WORKSHOP TO ASSESS CAUSES OF DECREASED SURVIVAL AND REPRODUCTION IN SOUTHERN RESIDENT KILLER WHALES: PRIORITIES REPORT

DECEMBER 2015

Table of Contents

BACKGROUND AND 5-YEAR PLAN OBJECTIVES

The objectives of a 2-day Southern Resident Killer Whale (SRKW) Health Workshop conducted during April 2015 were to discuss needs and potential strategies related to the following two questions:

- What is causing decreased SRKW reproduction?
- What is causing increased SRKW mortality?

Following a half-day of background presentations, workshop attendees engaged in discussion regarding study needs, data gaps, and approaches that may best determine what is causing decreased SRKW reproduction and increased mortality. Following the workshop, a list of potential action items generated during the workshop were then reviewed and prioritized by a smaller group of NOAA federal employees. Each voter was asked to categorize each action item's priority by when it should be initiated (within 18 months, within 3 years, within 5 years, greater than 5 years or not at all). These categories were scored as 3, 2, 1, and 0, respectively. Voters' scores were added and averaged. Thus, the highest possible priority score was 3.0. The final averaged scores were prioritized as follows: 3.0 = top priority to initiate within 18 months, 2.6-2.9 = initiate within 2 years, 2.0-2.5 = initiate within 3 years, 1.1-1.9 = initiate within 5 years.

This Priorities Report provides a prioritized list of recommended action items to better understand what is causing decreased SRKW reproduction and increased mortality. It also provides prioritized opportunities to establish important baseline information on SRKW and reference populations to better assess negative impacts of future health risks, as well as positive impacts of mitigation strategies on SRKW health. This is a dynamic document that may change as priorities change with more information and time. We plan to develop an implementation plan with information about principal investigators and collaborators, timelines, and costs. Smaller groups will likely focus on implementing specific priorities and projects. As we track implementation, we may convene a larger group to discuss updates on progress.

FINDINGS AND ASSUMPTIONS

- SRKWs have lower survival compared to reference populations.
- Expected reproduction of SRKWs should be similar to that of a thriving reference population not negatively impacted by anthropogenic factors.
- The pattern of SRKW survival compared with reference populations is indicative of environmental forces (e.g., physical, biological, and chemical), especially contributions of prey changes. If measuring food supply has limitations, efforts should focus on the condition of the whales (i.e., photogrammetry or nutritional markers with biopsy). Additionally, it is noted that constrained body condition can be driven by decreased prey, decreased dietary quality, increased activity, and underlying illness. As such, all of these potential contributors may be important to address.

- Standardized sample collection protocols, paired with appropriate laboratory quality assurance and quality control, are critical to assess killer whale health and reproduction.
- Live capture health assessments conducted with other species (i.e., bottlenose dolphins) are not feasible for killer whales.
- While the action items in this document have been prioritized based upon their scientific and technical value, initiating these action items is dependent upon the availability of proper funding and resources.

TOP PRIORITIES

The action items under the three subsections below (Build Out an Effective Toolbox, Track Animals of Interest & Continue Studies Related to Prey and Body Condition, and Use Case Reference Studies to Identify Risks to Reproduction and Survival) received the highest possible priority score. These top 12 action items are not listed in any order of priority. Pending funding and resources, the scientific team recommended initiating these top priorities within 18 months. Below each priority are the related Recovery Plan actions (e.g., recovery measure, or research and monitoring), followed by the status of the priority action. The number of the action corresponds to the Task Number in the Implementation Table of the Recovery Plan. The recovery measure priorities 1, 2, and 3 are assigned as 1) actions that must be taken to prevent extinction or to prevent the species from declining irreversibly; 2) actions that must be taken to prevent a significant decline in the population or its habitat quality, or in some other significant negative impact short of extinction; or 3) all other actions necessary to provide for full recovery of the species. The research and monitoring priorities 1, 2, and 3 are assigned as 1) actions that must be taken to identify those actions necessary to prevent extinction; 2) actions that must be taken to prevent a significant decline in the population or its habitat quality, or in some other significant negative impact short of extinction; or 3) all other necessary research actions for full recovery.

Build Out an Effective Toolbox

- **Develop and Maintain Centralized Database**. Adapt the developing SRKW database to match with the Marine Mammal Health Monitoring Analysis Platform (MMHMAP) relational database to incorporate multiple data sources, collaborators, and sample types. Associated activities may include selecting a subset (i.e., reproductive females) and pulling together all sample results from that subset, coordinating data sharing and entry efforts quickly after a field effort (e.g., photogrammetry and fecal/blubber progesterone concentrations), and developing a list of potential collaborators to maximize sample and resource use.
    - **Recovery Measure - Task 5.** Trans-boundary and interagency coordination and cooperation. 5.1 Cooperative research and monitoring. (Priority 3)
    - **Research and Monitoring - Task B.11**. Research support and coordination. (Priority 2)
    - **Status/Comments:** Initiated by Northwest Fisheries Science Center (NWFSC) in coordination with ongoing Health Map database development.

