries. There could be a redistribution of part of the catch from pre-terminal to terminal fisheries. There would be other types of benefits, such as ecological benefits and cultural benefits to First Nations people who use Chinook salmon.

Line 266. There should be some consideration as to where the predation by harbour seals may be occurring mainly. We know that harbour seals frequent the mouths of the Salish Sea rivers during the times when adult Chinook are present (e.g. mouth of the Cowichan River in the late summer and fall). It is possible that much of the predation by harbour seals on Chinook occurs at locations and times after SRKW have preyed on Chinook (Entrances to Salish Sea, and possibly coastal areas). I made a similar comment about this at the end of Section 5.

Line 272. I think this is the first mention of the summer period for SRKW diets, and it would be helpful to define the period that the report calls summer because it may not be consistent with common knowledge. Is summer the May-October period that aligns with the diet samples (e.g. Hanson et al. 2010; several presentations in Workshop 1 including Parken et al.), is it June-August which aligns with summer-run timing definitions for Chinook salmon, or is it July and August which was the period used to generate the Chinook prey consumption reported in line 1114s.

Line 277. I suggest clarifying the context of the 20% harvest rate statement as it depends on the set of stocks used. Among the 20 stocks presented by Kope and Parken at workshop 1, the average preterminal harvest rate for 2005-2010 was 29%, and for the Salish Sea stocks it is 30%, and for the 4 Fraser stocks presented by Parken at workshop 2 in slide 5, the 2005-2010 average was 21%. Perhaps citation of the Parken presentation with the following revision to the sentence would be sufficient. "*….to increase the abundance of the main Chinook stocks eaten by SRKW while in the Critical Habitat area.*"

Parken, C. 2012. Preterminal impacts on Fraser River Chinook stocks. Presentation at workshop 2.

Section 2.3.

Line 316. Some rewording of the sentence may be needed as it currently may appear to some readers that NOAA and DFO jointly developed the US Biological Opinion. That document may have used work done by DFO. E.g. large volume of scientific publications by Ford, Ellis, and Olesiuk.

Section 2.4

Line 365-367. The series constructed by Kope and Parken (workshop 1) did not rely on natural mortality rates, but the FRAM and CTC model indices did. Perhaps revise the first sentence to "*…The <u>FRAM</u> model indices of Chinook abundance…*" This critical comment pertains to the US Biological Opinion but not to the analysis done by Ward et al. at workshop 2 using the Parken-Kope index. Those indices were generated from the terminal run estimated for each stock and the abundance was reconstructed by adding back in the fish that were harvested in that catch year (recall these were age specific criteria also). Natural mortality was not considered in theses indices but it obviously happens continuously during the fishing season as fish migrate to inside waters.

It is not clear if the panel has this knowledge, but there are other human-induced sources of known mortality on Chinook salmon that are not accounted for the CTC of FRAM analysis (see Parken presentation at workshop 2 in slide 6). CWTs are recovered in fisheries that are directed at species other than salmon, such as groundfish trawl (i.e. Pollock), herring and sardine fisheries, scientific research surveys targeting juvenile salmon or other species (pelagic species scientific test fishing), fish that have been harvested illegally but encountered by government enforcement agencies. Not all of these fisheries in Canada and the US have been sampled consistently and they are omitted from the CTC model, FRAM model, and CTC CWT cohort reconstruction analysis. However this could also be an important source of mortality that is omitted from Chinook stock assessments. Variations in past sampling may be difficult to resolve but the panel has the ability to make strong recommendations about the value of implementing standardized CWT sampling in the non-salmon fisheries to improve the accuracy of Chinook abundance measurements and to better support Ecosystem Management.

The recommendations to examine models that represent fishing and natural mortality as continuous process is helpful. However, there may be considerably difficult with modeling natural mortality as time dependent on the abundance of predators (RKW, harbour seals, sea lions, etc.). It isn't clear how these functions would be defined and the modeled stock-specifically. For example, harbour seal predation rates may be much greater for Cowichan Chinook than for Fraser River Chinook, but it isn't clear if there is sufficient data to represent these processes appropriately. Further, it isn't clear how the relative abundance of alternate prey species may influence the predation rates (natural mortality) on Chinook salmon. Another complication is this new time varying uncertainty would be affect the fishery-specific time series of exploitation rates, and what the implication may be for coordinate Chinook resource management between Canada and the US. I think this is helpful suggestion, but it would also be helpful to have more specific information from the panel about this (e.g. more description of what is being thought of). This would help inform future work related to this critical recommendation.

Line 387. Items critical to the underlying hypothesis.
During workshop 1 some concerns were raised about the representativeness of the SRKW diet samples given the methods, as well as about the spatial and temporal representation of sampling (e.g. Parken et al. presentation had some slides about this). In subsequent pages of this panel's report the importance of using a sampling design to collect data and generate inferences is generally mentioned, however I suggest that this should be a fundamental or critical issue to resolve. The samples that have been collected were done so opportunistically (also convenience-based) and there isn't sufficient information to evaluate how well these samples represent SRKW feeding ecology at the annual temporal scale or over the entire spatial distribution of SRKW. Unfortunately, there is insufficient spatial and temporal habitat use data for SRKW to weight the opportunistically collected samples as an alternative approach. I think the RKW scientists have done their best to communicate this and have done a remarkable job given the resources that they had available to them.

One suggestion is to develop a system of hydrophone 'listening' stations along transects through the potential SRKW range to estimate the spatial and temporal distribution of SRKW. The

information would be valuable to identify how much time the SKRW pods spend in each area and to generate sample weights for the prey samples from different areas that have been collected. The spatial and temporal distribution data would also help SRKW diet samplers allocate sampling effort and to follow a survey sampling design. There are numerous examples of how mistakes are made when samples are collected opportunistically (the election polling companies figured this out a long time ago). Lines 390-393 generally identify that more data are needed on the winter distribution, but I think the issue is broader than that. For example, even during the summer some SRKW individuals leave the southern entrance of the Salish Sea and migrate to areas on the WCVI such as Swiftsure Bank. Presumably these migrations are made to find better feeding conditions. Representation of this part of the summer diet may also be valuable.

Section 4.0

Line 566. This report raises some uncertainty with the opening sentence since it uses what is mainly diet data collected from May to October in the southern entrance to the Salish Sea to make an inference to year-round feeding habits throughout the population's spatial distribution, which includes habitats that have had no diet samples collected. Several parts of this report express caution about taking inferences from an area and time and then extrapolating them to the areas and time with very little or no information. Thus I suggest revising the opening sentence to make the inference more appropriate and consistent with other parts of the report. *The apparent specialized diet of SRKW on Chinook <u>in the May to September period while the whales are in the southern entrance to the Salish Sea</u> means that it is biologically plausible…*

Lines 587-590. When I read the section on diet I thought it overlooked the presentation from workshop 1 by Parken et al. That analysis directly examined selectivity by comparing the frequency of Chinook salmon stocks in the SRKW diets in the southern entrance to the Salish Sea to the frequency of mature Chinook salmon returning to the Salish Sea as measured by their terminal runs (abundance at the river mouths). I don't think it is accurate to state that selectivity by SRKW is poorly known in line 588. Also, there was information presented on the age selective predation (which is presumably a result of size selective predation by SRKW), and there is much information showing that the average weight (size) and age composition varies among Chinook stocks (slide 13 of Parken et al.; scale age observations reported by Ford et al. in several publications and Lines 974-996 section on Size Selectivity). The sentence can be revised to communicate what was reported and where more information would be helpful.

Parken, C., J. Candy, G. Ellis, J. Ford, and A. Velez-Espino. 2011. Relative importance of Chinook salmon stocks to resident Killer Whales in Northern Haida Gwaii and the Salish Sea entrances. Presentation at workshop 1.

Slide 9 of Parken et al. summarizes the selectivity results for SRKW (southern entrance), with high selection for 4 of the stocks and low selection for the other 4. SRKW had high selection for spring- and summer-run stocks returning to the Fraser River, with the exception of the Lower Thompson stock which has small body size and lower weight (slide 13) due to a strong pattern of maturity at a young age (age 1.2→ where the -.2 means only two winters spent in the ocean). SRKW had low selection for fall run stocks returning to the Salish Sea, including Fraser Late, Strait of Georgia, and Puget Sound. Regarding energy intake, one can speculate that the spring- and summer-run stocks are more energy rich than fall-run stocks of the same size because more energy reserves are needed to sustain migration to the spawning grounds for spring- and

summer-run stocks than fall-run stocks: fall-run stocks around the Salish Sea spawn very near (within 100 km) to the tidal boundary, whereas spring- and summer-run stocks spawn much farther away, especially in the Fraser River, or these stocks may spawn at a higher elevation which makes the spawning migration energy demanding. Puget Sound Chinook are a mix of summer- and fall-runs, with much less abundant spring-runs. The low selectivity for Puget Sound Chinook by SRKW may result partly from the spatial distribution of feeding SRKW in the southern entrance to the Salish Sea compared to the migration routes mainly used by Puget Sound Chinook (slide 10), and partly from the young age at maturity and presumably smaller body size for Puget Sound Chinook (referenced on lines 984-987). Fall-run stocks may also have low selectivity because SRKW diets have high components of chum salmon during the fall, so predation rates may be lower on Chinook in Sep-Nov because there is suitable *alternate* prey for SRKW.