- **Standardized Sampling Protocols for Live Animals**. Define and prioritize type of data and samples that could be collected from reference populations (e.g., Northern Resident killer whale (NRKW), Southeast Alaska (SEAK) residents to coordinate with SRKW work.
    - **Recovery Measure - Task 5.** Trans-boundary and interagency coordination and cooperation. 5.1 Cooperative research and monitoring. (Priority 3)
    - **Research and Monitoring - Task B.11.** Research support and coordination. (Priority 2)
    - **Status/Comments:** Preliminary discussions regarding paired photogrammetry and biopsy sampling for NRKW underway with Southwest Fisheries Science Center (SWFSC), Department of Fisheries and Oceans (DFO) and Vancouver Aquarium, will be more fully developed in the implementation plan
- **Standardized Health Assessment Protocol and Health Index**. Determine and prioritize indices and tools to use for a standardized health assessment in killer whales (based upon behavioral, physical, and health parameters), which will result in a health index for individual animals that may be used prospectively and retrospectively with SRKW and reference populations. The protocol and index could include existing data such as photos of skin, photogrammetry measurements, and behavioral observations, and would be used to guide future standardized data collection of health parameters and potentially intervention for compromised animals. Associated activities may include increased work with managed care populations to validate protocols and indices. The health index will be used to guide research and intervention for individuals and on a population level to assess population fitness and to establish baselines.
    - **Research and Monitoring - Task B.4.** Investigate the health and physiology of the Southern Residents. B.4.1 Assess the health of population members. (Priority 2)
    - **Research and Monitoring - Task B.10.** Improve research techniques and technology. (Priority 3)
    - **Status/Comments**: NOAA is partnering with UC Davis to develop a workshop in 2016, see POTENTIAL INDICES TO INCLUDE IN HEALTH ASSESSMENT PROTOCOLS for a preliminary list of considerations to be developed at this workshop

- **Telemetry**. Continue use of telemetry to better assess SRKW population's exposure to risks, including prey availability in different geographic locations and over time (i.e., between years and seasonally). Expanded use and associated activities may include use of telemetry of compromised animals after careful consideration to 1) enable more rapid response if stranded and to assess survivorship of a compromised animal, and 2) increase ability to sample throughout the year. Reference populations should be incorporated when possible, and effects of tagging should continue to be monitored.
    - **Research and Monitoring - Task B.1.3.** Determine the effects of prey abundance and availability, and other factors on whale distribution and movements. (Priority 1)
    - **Research and Monitoring - B.2.2.** Determine the importance of specific prey populations to the diet. (Priority 1)
    - **Research and Monitoring Task - B.6.1.3.** Determine whether the Southern Residents are limited by critical periods of scarce food resources. (Priority 1)

- **Research and Monitoring - Task B.7:** Identify important habitats for the Southern Residents. (Priority 1)
- **Status/Comments:** In progress/ongoing telemetry initiated by NWFSC, note limitations (e.g., funding, permitting) in considering expanded use. Telemetry of compromised animals will be further discussed as part of the health assessment protocol and health index development.

- **Photogrammetry.** Continue using photogrammetry as a valid and non-invasive means to detect and track animals that 1) are pregnant or 2) have poor body condition. The utility of photogrammetry could be extended by combining results with references such as blubber hormones, observations by season, and managed populations and expand use by developing new techniques.
  - **Research and Monitoring - B.3.3.** Evaluate reproductive patterns. (Priority 2)
  - **Research and Monitoring - B.4.1.** Assess the health of population members (Priority 2)
  - **Research and Monitoring - B.10.** Improve research techniques and technology. (Priority 3)
  - **Research and Monitoring - B.11.** Research support and coordination. (Priority 2)
  - **Status /Comments:** Photogrammetry studies on SRKW and NRKW in progress/ongoing by SWFSC and Vancouver Aquarium. Collaborative efforts underway to compare photogrammetry measures with blubber lipids (SWFSC-NWFSC) and to compare photogrammetry measures with contaminants and genomics (SWFSC- Vancouver Aquarium). Photogrammetry planned for Alaska Resident killer whales (SWFSC and North Gulf Oceanic Society) to provide a further reference population.