Line 589 mixes two related concepts but uses incomplete logic in the supporting statement beginning with *"..because the energy density of Chinook varies among stocks"*. The logic would be more complete with revision to "*because the <u>average weight and energy density varies among Chinook stocks</u>*". This is part of the logic that is identified later in lines 984-987. The Parken et al. presentation at workshop 1 (slide 13) described how the average weight composition varies among Chinook stocks returning to the Salish Sea, and the text summary explained the linkage between average weight and the age-at-maturity patterns, which varies among Chinook stocks.

In general, I think the topic of SRKW selectivity for Chinook salmon stocks is far better understood than truly 'poorly known' SRKW ecology like the winter distribution and diets and the ocean distribution and rearing areas for spring- and summer-run stream-type Chinook stocks returning to the Fraser River.

Section 4.2

Lines 622-623. I agree that these data are difficult to attain, but I think an important part of the uncertainty with the information in hand can be clarified also. Even though the data can be difficult to attain if it had been collected in a statistically rigorous manner then inference could be generated appropriately from the small samples (one would expect the inferences to be accurate but imprecise). However, a critical part of the uncertainty for the information that was collected is that it is not statistically rigorous because it was opportunistically collected. There was no sample design used for these diet studies. The importance of this point is something the panel impresses on their students each year at least, because it is such a fundamental component of science.

Suggested rewording to the opening sentence. "*....because the data are difficult to collect and have been collected opportunistically. None of the diet studies were statistically designed to produce random, representative samples and opportunistic samples can produce incorrect inferences."* For example, the recommendation in lines 751-753 address concerns about potentially incorrect inferences that may arise due to sampling bias, and lines 748-750 are intended to address concerns about the spatial and temporal representativeness of the samples.

Section 4.3

Line 644. I think the sentence "*These methods are solid and state of the art*." would be more clear and accurate with some further qualification. I think the intent is to say that the methods used to identify the species and stock are proven, but they have been found to have some error (numerous salmon GSI publications have described error levels; e.g. Beacham et al. 2006; Parken et al. 2008; etc.). Each of the sample collection methods may have some biases that the panel has concerns about (e.g. lines 751-753). Further, the samples have been collected opportunistically and without use of a survey sampling design. Did the panel really intend to describe this data set as 'state of the art'? Numerous concerns were raised at workshops 1 and 2 about the limitations and concerns with these data, which produced several of the recommendations in Section 4.4.

Lines 646-647. It seems unusual that the lack of winter diet samples leads the panel to state the winter ecology of SRKW is unknown. What is known is that the SRKW use different habitats in the winter than they do in the summer/fall (May-Nov). If the SRKW were present in the Critical Habitats at from Dec-Apr then there would be more observations from the whale watchers, agency scientists, citizen science and just general human population in these areas (e.g. sightings from people on ferries etc.). What this tells us about the winter ecology is very obvious: they are not using the habitats that they frequent in the summer. So part of the winter ecology is known, and there is much to learn. Lines 905-908 also make use of this information about the winter ecology to generate SRKW diet hypotheses.

Lines 668-669. I agree that sampling effort should be expanded to include winter surveys, but a comprehensive diet sampling program needs to follows a statistical design intended to represent the annual diet. A repeat of the opportunistic, convenience-based summer diet sampling program has little value other than to provide information to plan future and more biologically meaningful studies. The sentence could be revised to the following to be more scientifically valuable. *"….and include winter surveys <u>and be spatially and temporally representative of SRKW distribution</u>*."

Section 4.4

Lines 748-750. This recommendation would help collect information to describe the spatial and temporal distribution of SRKW, but it has several limitations and risks (e.g. represents a fraction of individuals, invasive, etc.). Another approach is to use series of hydrophones to establish transects for one to monitor when the SRKW pods migrate between habitat areas. This information could describe how much time SRKW pods spend in each area. Also, it could be used to plan how much diet sampling effort to spend in each area or how much weight to apply to a set of diet samples collected from each area. This approach would help to provide spatial and temporal balance in the sampling design for diet and other aspects of SRKW ecology. This technique has issues also (e.g. cost). Just a suggestion.

Lines 751-752. The rationale for more fecal sampling is not just to '*detect non-salmonids'* but to accurately represent all components of SRKW diet. If the proportion of prey is the same in surface samples as they are in the fecal samples, then either method could be used to represent SRKW diets.

Lines 762-769. This seems somewhat repetitive to the statements in lines 748-750, but it really focuses on collecting specific data to help with the energetic needs. Detailed information to measure search time, handling time, and socializing could be very informative. Perhaps a hybrid approach could collect very specific information using individual tags and very general migration information using hydrophone transects.

Section 5.1

Lines 793-94. Contemporary abundances in British Columbia have also been reduced and many of the stocks in southern British Columbia are stocks of conservation concern. It may be more informative to say that stocks from BC through California have declined and many of the US ESUs are listed under the US federal legislation, while many of the Canadian ones are stocks of concern with specific fishery management strategies outlined in the Canadian federal fishery management plans.

Line 801. Declines have been more alarming in southern BC than Skeena and the outlying areas. Canadian fisheries are actively managed to reduce harvests of WCVI, Lower Georgia Strait, Fraser Spring-run Age 1.2, Fraser Spring-run Age 1.2, Fraser Spring-run Age1.3, and Fraser summer-run Age 1.3 stocks.

Lines 815-818. In workshop 2, Parken provided ocean distribution information for Fraser River Chinook stocks. The Fraser Summer-run Age 0.3 stock group is ocean-type and far north migrating. The stream-type stock groups (Spring-run Age 1.2, Spring-run Age 1.3, and Summer-run Age 1.3) appear to have a non-coastal distribution and are encountered in fisheries mainly as they return to the Fraser River and in the approach fisheries. Fraser Late Chinook are ocean-type and have a local coastal distribution and they are caught mainly in fisheries in southern BC and Washington State (central distribution).

Line 829. Suggested clarification

"*(1) Fraser Early (spring and summer) Chinook total abundance*"

Lines 840-841. Suggested clarification

"*designed to improve conservation status of ~~listed~~ populations of Chinook*"

This is more accurate and inclusive as listed population management does not include management of Canadian fisheries for stocks of conservation concern.

Section 5.2

Lines 903-904. Could cite Hanson et al. 2010 as this was also one of their findings and could cite the analysis of the Parken et al. presentation at workshop 1. Slide 9 showed high importance for 3 of the 5 Fraser Chinook stocks, and the low importance stocks were Fraser Late (fall run) and Lower Thompson (small body size). Even though the later two stocks had low importance relative to their run size they still may be important to SRKW diets (e.g. from an energy intake perspective).

Line914-920. In the winter, SRKW predation in the outside coastal waters of WCVI and Washington in the winter would probably include stocks such as Lower Columbia falls, Fraser Late, and Puget Sound summer/falls.

Lines 929. Suggested clarification.
"….expressed concern about how <u>size/age</u> *selectivity functions…*"

Lines 945-946. At workshop 2, Parken presented (slides 3 and 4) concerns about the quality and quantity of data that was used to represent the Fraser Early stock in the CTC Model, and how the stock was represented using opportunistically available data.

Lines 960-962. Note that the terminal run and pre-fishery reconstructed abundances presented by Kope and Parken at workshop 1 were limited to age-3 and older for ocean-type stocks and age 4 and older for stream-type stocks. An age-3 ocean-type fish (age 0.2) and an age-4 stream type fish (age 1.2) both spend 2 winters in the ocean before returning to spawn, and these fish are about the same size/weight (albeit there can be biologically meaningful size-at-age variation among stocks). We arranged the indices this way to best characterize the size classes that we interpreted as contributing SRKW diets. It would be helpful if the whale scientists could report the ages of the diet samples with more detail to organize them by ocean-age, since this would enable the salmon biologists to more accurately construct abundance indices that correspond to SRKW prey samples.

Lines 975-982. To improve communication among scientists from different fields, it is very important to organize the scale ages from the SRKW diet samples by ocean-age. As mentioned above, the ocean-age is what largely affects the size of the mature adult fish. An age-4 ocean type (age 0.3) will be about the same size as an age-5 stream-type (age 1.3), so when we are talking about total age the context is truly lost unless you also begin to talk about the Chinook life history. It is likely simplest to organize the SRKW diet samples by ocean-age. I think the panel needs to clarify this or perhaps I can make a presentation at Workshop 3 to communicate size-at-total age and size-at-ocean age concepts, along with variation in growth rate parameters (from VonBertalanffy analysis for Fraser stocks).

Lines 984-987. The influence of size/age selectivity on the frequency with which some stocks occur in SRKW diets was one of the main insights from the Parken et al. presentation at workshop 1. Specifically, the Lower Thompson stock was found among the SRKW diet samples at a frequency that was much less than one would expect based on its numerical abundance alone. This stock has small size (see slide 13) but has spring run timing. It migrates through the southern entrance at the same time as other Fraser River spring-run stocks, which are mainly age 1.3 at maturity and larger, however Lower Thompson is only rarely found in the diets. Since the stock migrates right through the Critical Habitats at a time when the whales are feeding on Chinook salmon, it is very likely that size selectivity contributes to the very low occurrence among SRKW diet samples. Also, the Lower Thompson is a spring-run group the probably has higher energy density to sustain its migration through the Fraser River Canyon to the Interior and to sustain during the holding period until spawning in August and September. Or alternatively, perhaps small Chinook are not brought to the surface to be shared with other SRKW and the size selectivity pattern is a result of biases in the sample collections (non-representative sampling).