- **Stranding Investigations.** Continue to improve detection, rapid reporting and response to strandings for both reference and SRKW populations
  - **Recovery Measure - Task 4**: Respond to killer whales that are stranded, sick, injured, isolated, pose a threat to the public, or exhibit nuisance behaviors. 4.1 Manage atypical individual Southern Residents. (Priority 3). 4.2 Respond to strandings of killer whales. 4.2.1 Develop protocols for responding to stranded killer whales. (Priority 3), 4.2.3. Investigate strandings of dead killer whales. 4.3 Respond to future resource conflicts between the Southern Residents and humans. (Priority 3)
  - **Status/Comments**: In progress/ongoing. The protocol for responding to stranded killer whales has been developed and will be updated periodically. A comprehensive summary report of West Coast stranding investigations is in development by J. Gaydos, S. Raverty and J. St. Leger. A live/sick stranded animal protocol will need to be developed.

Track Animals of Interest & Continue Studies Related to Prey and Body Condition

- **Identify and Track Animals of Interest.** Create and communicate a list of "Animals of Interest" to monitor routinely (e.g., every 3 months). This includes Reproductive Groups (A = females detected [e.g., by photogrammetry] as currently pregnant, B = females with consistent calves, females late to first visible calf, and females no longer with visible calves) and Health Groups (A = animals with and without poor body condition [e.g., by photogrammetry] and/or poor health index). Develop a more detailed sampling, communication, and outreach plan for a live animal with health concern ("higher risk" animal) for potential intervention and/or tracking to recover a fresh carcass.
    - **Recovery Measure - Task 4.** Respond to killer whales that are stranded, sick, injured, isolated, pose a threat to the public, or exhibit nuisance behaviors. 4.1 Manage atypical individual Southern Residents. (Priority 3)
    - **Recovery Measure - Task 5.** Trans-boundary and interagency coordination and cooperation. 5.1 Cooperative research and monitoring. (Priority 3)
    - **Research and Monitoring - Task B.11.** Research support and coordination. (Priority 2)
    - **Status/Comments:** Preliminary discussions between NWFSC, SWFSC, DFO, and Vancouver Aquarium regarding protocols and sharing information as animals of interest are identified. Identify additional partners (Center for Whale Research).

- **Assess Causes and Magnitude of Prey Changes.** Assess the potential role of increasing numbers of predators consuming prey sources. Quantify actual prey availability to the SRKW population.
    - **Research and Monitoring - B.6.1** Assess the effects of changes in prey populations. (Priority 1)
    - **Research and Monitoring - B.6.1.4** Assess threats to prey populations of the Southern Residents. (Priority 2)
    - **Status/Comments:** Initiated by NWFSC with Pacific Salmon Commission funding.

- **Assess Role of Body Condition and Blubber Content on Reproduction and Survival.** Improve knowledge of typical body condition changes (continued aerial observations and evaluate lateral observations) expected for certain life stages (e.g., growing animal, lactating animal). Use managed care populations and comparative wild populations as reference, but understand limitations of comparisons (seasonality, food availability, temp, etc.). Assess the value of percent lipid as a measurement of body condition, survival, and reproductive success.
    - **Research and Monitoring - B.3.1** Determine causes of mortality. (Priority 1)
    - **Research and Monitoring - B.10** Improve research techniques and technology. (Priority 3)
    - **Status/Comments:** To be developed from the implementation plan

Use Case-Reference Studies to Identify Risks to Reproduction and Survival

- **Conduct Case-Reference Studies.** Using the standardized health assessment indices, compare characteristics and diagnostics of females in Reproductive Group B (females with consistent calves, females late to first visible calf, and females no longer with visible calves), including the following: birth order, photogrammetry, and blubber indices (contaminants, hormones, % lipid, and fatty acids).
    - **Research and Monitoring - B.3.3** Evaluate reproductive patterns (Priority 2)
    - **Research and Monitoring - B.4.1** Assess the health of population members (Priority 2)
    - **Research and Monitoring - B.6.3.4** Determine the effects of elevated contaminant levels on survival, physiology, and reproduction in the Southern Residents. (Priority 1)
    - **Status/Comments:** With the exception of hormones, data are available and need to be mined. Analysis will be developed as part of the implementation plan.

- **Conduct Case-Reference Studies from Stranded Animals.** Compare health indices in stranded SRKW and reference populations (including other local marine mammal species) using archived tissues and reports, including use of methylated DNA for aging, understanding that these populations may have baseline differences from SRKW.
    - **Recovery Measure - 4.2.3** Investigate strandings of dead killer whales (Priority 3)
    - **Research and Monitoring - B.3.1** Determine causes of mortality. (Priority 1)
    - **Research and Monitoring - B.3.2** Evaluate survival patterns. (Priority 2)
    - **Status/Comments:** With the exception of methylated DNA for aging, data are available and need to be mined. Analysis will be developed as part of the implementation plan.