Lines 1044-1048. At workshop 2, Parken presented the number of estimated CWTs used to represent Fraser Early stocks in the CTC model and described several other issues. An enormous

component of the SRKW Chinook diets in the southern entrance is Fraser Chinook, in the range of 80-90% as reported by Hanson et al. 2010. The CTC and FRAM models represent all these Chinook stocks as 2 model stocks, and both of these model stocks had problems, issues and concerns with the CWT data that were used to represent the biodiversity of this stock complex. For the Fraser Lates, there were no CWTs so information from the mid 1980s was used and then hind-cast to the late 1970s using a sensitive out-of-base procedure by the CTC (which can produce problematic results, issues, and concerns for this stock). For the Fraser Early stocks, there are more than 100 spawning locations, and recently DFO analysis has identified 16 conservation units. The CTC recognizes 4 stock groups for its reporting yet only 2 sites were used to represent the entire production.

I really believe the people who did this work did the best they could with what they had, but by no means would I say this is reasonable, especially for the purposes of the SRKW investigations. For example, none of the spring-run stocks were represented. Among the 148 estimated CWT recoveries among the fisheries, 12% were from the stream-type summer-run stock and the remainder was from the ocean-type summer-run stock. Slide 6 of the Parken presentation at workshop 2 shows very general ocean distribution patterns for 7 genetic groups, with some very noticeable variations among them. The general comment on lines 901-904 identifies that Fraser River Chinook are the most important during the summer (May-Sep). Given this importance as prey and the quantity and quality of the CWT data used to represent the Fraser stocks, it seems appropriate to provide more cautious statements about the whether the methods are scientifically valid. Some say "garbage in→garbage out".

Another issue to consider is that it is correct that the ocean fisheries were much less restricted than they are now, but Canadian sport fisheries were poorly sampled in that period and many did not have catch estimated in order to accurately expand the CWT samples. In general the many recreational fisheries that were poorly represented by CWTs are much greater now (e.g. WCVI AABM sport, Northern BC sport) and some were better represented by CWTs then but are much smaller now (e.g. Strait of Georgia sport).

If one overlooks the issues and concerns with representing Fraser Early Chinook in the base period and focuses on what CWT information is available now, there are some critical knowledge gaps that would limit the ability of Canada and the US to coordinate fishery management of these stocks in a precise and meaningful manner. This information was also communicated in the Parken presentation at workshop 2. Fraser spring and summer run Chinook spawn in more than 100 rivers which can be organized into 16 Conservation Units (DFO Wild Salmon Policy), 6 genetic reporting groups, 4 stock management groups (PSC CTC), with ocean- and stream-type life histories and return timing at the mouth of the Fraser River ranging from April-September depending on the stock. Currently, all of this biodiversity is represented by two operational CWT indicator stocks: (1) the Nicola population is a spring-run, stream-type young age-at maturity stock in the Spring-run Age 1.2 stock group reported by the CTC and in the Lower Thompson genetic group, and (2) the Lower Shuswap is a summer-run, ocean-type stock in the Summer-run Age 0.3 stock group (CTC) and in the South Thompson genetic group. So CWT indicator stock represent 2 of 16 Conservation Units, 2 of 6 genetic groups, and 2 of 4 stock management groups. This seems like a critical knowledge gap to me, and it would be appropriate to identify this in Section 5.4.

Lines 1054-1062. It seems very reasonable to not expect a stock like the NOC stock to migrate into Juan de Fuca or Puget Sound during the summer months, especially after one reviews all the 1000s of CWT recoveries for fisheries in this area and for the NOC stock itself. However keep in mind that some SRKW individuals do make short term migrations during May-Nov to the outside waters of WCVI. Presumably they emigrate from their Critical Habitat and go to WCVI areas, such as Swiftsure Bank, in search of food. Thus some stocks that are not found in Juan de Fuca may still be important to the summer diets of SRKW when the SRKW are not in the Critical Habitat area. The NOC stock would be migrating past the WCVI when the SRKW exit the southern entrance of the Salish Sea around Sep-Nov, and perhaps the SRKW time their emigration to coincide with the very large abundance of returning NOC Chinook?

Also, there are currently few observations of SRKW in the winter period and SRKW have been found in Haida Gwaii in late spring. It is possible that some SRKW pods may use the ocean areas in the winter periods where the northern ocean distribution Chinook stocks reside as immature fish, such as Haida Gwaii or possibly SEAK. Certainly more information is needed about the winter distribution of the SRKW to better understand if some of the stocks selected by Ward were done so spuriously.

Lines 1064-1066. Good suggestion, but I think Ward examined the geographic ocean distribution of Chinook stocks (as southern, central, and northern) and reported stronger association for those with a northern distribution than a central or south distribution. He reported this to the coauthors of the presentation prior to workshop 2, and Erick can clarify this if needed. As the panel suggests, new aggregations of stock groups can be created for hypothesis testing.

Lines 1069-1072. The stocks most likely to be available during the winter in the central rearing area can be extracted from the CTC or FRAM models, or the actual CWT data (e.g. in workshop 2, Parken's presentation slides 5 and 6 identify which Fraser stocks may be good candidates and the stock scale has better resolution than either the CTC of FRAM models). Likely stocks on the WCVI are Lower Columbia Falls, URBs, Fraser Late and Puget Sound.

The statement about ocean-type Fraser stocks is incorrect, and just needs a minor correction. Harrison, part of the Fraser Late stock group, are ocean-type Chinook that are correctly identified in line 1070, but the Fraser Summer 0.3 stock group is also ocean-type (the 0 before the period in the European age format identifies them as sub-yearling smolts with 0 winters spent in freshwater), but has a northern ocean distribution. Slides 5 and 6 of the Parken presentation at workshop 2 illustrate this for the Lower Shuswap CWT indicator and other components of the South Thompson genetic group.

Lines 1079-1081. The suggestion to examine associations with stocks that have a southern distribution, e.g. California, was part of the background work that Ward et al did for workshop 2. Their analysis showed that SRKW survival and fecundity had no association with terminal run size or the reconstructed pre-fishery abundance (accounts for fishery catch and terminal run) for stocks with a southern distribution. I am unsure if these results were presented at workshop 2, but if not please follow up with Eric.

Lines 1084-1089. I agree with the panel's point. There are time series of harvest rates for each stock that could be used to more accurately represent how abundance may change with relative fishery reductions to a 'base period' (e.g. a 50% reduction to the stock specific harvest rates observed during 2005-2010, or some other period).

Lines 1089-1092. Time series of mature runs (pre-fishery) can be generated for the stocks presented by Kope and Parken at workshop 1. I think this would provide the refinement that the panel is interested in.

Section 5.4

Line 1094. Suggest recommending more CWT indicator stocks to better represent the distribution and abundance of spring- and summer-run Fraser River Chinook stocks that occur frequently in SRKW diets. Data are needed to improve the evaluation of the relationship between SRKW population dynamic rates and the abundance of the key Chinook stocks that the SRKW prey on while in their Critical Habitat.

Lines 1099-1102. There are also a small number of observations in northern BC and SEAK that could be investigated. The SEAK observations were recently determined by DFO (Ford and Ellis) based on a set of historic photos. There may be other data sources, such as the one discovered recently by Ford and Ellis, that need to be data mined more thoroughly. Previous suggestions in the panel's report for satellite tagging and in this review for hydrophone transects are needed to address the critical data gap of the SRKW winter distribution and relative habitat use (i.e. how much time is spent in habitats by SRKW pods).

Line 1094. Other suggestions to consider:

During this process, the panel heard presentations about alternate prey eaten by SRKW as well as potential competitors such as marine mammals. I wasn't sure if this was the appropriate place in the report for these suggestions.

It sounded like it would be worthwhile to evaluate how much, if any, of the variation in SRKW fecundity and survival are associated with the abundance of chum salmon. There has been considerable stock identification work done on chum fishery catches in the northern and southern entrances to the Salish Sea, and perhaps this information could be used to develop an index with chum stocks occurring in the SRKW diet samples.

There are time series of competitors for Chinook salmon, such as harbour seals, California sea lion, and possibly for birds that prey on juvenile Chinook in freshwater (e.g. mergansers) and the ocean. Are any of these abundance series helpful covariates in the associations found with Chinook salmon abundance? There are several ways to model and investigate the influence of competitors.

Analysis with marine mammal time series should consider the season and location of predation. For example, there are many harbour seals throughout the Cowichan River estuary from August to October and they have been found to eat mature, returning Chinook salmon (work by Peter

Olesiuk), however their influence on the abundance of Chinook in this area and time occurs after Chinook were vulnerable to SRKW predation (after fish passed through the Critical Habitat).

COMMENTS ON DRAFT FINAL REPORT OF THE INDEPENDENT SCIENCE PANEL "THE EFFECTS OF SALMON FISHERIES ON SOUTHERN RESIDENT KILLER WHALES" (dated 3 May 2012)

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13 June 2012

I have reviewed the Draft Science Panel report on the above topic, with particular attention to ecosystem-related issues. Dr. Dave Preikshot has also reviewed the Draft report, and his comments are included here.

Overall, we agree with the Panel's recommendations for "Other ecosystem factors" (page 13, lines 397-402), in particular on the need for situating the Southern Resident Killer Whale (SRKW) – Chinook problem within a broader ecosystem context, and the recommendation for further development of ecosystem trophic models which can explore these relationships. We also agree that exploring a range of indices of ocean productivity as alternatives to Chinook abundance would be helpful, and note that these are topics of active current investigation.

We have 2 detailed points:

1) The Panel recognised the 'narrow' ecosystem context within which this problem was examined (e.g. page 11, lines 344-348), and recommends the need for "more evaluation of ecosystem factors affecting killer whales" (page 13, lines 399-400).

Comment: Such an ecosystem context would permit more detailed examination of potential interactions with competitors (of killer whales) for food. If and when a broader range of prey are identified for Southern Resident Killer Whales, such ecosystem modelling would also permit analyses of the roles of these other prey items in killer whale survival and growth, and their interactions with Chinook salmon. Ecosystem modelling can provide a framework for evaluating the "competing risks of death' concept, as noted by the panel (page 35, lines 1035-1037). Ecosystem models may also be useful to evaluate the 'measures for success' of management actions, i.e. to identify direct relationships between management actions and desired goals (*c.f.* page 12, lines 382-386). Perhaps the best tool to use for these types of questions would be a spatially-explicit version of ecosystem trophic models, which would provide the ability to focus on specific

locations and stocks of Chinook relative to feeding by SRKWs. Such models have not yet been developed for the Strait of Georgia.

2) The Panel recommends that "a range of indices of ocean productivity as alternatives to Chinook abundance" be developed/considered.

Comment: We agree with this recommend, but note that it does not appear to be discussed in Part II of the report, which provides the background for the recommendations in Part I. We suggest that the basis or justification for this recommendation should be identified in Part II.

COMMENTS ON DRAFT FINAL REPORT OF THE INDEPENDENT SCIENCE PANEL "THE EFFECTS OF SALMON FISHERIES ON SOUTHER RESIDENT KILLER WHALES"

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***To*: Independent Science Panel of the Bilateral Scientific Workshop Process to Evaluate the Effects of Salmon Fisheries on Southern Resident Killer Whales**

Most of the comments in this review are based on results of an ongoing investigation at DFO's Pacific Biological Station, Nanaimo BC, on the sensitivity of resident killer whale population dynamics to Chinook salmon abundance that is part of a 2012-2013 project funded by the PSC Southern Endowment Fund. A detailed presentation of preliminary results from this investigation is planned for Workshop 3. This investigation addresses many of the fundamental questions generating these workshops and raised by the Science Panel, it complements much of the work conducted by Ward et al., and adds a new perspective to the study of killer whale-Chinook salmon interactions on the grounds of state-of-the-art matrix population modelling, comparisons between SRKW and NRKW population responses to Chinook salmon interactions, and the use of rich Chinook data generated and compiled by the PSC Chinook Technical Committee that includes, abundance, catch, exploitation rates, and life history information for stocks and stock aggregates coastwide. The findings of this ongoing investigation concur with many of the Panel's conclusions but some discrepancies exist. The comments that follow are mainly focus on these discrepancies and in new findings and they are structured by sections of the draft final report.

Executive Summary

Saying that the SRKW population growth in the last 4 decades has been 1% per year gives a false impression that population size is growing. The period from which this average population growth rate was derived starts right after the period of the live-capture fishery for exhibition in aquaria, which produced a large impact on SRKW population

size and stage structure, and included years of substantial uncertainty on individual ages and birth and death rates. The computation of population growth during the last RKW generation (~25 years; 1987-2011) showed a population growth of 0.9901 (0.99% annual decline). This population growth rate is more representative of the recent trend in SRKW population size.

I share the Panel's concerns on whether the index of Chinook abundance reflects the Chinook stocks most important to SRKW. The study of killer whale-Chinook salmon interactions is more efficient under a hypothesis-based framework, as oppose to a "shotgun" approach. The following hypotheses (Box 1) proved to be useful to evaluate killer-whale- Chinook salmon interactions, identify relevant Chinook stocks, and point the focus of future research.

Box 1. Hypotheses addressed in this investigation regarding RKW - Chinook salmon interactions (Velez-Espino et al. unpublished).

- Hypothesis 1a (based on current evidence):
  there is a strong link between SRKW population growth and the terminal run size[1] of Fraser Early and Puget Sound Chinook stocks

- Hypothesis 1b (based on current evidence):
  there is a strong link between NRKW population growth and the terminal run size[1] of Northern BC, Central BC, WCVI, and Georgia Strait Chinook salmon stocks as well as the ocean (pre-terminal) abundance of Fraser Early, Puget Sound, and Upper Columbia Chinook stocks[2]

- Hypothesis 2a (Assuming Chinook salmon remains an important diet component throughout the year and outside critical habitats. Criteria for selection: large stocks with coastal ocean distributions are most likely encountered by RKW):
  there is a strong link between SRKW population growth and the terminal run size of large (ocean-type life history[3]) stocks such as WCVI, Columbia Upriver Brights, Fraser Late, Oregon Coast, and coastwide (excluding Southeast Alaska[4]), as well as the ocean (pre-terminal) abundance of stocks with large contributions to ocean fisheries such as WCVI, Columbia Upriver Brights, Fraser Late, Oregon Coast, Puget Sound, and coastwide (excluding Southeast Alaska[5])

- Hypothesis 2b (Assuming Chinook salmon remains an important diet component throughout the year and outside critical habitats. Criteria for selection: large stocks with coastal ocean distributions are most likely encountered by RKW):
- there is a strong link between NRKW population growth and the terminal run size of Fraser Early, Puget Sound and large stocks such as Columbia Upriver Brights, Fraser Late, Oregon Coast, and coastwide (including Southeast Alaska[6]), as well as the ocean (pre-terminal) abundance of stocks (ocean-type life history[3]) with large contributions to ocean fisheries such as WCVI, Fraser Late, Oregon Coast, Puget Sound, and coastwide (excluding Southeast Alaska[5])

1 The terminal run includes terminal catch, which occurs after fish are available for killer whales, and therefore represents the Chinook available for RKW in their summer ranges.
2 Based on diet composition studies.
3 Ocean-type Chinook stocks spend most of their ocean life in coastal waters and are therefore within known RKW geographic range.
4 Out of the known preferred geographic range of SRKW.
5 South East Alaska Chinook salmon stocks exhibit a stream-type life history and perform extensive offshore oceanic migrations, and it is unlikely they are available for RKW. These stocks contribute on average less than 1% to the Chinook salmon available for PST ocean (pre-terminal) fisheries.
6 Within the known geographic range of NRKW.

The Panel's concerns on foregone ocean harvest not resulting in proportionally higher Chinook abundance due to maturation schedules can be addressed by making use of the time variant, stock-specific, maturation-rates produced by the CTC. The concept of "terminal run equivalents" was used in our study to convert changes in ocean harvest rates into expected changes in terminal run sizes.

All recommendations listed by the Panel seem appropriate. In addition, our study found significantly lower calf survival and fecundity of old females (31-50 years old) in SRKW than in NRKW. These differences could be related to greater inbreeding coefficients in SRKW or disruption of mating behaviour trying to avoid inbreeding (Ford et al. 2011 found evidence of inbreeding avoidance in SRKW) and deserve further investigation. We also found support for hypotheses 2a and 2b above that require more studies of RKW diet composition in fall, winter and spring that can validate the uncovered interactions between RKW vital rates and Chinook salmon abundance. This would help strengthen cause-effect interpretations.

Section 2.2 (Part I)

SRKW population size has been declining during the last generation at an average annual rate of 0.99%.

In agreement with the Panel conclusions, we found the recovery target population growth rate of 2.3% for SRKW has a zero probability of being met even under the maximization of vital rates with significant interactions with Chinook abundance. However, if current trends continue, SRKW will not reach a population size leading to downlisting or delisting. This was also demonstrated with projections of the probability of population size falling below a given threshold (Figure 1), projections of population size under demographic stochasticity, (Figure 2), and the probability of falling bellow a population threshold (30 individuals) in the future under environmental and demographic stochasticity (Figure 3).

As desirable as it is, it is important to recognize that currently there are no scientific bases for determination of SRKW carrying capacity. There is minimum contrast in the SRKW abundance time series, and only an ecosystem-based approach could shed some light on SRKW carrying capacity. The sentence indicating 96 animals as the largest known SRKW population size may need some qualification since SRKW population size was 97 individuals in 1993 and 1996 and 96 individuals in 1995.

I share with the Panel the concern about the indices of Chinook abundance used for the core analyses. The main issue with interpretations of these analyses is that correlations between Chinook abundance and SRKW demographic rates are weakly connected to the existing information on Chinook stocks comprising most of the SRKW's summer diet. Base on the hypotheses described in Box 1, the ongoing investigation found a significant correlation between Fraser Early-Puget Sound terminal run and the fecundity of old females (Table 1). However, this interaction had a small effect on the observed variation

on population growth (retrospective analysis; Figure 4) and potential population growth (prospective analysis; Figure 5): 0.16% contribution to the observed CV in population growth; with an elasticity of 0.008, a 10% change in the terminal run of FE+PS is expected to produce a 0.08% change in population growth. This interaction had a negligible effect on quasi-extinction and recovery probabilities. Under hypothesis 2a, WCVI terminal run (correlated with the survival of old reproductive females) and Puget Sound ocean abundance (correlated with the survival of young [10-30 years old] and old reproductive females) showed a greater influence on observed and potential population growth. These stocks were selected for the exploration of fishing scenarios under hypothesis 2a.

Based on two fishing scenarios, (1) maximization of WCVI terminal run as a result of no ocean (pre-terminal) fishing and (2) maximization of survival of young and old reproductive females resulting from a 75% reduction in Puget Sound ocean harvest rates, SRKW mean stochastic population growth rates were 0.995 for scenario 1 and 1.0053 for scenario 2. Although the maximization of effects by scenario 2 produces a clearly positive population growth rate (95% CI: 1.0052-1.0054; Figure 6) under and IID environment with a zero probability of downlisting (Figure 7), SRKW still exhibited a probability of quasi-extinction greater than zero under full environmental and demographic stochasticity (Figure 8). These results concur with the Panel's conclusions about the small effect of reduced Chinook harvest rates on SRKW population viability, which in this investigation was evident even under the assumptions portrayed by hypothesis 2a.