- **Assess Survival and Stranding Demographics.** Compare survival by age class and sex across SRKW and reference populations, including seasonality of mortality and strandings.
    - **Research and Monitoring - B.3.1** Determine causes of mortality. (Priority 1)
    - **Research and Monitoring - B.3.2** Evaluate survival patterns. (Priority 2)
    - **Status/Comments:** In progress as part of the summary report of West Coast strandings in development by Gaydos, Raverty and St. Leger.

ADDITIONAL PRIORITIZED NEEDS

Here we provide a comprehensive list of additional actions that were prioritized to initiate within 2 years (priority scores 2.6-2.9), 3 years (priority scores 2.0-2.5), and within 5 years (priority scores 1.1-1.9). Some of these actions are currently underway or are linked to the top priority actions. We may revisit these additional prioritized needs as we track implementation and receive updates on progress.

Topic	Suggested Time to Initiate if Funding & Resources Available	Need / Action Item	Priority Score	Recovery Action Task No.
Survival	Next 2 years	Continue to assess relationships between health indices and survival over time with prey availability and quality. May include seasonal and intra-annual monitoring, assessing effects of repeated cycles of poor prey availability, and investigating the role of prey quality (e.g., fatty acids) as a driver of SRKW mortality. Need to consider lag time with prey availability and loss of body condition. If food limitation is a main driver of survival, integrate other factors in times of food limitation; investigate trends in food limitation and survival.	2.9	B.3 B.6.1
Survival	Next 2 years	Explore evidence of nutritional stress and stages of starvation in SRKW, including continued photogrammetry coupled with the potential use of breath analysis, hormone analysis, and stable isotopes, including defining which markers have proven useful in other cetaceans. Potential reference populations include *Tursiops* populations.	2.9	B.4
Survival	Next 2 years	Evaluate immune parameters between SRKW and reference populations. May include skin genomics sampling, susceptibility testing for infectious diseases and certain concentrations of contaminants of concern, molecular signature and gene expression (skin/blow), and herpesvirus shedding as a comparison between populations as a potential indicator of stressors on a population.	2.9	B.4 B.11
Reproduction & Survival	Next 2 years	Assess if photogrammetric measures of body condition and other health indices are predictors across populations of A) successful calves, B) survival.	2.8	B.3 B.11
Reproduction	Next 2 years	Assess the use of expanded hormone analyses in blubber, feces, and breath to detect pregnancies and track calving success using a standardized laboratory and validated assays with QA/QC. Note: NIST is developing broader analysis for more hormone metabolites that may be able to determine trimester of pregnancy.	2.8	B.3.3 B.10
Reproduction	Next 2 years	Using the increased ability to improve detection of pregnancies (photogrammetry, hormones), assess the impact of first pregnancy *versus* multiple pregnancies, as well as calving intervals, on pregnancy and perinatal success rates. May include measuring PCB congener ratios to determine how long since a dam has given	2.8	B.3.3 B.6.3.1 B.6.3.4

		birth, use of contaminant levels to determine if pregnancy was first calf, looking at birth order (vs. determining first calf), and comparing target contaminants between case and reference populations if first calf losses are higher than subsequent pregnancies.		
Survival	Next 2 years	Assess how to study the impact of environmental contaminants on KW immune function, understanding a lack of blood samples. Note: Peter Ross, Ailsa Hall, and others working on genomics to assess impact of POPs, Peter Ross directly on killer whales.	2.8	B.6.3.4
Reproduction & Survival	Next 2 years	Study potential relationship between blubber indices related to nutritional status (e.g., percent lipid, lipid type, and fatty acids) on reproductive outcome and survival. There are current collaborations between blubber fatty acid analysis and photogrammetry (SWFSC, NWFSC).	2.7	B.3.2 B.3.3
Reproduction	Next 2 years	Use reference populations (including *Tursiops* in wild and managed populations) to investigate if calves with higher contaminant loads have altered future reproduction (e.g., developmental changes). May include investigating offloading to first-born calves and effect on the calves; consider running metabolomics, genomics, hormones on paired milk, blubber samples (NIST).	2.7	B.6.3.4 B.11
Reproduction	Next 2 years	Explore increased risk of contaminant release in pregnant and lactating dams with poor body condition and during growth (e.g., reference managed populations, archived blood samples).	2.7	B.6.3.4 B.11
Reproduction	Next 2 years	Monitor reproductive hormone levels in blubber, feces, and/or breath samples with increasing frequency to detect potential pregnant/non-pregnant animals, including looking for calves over time to verify successful pregnancy (include QA/QC of various tests and samples, and how they are associated); validate with photogrammetry.	2.6	B.3.3 B.10
Reproduction	Next 2 years	Explore mechanisms and metrics in other animal models of how food restriction would lead to inability to get pregnant or lead to early, mid-, or late-term losses.	2.6	B.3.3
Reproduction	Next 2 years	Investigate if higher contaminant concentrations (primarily limited to those that are in feces and persist in blubber) are associated with lower reproductive success of females by comparing levels to a reference population (e.g., NRKW, Alaska residents, and transients). May include conducting studies in conjunction with biopsy and photogrammetry on females as they progress through various reproductive stages, catching fetal/calf loss by drop/change in 'contaminant' concentration, sampling females prior to first calf and comparing to post-reproductive profiles, and validating whether fecal contaminants are reflective of total body burden (taking seasonality into account).	2.6	B.6.3.1 B.6.3.4 B.11
Survival	Next 2 years	Use health assessments and necropsy data to assess potential causes of poor body condition other than prey.	2.6	4.2.3 B.4
Survival	Next 2 years	Explore potential for HPA axis dysfunction as contributor to decreased survival (e.g., adrenal pathology, measure fecal and blubber glucocorticoids), especially with regard to petroleum product / PAH exposure.	2.6	B.3.2 B.6.3.4