Figure 1.

SRKW Status Quo

Probability of SRKW population size < 30 in the future in an IID environment (5000 realizations; 20 runs)

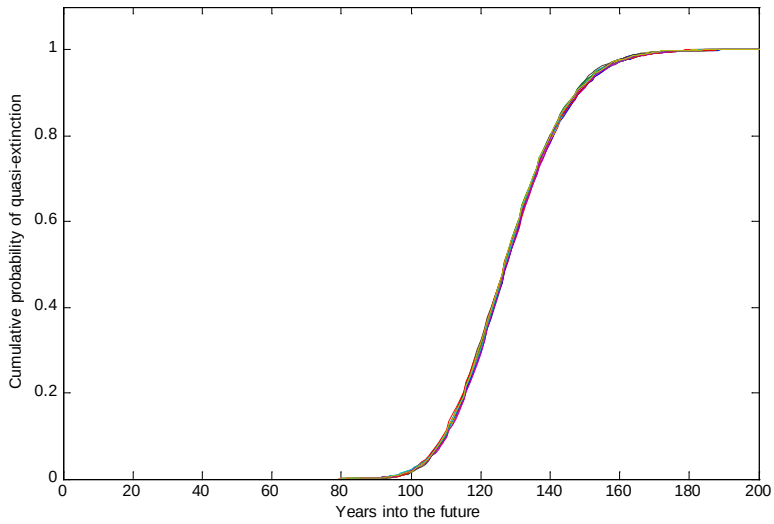


Figure 2.

SRKW Status Quo

Projections of SRKW population growth under demographic stochasticity (100 realizations)

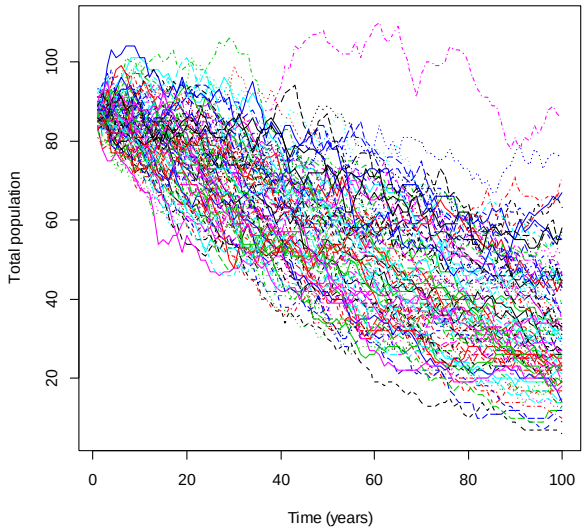


Figure 3.

SRKW Status Quo

Probability of SRKW population size < 30 in the future under environmental and demographic stochasticity (3000 realizations)

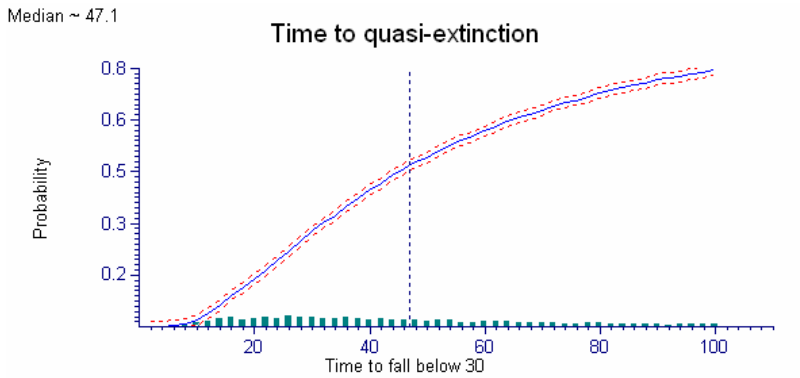


Table 1.

SRKW-Chinook regression models

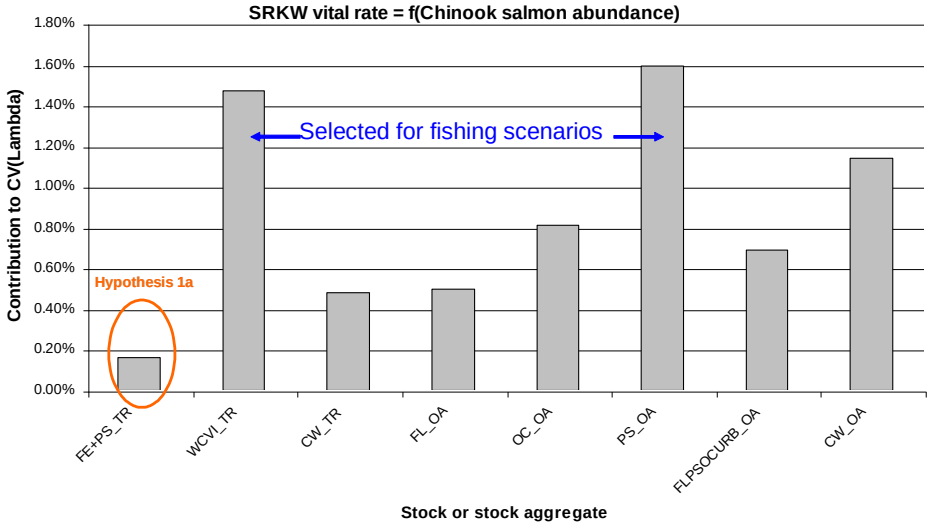
Summary of significant regressions (p < 0.10)				
Vital Rate	**Stock or stock aggregate**	**Lag(s)**	**Adj. R2**	**P-value**
Fecundity (Female 2)	FE + PS Terminal Run	2	0.132	0.0452
Survival (Male 1)	FE + PS + FL Terminal Run	0	0.083	0.093
Survival (Male 1)	FE + PS + FL Terminal Run	1	0.081	0.096
Survival (Female 2)	UpRiver Brights Terminal Run	1	0.153	0.0335
Survival (Male 1)	Fraser Late Terminal Run	0	0.109	0.0639
Survival (Female 2)	WCVI Terminal Run	0	0.168	0.0267
Survival (Female 2)	WCVI Terminal Run	0, 1	0.259	0.0165
Survival (Female 2)	Coastwide Terminal Run	1	0.119	0.0545
Survival (Male 2)	Coastwide Terminal Run	1	0.095	0.0778
Fecundity (Female 1)	Coastwide Terminal Run	0, 1, 2	0.156	0.0967
Survival (Female 2)	Fraser Late Ocean Abundance	0	0.112	0.0613
Survival (Female 3)	Fraser Late Ocean Abundance	1	0.147	0.0367
Survival (Male 1)	Fraser Late Ocean Abundance	0	0.126	0.0495
Survival (Female 2)	UpRiver Brights Ocean Abundance	0	0.0805	0.0901
Survival (Female 2)	Oregon Coastal Ocean Abundance	0	0.173	0.0245
Survival (Female 2)	Oregon Coastal Ocean Abundance	1	0.081	0.0962
Survival (Female 2)	Oregon Coastal Ocean Abundance	0, 1	0.142	0.0769
Survival (Female 1)	Puget Sound Ocean Abundance	1	0.086	0.0888
Survival (Female 2)	Puget Sound Ocean Abundance	1	0.216	0.0127
Survival (Female 2)	Puget Sound Ocean Abundance	0, 1	0.19	0.0419
Survival (Female 2)	FL+URB+OC+PS Ocean Abundance	0, 1	0.223	0.0272
Survival (Female 2)	Coastwide Ocean Abundance	0	0.357	0.0012
Survival (Female 2)	Coastwide Ocean Abundance	1	0.194	0.0179
Survival (Male 2)	Coastwide Ocean Abundance	0	0.081	0.0956
Survival (Male 2)	Coastwide Ocean Abundance	1	0.302	0.0032

Hypothesis 1a

Hypothesis 2a

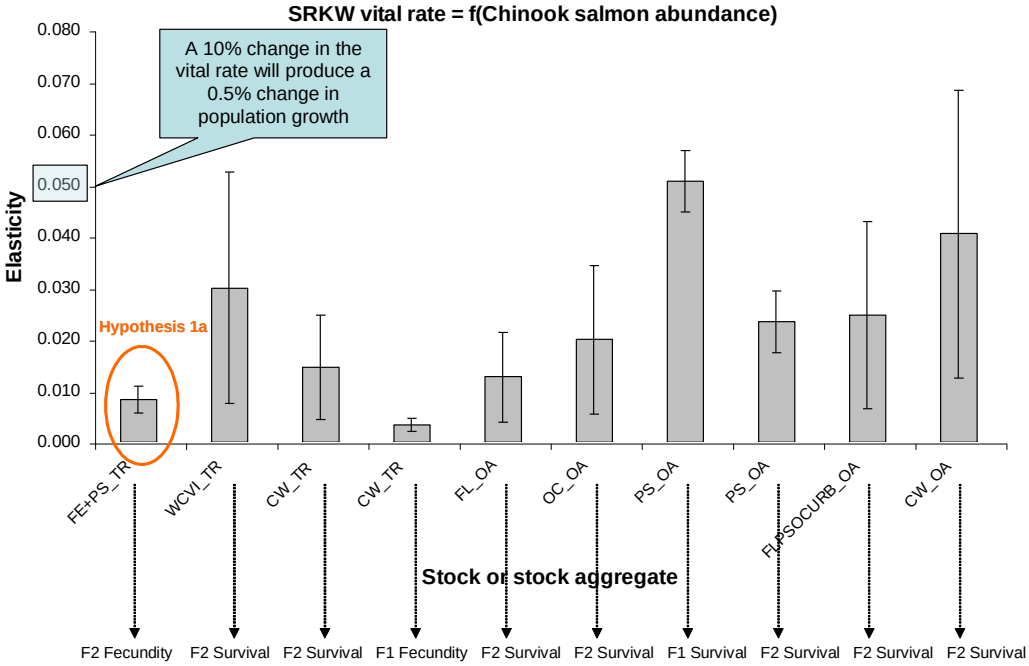
Female 1: Young reproductive females (10-30 years old); Female 2: Old reproductive females (31-50 years old); Female 3: Post-reproductive female; Male 1: Young mature male (10-21 years old); Male 2: Old mature male (22+ years old)