Survival	Next 2 years	Explore the use of necropsy findings to better characterize levels of poor body condition and emaciation (e.g., epicardial fat, zymogen depletion). Note: limitation due to moderate to advanced decomposition. Combine necropsy forms and body condition to compare between reference populations and other cetacean species.	2.6	B.4
Survival	Next 3 years	Explore and model resiliency of SRKW during times of increased risk (e.g., lower prey availability) compared to reference populations.	2.4	B.3
Survival	Next 3 years	Use lipophilic hormones in blubber as an indicator of stress/nutritional state/adrenal function for the overall SRKW population compared to reference populations. While this study likely needs to be prospective, retrospective samples can help develop demographic and seasonal profiles. May include focusing on adult males to limit variability, assessing the impact of human interactions (HI) and pairing with HI indices controlling for other potential factors (e.g., nutritional, seasonality), better understanding how cortisol varies throughout life stages, environmental factors, etc., pairing blubber and feces levels when able, comparing population level differences in feces (but limited unless differences between populations are very large), investigating the adrenal gland cortex, assessing how blubber cortisol is a delayed response compared with blood (reference Tursiops blubber hormone studies), investigating blubber cortisol concentrations between populations (relative to body condition or disease state), incorporating air quality information when assessing cortisol as a marker of petroleum exposure, and understanding that an inability to mount a cortisol response from contaminant exposure can reduce survivorship and increase reproductive failure.	2.4	B.4 B.10
Reproduction	Next 3 years	Use photogrammetry with increasing frequency (e.g., seasonally) in SRKW and reference populations to detect pregnancies (noted as a priority), associated dam ages at pregnancy (including when first calf if produced), track animals around expected parturition dates, and reduce the gap in visualizing the animals between birth and first sighting.	2.3	B.3.3 B.11
Reproduction	Next 3 years	Continue paternity testing to determine sire contributions to population.	2.3	B.9.1
Survival	Next 3 years	Investigate observations of animals with poor body condition (e.g., peanut heads) and timing of disappearance.	2.3	B.3.2 B.4.1
Survival	Next 3 years	Improve and increase detection, rapid reporting, response to, and critical data/sample collection for strandings for both reference and SRKW populations. Include increased access to RNA later for necropsy sampling (in necropsy protocol), and protocols for proper handling and storage.	2.3	4.2 B.11
Reproduction	Next 3 years	Investigate how social constraints on a small population may be impacting reproductive success (much of this has been studied and published by Ward without clear	2.2	B.3.3 B.5