Figure 4. Contribution of vital rates linked to Chinook salmon abundance to variation in SRKW population growth



FE: Fraser Early; PS: Puget Sound; CW: Coastwide; FL: Fraser Late; OC: Oregon Coastal: FLPSOCURB: FL+PS+OC+Columbia Upriver Brights; TR: Terminal Run; OA: Ocean (pre-terminal) abundance

Figure 5. Elasticities of SRKW vital rates linked to Chinook salmon abundance



F1: Young reproductive females (10-30 years old); F2: Old reproductive females (31-50 years old)

Figure 6. **Scenario 2(2a)**: Increasing Puget Sound ocean abundance as a result of 75% reductions in ocean harvest rates →maximizing survival of SRKW young and old reproductive females

Projections of SRKW population growth in an IID environment (5000 realizations)

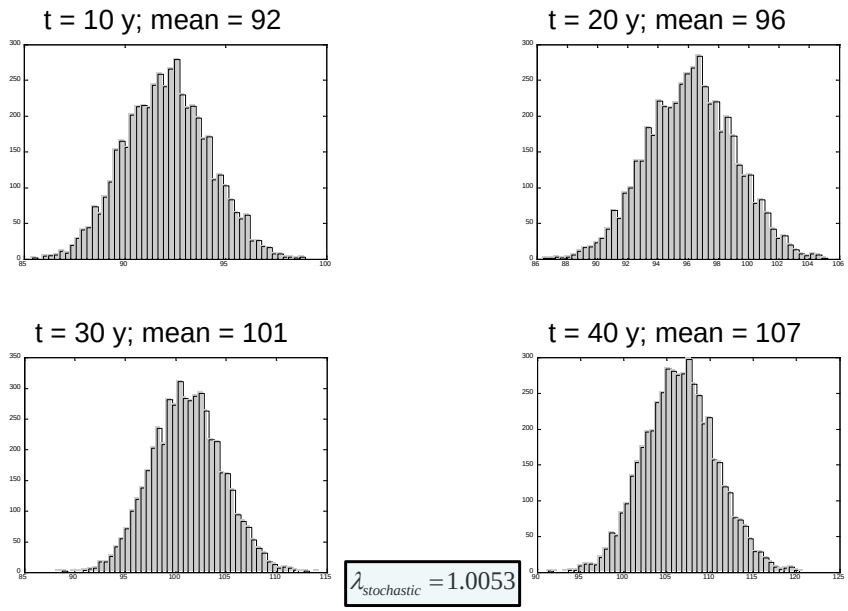


Figure 7.

Scenario 2(2a): Increasing Puget Sound ocean abundance as a result of 75% reductions in ocean harvest rates →maximizing survival of SRKW young and old reproductive females

Probability of SRKW population size < 30, downlisting (120), and delisting (164 individuals) in the future in an IID environment (5000 realizations; 20 runs)

- Probability of falling below 30 = 0.0 even after 500 y
- Probability of meeting downlisting recovery target = 0.0
- Probability of meeting delisting recovery target = 0.0

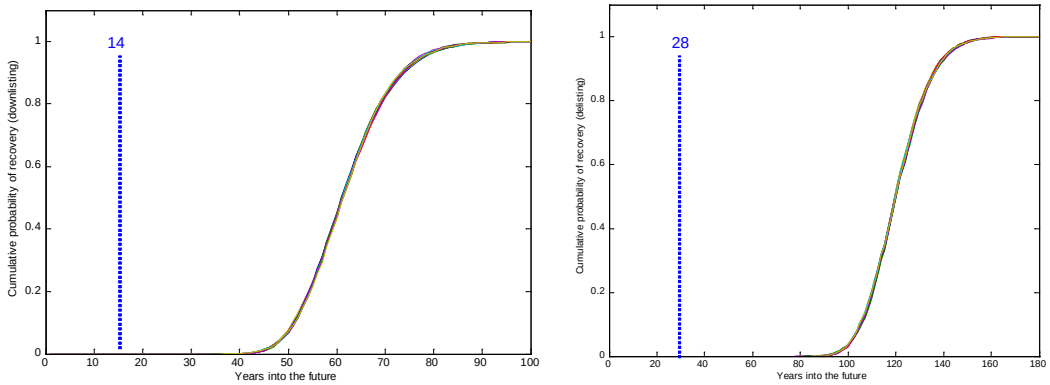
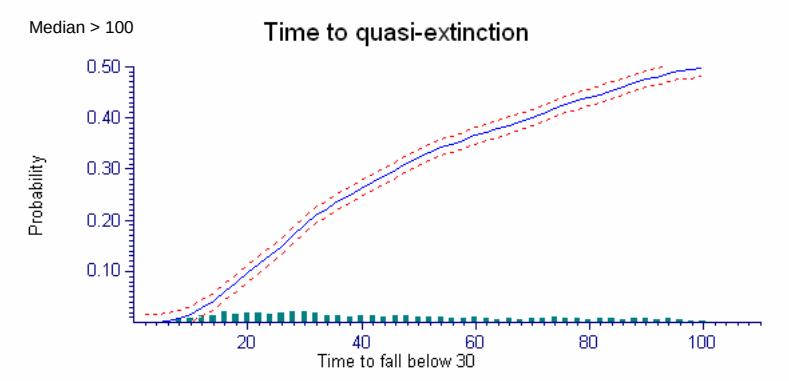


Figure 8. **Scenario 2(2a)**: Increasing Puget Sound ocean abundance as a result of 75% reductions in ocean harvest rates →maximizing survival of SRKW young and old reproductive females

Probability of SRKW population size < 30 in the future under environmental and demographic stochasticity (3000 realizations)



The Panel expressed their little confidence in predictions of population size more than 5 years in the future due to the increasing uncertainties with time. This makes sense only if the question is: what is going to be the SRKW population size *t* years in the future? But given the questions driving this process, longer time horizons are required to compare alternative fishing scenarios, focusing on the relative differences of projections rather than their absolute values. In addition, demographic projections of population growth (based on asymptotic dynamics) need to consider transient dynamics caused by deviations from the stable stage distribution. Transient dynamics of long-lived, slow-reproducing species are more sensitive to population state than short-lived, fast-reproducing species. Our analyses of transient dynamics showed that SRKW projections of population growth require a minimum time horizon of 23 years to significantly reduce the noise in projections caused by transient dynamics.

Section 2.4 (Part I)

I appreciate the inclusion in this section of revised SRKW abundance and growth rates under more realistic fishery scenarios. For this critical piece, the approach used for this ongoing investigation is expected to be extremely useful to further explore the sensitivity of resident killer whale population dynamics to Chinook abundance, and more specifically to particular stocks of stocks aggregates and their harvest rates.

A critical piece that seems to be missing in this section is the study of Northern Resident killer whale – Chinook salmon interactions. We have gained vital understanding of the

role of Chinook salmon abundance on both resident killer whale populations by conducting thorough analyses that uncovered numerous linkages between Chinook abundance and all NRKW vital rates. A subset of the most significant relationships is shown in Table 2. By contrast, these linkages were few in SRKW and occurred mainly with the survival of older reproductive females (Table 1). In addition, there was greater support for hypothesis 1b, which is based on the evidence regarding summer diet composition. Thus, there is a broader and stronger response of NRKW vital rates to Chinook salmon abundance but these levels of Chinook abundance are not limiting NRKW population growth since the population is still in growing mode. Uncovered interactions between SRKW vital rates and Chinook salmon abundance do not explain the stationarity in population growth – other mechanisms must be at play limiting SRKW population growth and overwhelming or masking predator-prey dynamics.

Table 2.