		evidence of social drivers). May include investigating the role being a first-born female calf plays for later reproductive success, how fractionation/cohesion of social groups and its influence on reproductive success (may be difficult to assess), potential impact of historically harvested animals on current social structure (primarily from K & L pod), and the role senescent females and males have in perinate survival (behavior and social structure).		
Reproduction & Survival	Next 3 years	Compare dietary quality of prey and nutrients in animals consumed by SRKW and references (e.g., NRKW) and assess changes in quality and size of prey over time; match with poor body condition and temporal scale, and test prey available at that time	2.2	B.6.1.2
Survival	Next 3 years	Determine the prevalence and compare evidence of human interactions (HI) between SRKW and reference populations by using live observations and gross pathology, include sub-lethal effects. HI may include entanglements, ship strikes, hook ingestion, and marine debris. Stranding information has been collected, and analyses are in progress. For live animals, photos could be reviewed retrospectively, but may be biased toward injured animals. Consider including HI observations in health assessment.	2.2	B.6.4
Reproduction	Next 3 years	Use reference populations (e.g., managed populations/SeaWorld) to determine reference fetal measurements (e.g., body lengths, bi-parietal and thoracic diameters), hormones, etc. at various stage of pregnancy to plot on gestation curve. This may aid in differentiating between a late term loss or smaller than expected calf. Will need to assess limitations of different reference populations, including a morphologic study comparing different stocks. Include with other indices, such as hormone levels.	2.1	B.4.2
Reproduction	Next 3 years	Explore mechanisms and metrics of how contaminants, including endocrine disrupters and AMAPP effort, may lead to inability to get pregnant or early term losses, including transgenerational effects.	2.1	B.6.3.4
Survival	Next 3 years	Explore how contaminant release from mobilized fat (leading to increased tissue exposure) in a negative energy balance may affect animal health.	2.1	B.6.3.4
Survival	Next 3 years	Investigate the frequency of near-parturition associated effects (including morbidity and mortality) in adults by mining archived data of SRKW and reference populations.	2.1	B.3.2 B.3.3
Survival	Next 3 years	Implement semi-annual conference calls between collaborators, including trans-boundary partners, doing active field work (with one face-to-face discussion annually). Consider these meetings as a requirement.	2.1	B.11
Reproduction	Next 3 years	Investigate if endocrine abnormalities affecting thyroid, adrenal and reproductive systems are adversely affecting reproductive success.	2.0	B.3.3 B.4
Reproduction	Next 3 years	Analyze existing samples, including blubber, feces, and blow in SRKW and reference populations, for concentrations of thyroid hormones, glucocorticoids, and	2.0	B.4 B.10

		aldosterone. May include validating endocrine measurements in these samples using managed populations, comparing hormone concentrations between females that are successful and not using archived specimens, QA/QC and SOP's for hormone assays, evaluating thyroid disorders beyond current capacity with existing assays (including assessing need for further assay development), evaluating archived adrenal/thyroid tissue (+pituitary) morphologically to characterize these tissues, and assessing variability of sample results and in sample collection/handling. Noted that MMHSRP permit includes biopsy of captive animals for health studies.		
Reproduction & Survival	Next 3 years	Explore if harmful algal blooms (HABs) negatively impact reproductive success or survival. May include using telemetry to assess opportunities for exposure in areas with HABs, using sympatric odontocetes for surrogates of exposure, and leveraging close collaborations with HAB groups within the range.	2.0	B.1.1 B.1.2 B.8
Survival	Next 3 years	Investigate the potential impact of poor nutrition on health and survival (co-morbidity). This may include investigating increased incidence of infectious or parasitic disease during periods of environmental stress; comparing the incidence of trauma and human interaction, incorporating behavioral information, entanglement and human interaction as an indicator of poor health; improving the ability for stranding response to increase sample size for post-mortem investigations; monitoring a targeted population to determine what role malnutrition is playing in morbidity and mortality; enhancing investigations into the differences in pathologic findings of animals between good/poor prey years (normal health parameters as well as morphologic diagnoses); and correlating life history, pathologic findings, environmental factors of dead animals.	2.0	B.3.2 B.4
Reproduction	Next 5 years	Use photogrammetry with increasing frequency to better detect pregnancy and track animals around expected parturition dates (with validated measurements specific to trimester or month of gestation).	1.9	B.3.3
Reproduction & Survival	Next 5 years	Explore if anthropogenic noise and interactions negatively affects reproductive success, calf survival, and general survival, including accessing ongoing or expected studies.	1.9	B.6.2
Survival	Next 5 years	Determine how much breath sample is needed to do hormone and other analyses. Work with reference populations (e.g., managed populations/SeaWorld) to test collection devices and number of exhalations. SWFSC already collecting breath samples from whales (i.e., humpback whales) using UAS.	1.9	B.10
Reproduction	Next 5 years	Explore potential for HPA axis dysfunction as contributor to reproductive failure (e.g., adrenal pathology, measure fecal and blubber glucocorticoids), especially with regard to petroleum product / PAH exposure.	1.8	B.3.3 B.6.3.4
Survival	Next 5 years	Investigate if male survival is lower due to higher contaminant burdens, including use of reference	1.8	B.3.2 B.6.3.4

		populations.		
Reproduction	Next 5 years	Explore ability to determine calf success rate in past females by using ovaries from necropsy to identify number of past pregnancies and look at number of identified calves. Conduct a cross-population study of ovaries (animals appear able to conceive, carry to near-term and then succumb. Many appear to be live births.)	1.7	B.3.3
Reproduction	Next 5 years	Explore literature for associations between testosterone/fertility and contaminants across populations in other animal models.	1.7	B.6.3
Reproduction & Survival	Next 5 years	Explore potential role of infectious and parasitic diseases involved in SRKW abortions and decreased survival (e.g., *Brucella*, *Salmonella*, protozoal) by added testing of live animal samples.	1.7	B.3 B.6.5
Survival	Next 5 years	Measure and compare biotoxin exposure (not limited to domoic acid) in SRKW with reference populations. May include use of fecal data retrospectively during times of and geographic overlap with blooms (understand limitations in time and location since exposure can be prey dependent), testing in fish, and assessing the potential to use antibodies and other biomarkers to assess past exposures to biotoxins.	1.7	B.8
Survival	Next 5 years	Assess the variability of immune genome parameters (e.g., MHC) in SRKW population compared with reference populations. Use MCH variability to assess if is there a genetic bottleneck in the population.	1.6	B.9
Reproduction & Survival	Next 5 years	Explore how specific nutrient, vitamin, and mineral deficiencies (changes in prey quality) may negatively impact general survival, and fetal, neonatal and calf survival (e.g., folate, fatty acids), including direct ties to fish oil and reproductive success in humans.	1.4	B.3.2 B.4
Survival	Next 5 years	Investigate what may be causing increased variability in the microbiome of SRKW. May include use of PCR and negative staining electron microscopy to test for potential viral pathogens, assessing potential dietary and seasonal changes, using reference populations (Navy study), and matching with nutritional/photogrammetry/seasonal information.	1.4	B.4
Reproduction	Next 5 years	Compare prevalence of successful sires (paternity testing) in reference populations. If SRKW are low, explore feasibility of understanding why there are not many males that are reproductively active and showing up in the genetics (e.g., potential impacts of social structures on male breeding, low testosterone levels).	1.3	B.3.5 B.9.4
Reproduction & Survival	Next 5 years	Look at calving interval overlaid with salmon abundance (complicating factor – there has been a changing search effort over time. There is less probability of missing births now than 10 years ago, but cannot quantify that change in effort).	1.3	B.3.3 B.6.1
Reproduction & Survival	Next 5 years	Create a document with a glossary associated with contaminant studies to define contaminants of interest and which samples may be used to detect them (e.g., contaminants detected in blubber). May include using list of contaminants of concern prioritized by AMAPP/California Prescott Project/Puget Sound	1.2	B.6.3

		Partnership and assessing potential contaminants most relevant to SRKW, and assessing potential risks of endocrine disrupters on calving success. Although transients have higher contaminant levels than SRKW for bioaccumulative POPs, not all contaminants have been analyzed.		
Reproduction & Survival	Next 5 years	Compare inbreeding among populations and, if different, assess if inbreeding is having negative effect on survival and reproductive success.	1.1	B.9.2

POTENTIAL INDICES TO INCLUDE IN HEALTH ASSESSMENT PROTOCOLS

Note: Protocols should capture what can be done with live animal observations, retrospectively with existing data, and with reference populations.

- Measure body condition and skin lesions from photogrammetry
- Respiratory rate, heat rate, smell of breath, behavioral observations
- Ingestible tags (temperature pill, *Tursiops*)
- Suction cup tags cardiac monitoring (see studies by Ponganis)
- Fecal samples: Current analysis: hormone analyses, cytology, Parasites/ova, KW genetics and prey genetics, Fecal microbiology/culture (normal flora), Microbiome, PCR – *Campylobacter, Salmonella, Brucella, Vibrio, E. coli,* NEM – viral discovery, Algal toxins – DA, saxitoxin, +/- microcystin, okadaic acid (consult with biotoxin group re: biotoxins of interest), Contaminants, Yeast, 18S ribosomal RNA for protozoa and apicomplexan
- Blubber/skin: Skin microbiome, Fatty acids, POPs, PAH (some), Genomics, Genetics, Hormones, % lipid, Stable isotopes, Histopathology/gross appearance, Lesion sampling, PCR, qPCR (morbillivirus, cyp1, etc.), RNA evaluation, Proteomics, Lipidomics, Other omics, IHC (cyp1, etc.), Mixed function oxidases, Human interaction form for gross lesion documentation, Photography to document BCS/lesion
- Underwater visual observations/video
- Presence of pathogens and parasites in the environment (other animals as sentinels for local pathogens)
- Thermal imaging as an ancillary test to look for evidence of inflammation to differentiate active vs chronic lesions, tag effects (discussion mentioned limitations to this tool in health assessments)
- Breath samples: What is the substrate?, Cytology, Microbial community/culture combined with cytology, Respiratory gases, Coordinate sampling list to maximize utility of each sample, Importance of baseline studies, Use of drone, Develop specialized sampling technology for KW (UC Davis engineering school), Smell – start by documenting alterations in exhalation smell, evolving to determine what the components of the gases are, Potential use of compound “smell” detector, Use of existing whale-sniffing dogs, Using respiratory quotients as a measure of metabolism (Navy studies – no alteration noted with glucose metabolism – contact Dorian Houser for other input), What question are we looking to answer with breath analysis? Metabolic disease, respiratory disease, indicator of early compromise etc.), Population survey to establish baseline (and compare with reference populations), follow by identifying animals or compounds of concern