Summary of significant regressions (p < 0.10)				
Vital Rate	**Stock or stock aggregate**	**Lag(s)**	**Adj. R2**	**P-value**
Survival (Calf)	WCVI Terminal Run	0	0.275	0.005
Survival (Female1)	WCVI Terminal Run	0,1	0.233	0.0236
Survival (Male2)	WCVI Terminal Run	0	0.129	0.0474
Survival (Female2)	Georgia Strait Terminal Run	0	0.114	0.0589
Survival (Male1)	Georgia Strait Terminal Run	0,1	0.252	0.0182
Fecundity (Female2)	Georgia Strait Terminal Run	2	0.105	0.0675
Survival (Female1)	Northern BC Terminal Run	1	0.256	0.0068
Fecundity (Female2)	Northern BC Terminal Run	0,1	0.16	0.0617
Fecundity (Female2)	Central BC Terminal Run	1,2	0.142	0.077
Survival (Female2)	Fraser Early Ocean Abundance	0	0.091	0.0832
Survival (Female3)	Fraser Early Ocean Abundance	0,1	0.134	0.0853
Fecundity (Female2)	Fraser Early Ocean Abundance	2	0.148	0.0326
Survival (Juvenile)	UpRiver Brights Ocean Abundance	0	0.107	0.0655
Survival (Male1)	UpRiver Brights Ocean Abundance	0	0.096	0.0775
Survival (Male2)	UpRiver Brights Ocean Abundance	1	0.28	0.0046
Survival (Juvenile)	Puget Sound Ocean Abundance	1	0.296	0.0035
Survival (Male2)	Puget Sound Ocean Abundance	1	0.09	0.0839
Survival (Female2)	Fraser Early Terminal Run	1	0.086	0.0885
Fecundity (Female2)	Fraser Early Terminal Run	2	0.149	0.0351
Survival (Juvenile)	Puget Sound Terminal Run	1	0.19	0.019
Fecundity (Female2)	Puget Sound Terminal Run	1	0.097	0.0758
Fecundity (Female2)	FE+PS Terminal Run	2	0.183	0.0214
Survival (Calf)	FE+PS+WCVI+URB Terminal Run	0	0.119	0.0551
Survival (Female3)	FE+PS+WCVI+URB Terminal Run	0,1	0.132	0.0868
Fecundity (Female2)	FE+PS+WCVI+URB Terminal Run	1	0.18	0.0221
Survival (Calf)	Fraser Late Terminal Run	0	0.097	0.0755
Fecundity (Female2)	Fraser Late Terminal Run	1	0.13	0.047
Survival (Juvenile)	UpRiver Brights Terminal Run	0	0.124	0.0515
Survival (Male2)	UpRiver Brights Terminal Run	1	0.14	0.0403
Survival (Male2)	Coastwide Terminal Run	1	0.135	0.0433
Fecundity (Female2)	Coastwide Terminal Run	2	0.142	0.039
Survival (Calf)	Fraser Late Ocean Abundance	1	0.275	0.005
Survival (Female3)	Fraser Late Ocean Abundance	0,1	0.127	0.0923
Survival (Calf)	Oregon Coast Ocean Abundance	0	0.126	0.0498
Survival (Female1)	Oregon Coast Ocean Abundance	0,1	0.252	0.0183
Survival (Male1)	Oregon Coast Ocean Abundance	0	0.192	0.0186
Survival (Male2)	Oregon Coast Ocean Abundance	1	0.385	0.0007
Survival (Calf)	FL+URB+OC+PS Ocean Abundance	1	0.137	0.0419
Survival (Female1)	FL+URB+OC+PS Ocean Abundance	0,1	0.155	0.0652
Survival (Male2)	FL+URB+OC+PS Ocean Abundance	1	0.345	0.0015
Survival (Calf)	Coastwide Ocean Abundance	1	0.147	0.0366
Survival (Juvenile)	Coastwide Ocean Abundance	0	0.103	0.0696
Survival (Female1)	Coastwide Ocean Abundance	0	0.216	0.0128
Survival (Male2)	Coastwide Ocean Abundance	1	0.365	0.0011

Hypothesis 1b

NRKW – Chinook regression models

Hypothesis 2b

Section 3.1 (Part II)

I am surprised that in light of the detailed existing information on SRKW population size and dynamics, the Panel insists in conveying the message that SRKW population size is increasing, or like they mention in the last paragraph of this section is "not declining". I strongly feel the Panel should avoid sentences that give a false impression of positive population growth because this is not the case. If a similar statement were based on the population growth rate for the last generation, then an average population decline of 0.99% per year would suggest the population is declining. It is important to interpret the rates of population growth derived from particular periods within the context of observed population size relative to their maximum of 97 individuals in 1993 and 1996. Given the current population size of 87 (85-86 after recent mortalities) it is clear that the population is "not growing" either.

Section 3.3 (Part II)

Ward et al. found evidence for differences in fecundity between NRKW and SRKW. Similarly, I found significant differences in the fecundity of old reproductive females between these two populations. But the most important difference was found in calf survival (Figure 9). An important difference in the vital rate attributes of these two populations is that vital rates have larger temporal coefficients of variation in SRKW than NRKW (Figure 9). Greater variability in vital rates produces greater uncertainty in future population size, which translates into lower population viability and generally greater extinction risk.

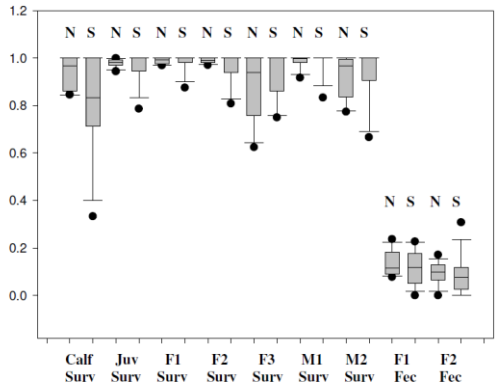
The Panel states that evidence for a positive population growth rate in SRKW suggests that population size should be increasing. And then they pose the question why the population remained small despite a positive growth rate? The answer is that the population has not increased on average during the last generation (25 years) and that the positive population growth derived from the time period used by Ward et al. is ultimately positive because it started right after the period of live captures for the aquarium trade which reduced substantially SRKW population size. Bigg (1982) and Olesiuk et al. (1990) estimated that 48 individuals were taken from the SRKW population between 1962 and 1977. The story supported by the SRKW abundance time series is that after the extraction of a big portion of the population, it responded by increasing from ~70 individuals in 1975 to 97 individuals in 1996, after which the population has been generally declining to its current population size of 87 (85-86 including most recent mortalities).

I concur with the Panel in that the primary cause for concern for SRKW population viability is its small population size and large vulnerability to demographic stochasticity as indicated in Figure 2. As indicated by the Panel, the possibility of growth rates less than 1 cannot be ruled out, and this clearly demonstrated by our analyses (Figures 1, 2 and 3). However, based on the recorded time series of SRKW's abundance, there is no evidence that the long-term recovery has ever exceeded the recovery goals. A recovery

population growth rate of 2.3% annually cannot be increased by maximizing individual vital rates (Figure 10), and the best chance of ever reaching such goal would be a simultaneous maximization of several vital rates, which is possible but this has not been observed during the studied time period.

Figure 9.

Vital rates



* Greater vital rate variability in SRKW than in NRKW

* Lower calf survival in SRKW than in NRKW (p = 0.03)

* Lower fecundity of older females in SRKW than in NRKW (p = 0.08)

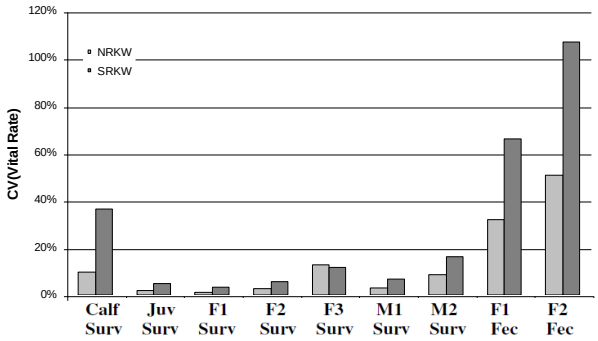
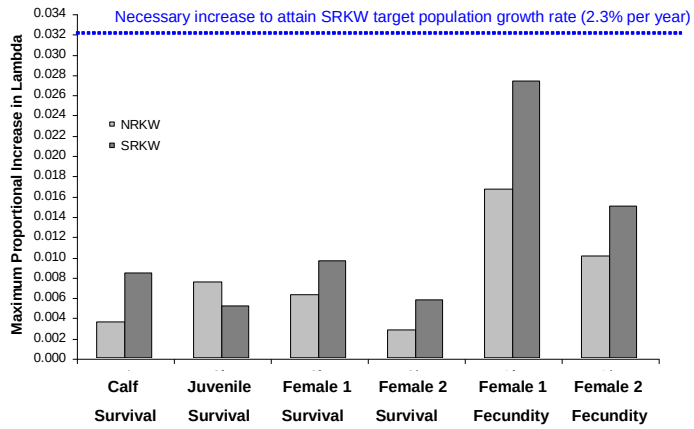


Figure 10.



Section 5.3 (Part II)

Regarding Chinook salmon abundance indices, CTC AABM fishery indices are not an appropriate metric for evaluation of the availability of Chinook to SRKW. However, their individual stock components are useful because they represent indices of cohort abundance vulnerable to fisheries under CTC base period exploitation rates. And therefore these can be seen as pre-season abundances. However, the run reconstructions are not necessarily projected pre-season abundances since they use both model and CWT data to reconstruct the time run sizes. Improvements to the methods so far used for the evaluation of killer whale- Chinook salmon interactions can include a hypothesis-oriented process like the one described in Box 1 and use both terminal run reconstructions and indices of ocean abundances (e.g., CTC's stock-specific components of fishery indices) consistent with these hypotheses and the known geographic ranges of both killer whales and Chinook stocks. Bernard's attempt to select biologically meaningful Chinook stocks for statistical analyses is basically what we portray in hypothesis 1a. In contrast, hypothesis 2a requires the assumption of Chinook salmon stocks being important in the SRKW's diet throughout the year and includes those Chinook stocks with large contributions to ocean fisheries, large terminal run sizes, and ocean distributions overlapping with the known geographic range of SRKW. The scheme presented in Box 1 can be modified on the basis of alternative rationales.

The main limitation of the methods used to explore fishery scenarios by Ward et al. is the absence of a common currency between ocean abundance and terminal run. Fishing scenarios can be explored by converting changes in ocean catch to terminal run equivalents (*TRE*), which can be estimated by fishery and age as the product of catch and maturation rates (*MR*):

$$TRE_{s,y} = \sum_{\text{PreTerm Fishery}} \sum_{a=3}^{6} Catch_{s,y} * MR_{s,y}$$

This information can be compiled for CTC exploitation rate indicator stocks and is been used by our ongoing investigation to explore a variety of fishing scenarios for both SRKW and NRKW.

Section 5.4 (Part II)

I concur with the Panel's recommendation to include Chum salmon in future analyses, and we are already compiling the data to do so. It may be challenging to have preliminary results with Chum salmon as an additional covariate for Workshop 3 but these analyses are detailed in the PSC project proposal and their results will be recorded in a completion report for the PSC by February 2013.

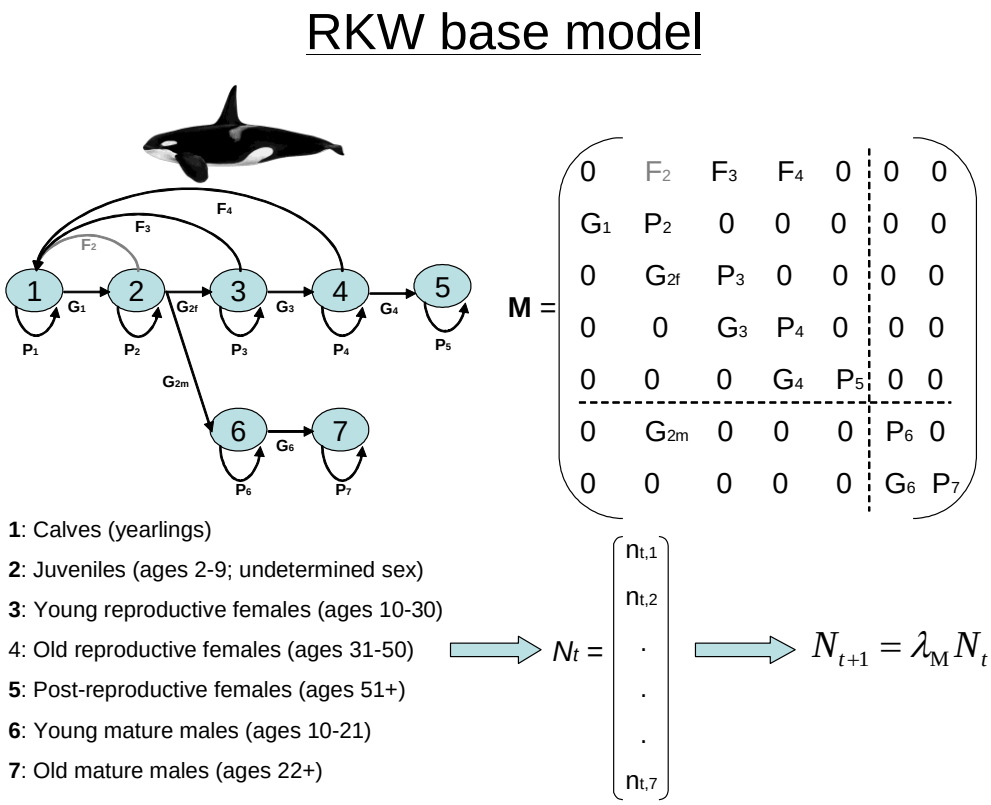
Section 6.1 (Part II)

The first sentence of this section is misleading. The Panel asserts there is strong evidence that SRKW population growth has been clearly positive over the past several decades and that recent growth rates are near or at recovery goals for some SRKW pods. There is not strong evidence the population growth rate is positive, particularly if one considers the last 25 years or most recent generation time, as discussed before, and it is incorrect to talk about recovery goals at the pod level since they are not discrete, independent demographic units nor recovery goals in the recovery plan seem to be specified at the pod level. Interpreting recovery goals at the pod level lacks demographic basis and goes against main stream conservation biology. I think with this sentence the Panel is really overestimating SRKW's population viability.

Section 6.2 (Part II)

The methods employed to evaluate the relationships between Chinook abundance and killer whale vital rates seem reasonable. We gained substantial resolution in these linkages by using a stage-structured approach, cancelling the influence of age on these relationships, and facilitating the use of simple and multiple linear regression models that need not to be logistic in nature. The base stage-structured model used in our ongoing investigation (Figure 11) seems to capture the main dynamics of the system while limiting the number of relevant life stages and allowing explorations of linkages that are unambiguous and easily interpreted.

Figure 11.



I strongly concur with the Panel in that a more critical evaluation of models than what is provided by AIC is required. Biologically significant linkages between killer whale vital rates and indices of Chinook abundance cannot be based on statistical inference alone. They need to be based on their biological relevance to support causation and on the influence of these linkages on observed population growth (retrospective analysis; Figure 4) and their influence on potential population growth (prospective analysis: Figure 5). The significant linkages are not only those that significantly explain a given portion of the variability in a vital rate but also those that have exerted or can exert the greatest changes in population growth rates.

Section 6.3 (Part II)

Regarding our modelling approach, on the one hand, limiting future variation in vital rates and Chinook abundance by the variation observed in the past, as implement under an IID environment, can certainly overestimate population viability while successfully maintaining the covariation between vital rates. On the other hand, allowing for random variation in vital rates and Chinook abundance as determined by their probability distributions has the risk of generating virtual populations that are biologically unrealistic and population viability can be over or underestimated. The inclusion of a covariation

matrix constraining the random process is therefore important and this seems to be missing in the analyses by Ward et al. Moreover, the inclusion of demographic stochasticity in PVAs of small populations is essential even if it gives more pessimistic scenarios of population viability. I am not certain demographic stochasticity was included in the PVAs. Chiefly, PVAs of SRKW would be robust by including environmental and demographic stochasticity and by maintaining the covariation structure of vital rates. In addition, some of the limitations to estimate process error and to interpret regression coefficients in the logistic regressions used by Ward et al. were not an issue in our stage-structured approach (as opposed to an individual-based approach) to linkages between killer whale vital rates and Chinook abundance, which allowed for the implementation of simple and multiple linear regressions.

There is a genuine concern expressed by the Panel about the underestimation of uncertainty in PVAs associated to other factors influencing SRKW population dynamics. It is important to remember that the aim of PVA is not to provide perfect forecasts but to allow comparisons of scenarios under a number of assumptions such like "the relative weight of Chinook salmon abundance and other factors have on vital rates will remain the same" or "the observed range of variation and covariation in vital rates will remain the same". Also consider that as model complexity increases by including other processes, the increased difficulty of obtaining precise parameter estimates will quickly come to outweigh any perceived advantage of enhanced biological realism. Within the context of the main questions driving this process and the workshops, we should think in terms of the relative differences in population projections under different scenarios of interest rather than expecting perfect forecasts of population size and viability.

Section 6.4 (Part II)

Completely agree with the Panel that the recovery target of 2.3% annual growth rate should be re-assessed. During the 1987-2011 period, the NRKW population exhibited a population growth of 1.0165 (1.65% annual increase), and it seems logical that a population growth-based recovery target for SRKW should be lower and definitely never exceed this rate.

Analysis of the relationship between Chinook salmon abundance and SRKW population viability are inappropriate at the pod level. The retrospective analysis conducted by Brault and Caswell (1993) decomposed the variance in observed population growth to the level of pod contributions to test the effect of social structure on pod-specific dynamics. However, pods are not independent, discrete demographic units upon which lambda can be interpreted within the context of population viability. Similarly, it does not make much sense to talk about recovery goals at the pod level. This would not be in line with basic tenets of conservation biology.

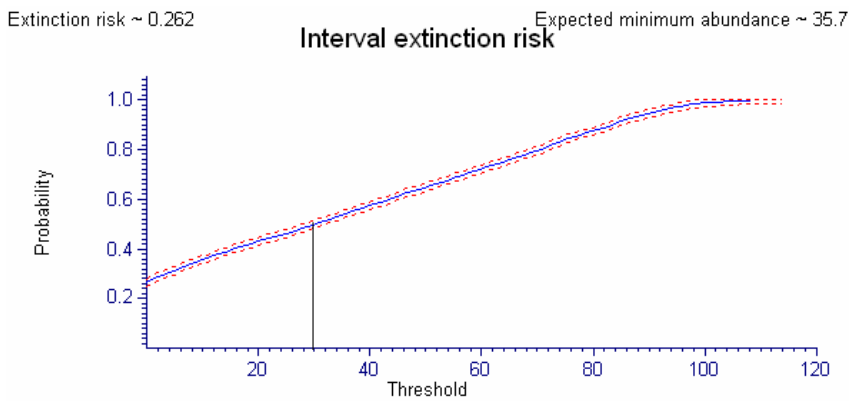
The results of our analyses support the Panel perception about a detectable effect of Chinook abundance on SRKW extinction being quite unlikely. And the same was evident in our analyses for recovery probabilities. As shown earlier, the most extreme scenario

uncovered so far in our ongoing investigation is that of the maximization of survival rates of young and old reproductive females resulting from 75% reductions in ocean harvest rates for Puget Sound Chinook stocks. This extreme scenario produces a stochastic population growth of 1.0053 (0.53% annual increase; 95% CI: 0.52%-0.54%), far from the recovery target and with probabilities of falling below 30 individuals increasing with time (Figure 8), a 0.262 probability of extinction within the next 100 years, and a 49.7 % risk of falling below 30 individuals at least once during the next 100 years (Figure 12).

Figure 12.

Scenario 2(2a): Increasing Puget Sound ocean abundance as a result of 75% reductions in ocean harvest rates →maximizing survival of SRKW young and old reproductive females

Probability of SRKW population size < 30 in the future under environmental and demographic stochasticity (3000 replications)



"There is a 49.7% risk that SRKW abundance will fall below 30 at least once during the next 100 years"