- Skin lesions/condition: Observational data on skin lesions, coupled with biopsies, gene expression, More coordination of skin lesions observations, compared with incidence of infectious disease mortality, compared with body condition, development of skin lesion grading scale (*Tursiops*, right whales)

POTENTIAL ANTHROPOGENIC FACTORS THAT MAY IMPACT SRKW REPRODUCTION & SURVIVAL

In our discussion of reproduction and mortality, several anthropogenic factors were raised or linked to particular health parameters. Research and management actions have been ongoing to address these threats (NOAA Report: Southern Resident Killer Whales, 10 Years of Research and Conservation). Where possible, these factors should be evaluated as potential sources of changes in health of SRKW. The factors are grouped below by the major threat categories.

Contaminants

- Urban habitat
- Water quality
- Air quality
- Boat exhaust

Vessels and sound

- Seismic testing, geoexploration, sonar
- Acoustic trauma
- Puget Sound vessel survey
- Vessel traffic (radar data can pick up recreational vessels [security concerns])
- Soundscape map of Puget Sound
- Marine construction

Other

- Assessing oil spill risk (part of vessel study)
- Fukushima - radionuclides
- Year-round exposure both inland and offshore for all threats
- Cumulative effects and interactions among all threats (e.g., reduced prey availability and contaminant exposure)

POTENTIAL PATHYWAYS FOR RECOVERY

As part of the workshop, we opened the discussion to ideas for supporting recovery as related to health parameters. Several suggestions were incorporated into the toolbox, such as incorporating biomedical information into a database and identifying a list of animals of concern. Additional suggestions are listed below under the major threats and sections of the recovery plan. Some of the discussion centered on updates regarding ongoing recovery implementation or raised ideas similar to actions identified in the recovery plan.

Prey

- Adaptive fishery management
    - Investigate our influence on salmon abundance – if we predict a bad year, can we make certain management decisions to reduce the impacts of a bad year
        - Difficulty in predicting PDO, and salmon abundance
        - Long-term predictions vs. short-term
        - Adaptations to prey shifts, spatial movement
- Hatchery fisheries designed to feed the whales (summer near San Juans; spring Columbia River)
    - Role of previous hatchery effects on historical SRKW nutritional plane
- Should there be a SRKW salmon allocation (e.g., CIBW discussion)

Contaminants

- PBDEs
    - Wastewater treatment plants as primary source of PBDEs in Puget Sound
    - Update: NOAA/EPA Working Group developed PBDE recommendations including how to improve effluent practices

Vessels and Sound

- Vessel traffic
    - Identify times when there are a higher prevalence of animals in poor body condition – public bulletin, voluntary closure or no-go zone
        - Requires a health index
        - May need a dynamic area that gets closed (similar to right whales)
- Give SRKW a day off from whale watching tours – more resilience than organisms under constant pressure
    - Ability to collect data to document effect

Disease

- Prioritization of pathogens of concern
    - Live animal response protocol
        - Sample prioritization
        - Disposition options
        - Zoonosis risk
    - Revisit diseases of concern (Gaydos et al. 2004)
    - Investigate improved response to known outbreaks
    - Morbillivirus susceptibility

        - Development of a response plan for pathogens with potential for acute mortality, have a rapid detection and response plan
        - Mitigation strategy for potential viral diseases
        - Develop rapid MV field test (NOS/TBD)
        - Long-term: identify possible pathogens of concern that might be introduced into SRKW range as waters warm

Other

- Oil spill hazing – Oil spill response plan
    - Update: Can- Transboundary Response Plan (Can-USPAC) wildlife guidelines – currently being updated
    - Consider a SRKW tracking network (hydrophones in critical habitat) – acoustic deterrent devices
    - Update: Pacific NW ERMA includes transboundary waters
- Collection of baseline information that would be required in a NRDA situation (e.g., PAHs) keeping in mind importance of establishing baselines and comparisons with reference sites
- Education and Outreach plan
    - Citizen science
- Health assessment of local cetacean species as a reference for environmental factors with potential to affect SRKW