2012 Salish Sea Marine Survival Research Planning and Ecosystem Indicators Development Workshops

RESULTS AND RECOMMENDATIONS

November 5th-9th

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The report is based upon the conversations of the workshops participants and the recommendations of the Salish Sea Marine Survival Research Planning Workshop Advisory Panel. The participants' lists are available at the workshops web site, http://www.lltk.org/SSMSPworkshop, and the Advisory Panel is listed on p. 8 of this document.

Acknowledgements:

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The Results and Recommendations of the Salish Sea Marine Survival Research Planning and Ecosystem Indicators Development Workshops

Summary Report – April 4, 2013 (FINAL VERSION)

Overview

In November 2012, two international workshops were held in Bellingham, Washington over the course of 5 days to discuss the causes of salmon and steelhead mortality in the Salish Sea region: the inland sea shared by U.S. and Canada that consists of the Strait of Georgia, Puget Sound and the Strait of Juan de Fuca. The workshops were called for based upon two concerns:

- Observed marine (juvenile outmigrant to adult) survival rates for many stocks of wild and hatchery Chinook, coho and steelhead have declined significantly since the 1970's and 80's, in some cases to less than one tenth of the levels experienced then, an indication that substantial changes are occurring in the marine environment. At the same time, wild pink salmon adult return abundance has increased substantially since the 1990's and chum and sockeye abundance has varied extraordinarily over the past three decades. The commonality in patterns of survival and abundance among Salish Sea stocks compared to survival and abundance trends of stocks outside the region suggest that overall survival is strongly impacted during the period when salmon and steelhead are in the Salish Sea
- The total number of adults returning has varied by orders of magnitude for most Salish Sea salmon species and stocks, even from year to year.

The uncertainty surrounding the causes of salmon and steelhead mortality, especially in the marine environment, poses a significant risk to wild salmon and steelhead recovery as well as the management of sustainable hatchery and wild stock fisheries; and to the preservation of associated tribal treaty rights. The outcomes of these workshops are contributing to ongoing U.S.-Canada research and assessment efforts that will:

a) identify or help prioritize hatchery, harvest, habitat and ecosystem management actions to increase the survival of Salish Sea wild and hatchery salmon and steelhead (including ESA listed populations);

b) improve the accuracy of adult salmon and steelhead return forecasting for natural spawning, harvest, and hatchery management; and

c) help us more accurately evaluate the success of freshwater habitat restoration and hatchery activities by reducing uncertainty around the role of the marine environment in overall productivity.

Ultimately, the research and assessment results and subsequent management actions may also benefit other Salish Sea marine life, such as ESA-listed southern resident killer whales.

The first of the two workshops was a three-day effort convened by Long Live the Kings and the Pacific Salmon Foundation to determine the critical elements for a joint U.S.-Canada research program focused on identifying the primary factors affecting the survival of salmon (mainly Chinook and coho) and steelhead in the Salish Sea. The second workshop, led by NOAA Fisheries staff, was held immediately following the marine survival workshop to discuss ecosystem indicators for adult salmon return abundance forecasting. There was a large degree of cross-participation by organizers, speakers, and attendees.

The 90 participants of the **Salish Sea Marine Survival** research planning workshop, and subsequently a 15 member Advisory Panel, reviewed the presentations and background materials and provided recommendations for a U.S.-Canada research program. They are summarized as follows:

- A collaborative international research program would have significant ecological and operational merit, and a unified approach agreed to by numerous U.S. and Canadian scientists would increase the likelihood management and the public will accept its results.
- Don't try to "explain" the entire ecosystem. The program should be driven by an improved understanding of the fish and what they are telling us, but be adequately multifaceted to identify ecological stressors and survival drivers.
- Design the research carefully so that short- and long-term research efforts will inform management. Perform short-term experiments and process/diagnostic studies in a larger monitoring and assessment framework. Focus on narrowing the field of factors affecting survival and provide a mechanistic context for their influence on survival in the short term. These studies will contribute data to longer time series and help refine the monitoring and assessment design. Use long-term time series analyses to evaluate the utility of the mechanistic relationships over longer periods of environmental variability, and to determine whether changes to certain factors explain salmon and steelhead survival trends.
- Understand where/when bottom-up (e.g., physical environment and prey resources) and top-down (e.g., predation and disease) processes prevail and then use this as a framework for evaluating other factors that may affect survival. Build from primary hypotheses based on existing evidence; however, don't discount the other factors presented at the workshop given the complexity of the salmon-marine environment relationship and the limited data available. Evidence of size-selective mortality in **Chinook and coho** suggests factors affecting size and growth are most important to their early marine survival, with food supply as the strongest likely mediator. However, **juvenile steelhead** mortality may be associated with predation, given their larger size at outmigration, very short residence time in the Salish Sea marine environment, evidence of high and rapid mortality in the marine environment, and no compelling evidence of size-selective mortality.
- Prioritize retrospective analyses and modeling to consolidate existing data, combine the effects of multiple factors/stressors, refine/increase the defensibility of hypotheses, better identify information gaps, potentially narrow the field of likely survival drivers, and provide a framework for future data inputs.
- Look for obvious and significant data gaps (e.g., zooplankton and ichthyoplankton prey availability), and implement specific monitoring activities immediately, most importantly a bottom-up program to evaluate prey availability and concurrent size, growth, and subsequent survival of the salmon themselves.
- For steelhead, it would be better to first determine whether there are mortality hotspots and then assess whether predation is a survival driver through experimental studies.

- Consider large-scale and targeted experiments. For example, hatchery manipulations may alter abundance and distribution of juvenile fish at specific times and places.
- Address the following in the U.S.-Canada operational structure: cross-border research collaboration; data standardization and sharing; fundraising and outreach needs; and strategic integration with existing programs, relevant groups, forums, etc.

During the **Ecosystem Indicators** development workshop, roughly 50 participants convened to: (1) identify a suite of freshwater and marine ecosystem indicators that could be used to improve forecasts of returns of the numerous species and stocks of salmon in the Salish Sea, (2) determine a plan for monitoring promising indicators and closing spatial or temporal gaps in existing indicators, (3) identify important monitoring programs at risk, and (4) improve ways to share and synthesize data, standardize data collection methods, and coordinate efforts. For six species of salmon, workshop participants identified the most promising indicators in three categories: physical environment, prey and growth, and predators and abundance. Freshwater, estuarine, nearshore, and offshore habitats were considered separately in the context of species-specific life histories and migration patterns. Large-scale climate indicators are consistently monitored and available in standard formats. Biological indicators are less consistently monitored, tend to have gaps in space and time, and are at greater risk of being interrupted as agency priorities change. Food supply probably mediates salmon survival in most years, and there is a notable lack of zooplankton and ichthyoplankton data. Estuary habitats have the most difficult monitoring problems and the weakest data sets in many watersheds, though sufficient data are lacking in most marine environments, both nearshore and offshore. There is a need for basin-wide coordination of data collection, compilation, and analysis. A Salish Sea database will require development of a regional infrastructure and stable, long-term management.

An Ecosystem Indicators report and Salish Sea Marine Survival research proposal will be completed in 2013. These reports will provide the initial framework for implementing each program, with a significant degree of overlap between the efforts built in.

The remaining sections of this document describe the results of the two workshops. The marine survival research program recommendations and next steps are described, followed by the outcomes, recommendations and next steps identified in the ecosystem indicators workshop. Finally, a brief synopsis is provided that describes where the needs identified in both workshops overlap.

Please visit the workshops' web site for presentation and poster abstracts, and to view each of the workshop presentations in .pdf format, at http://www.lltk.org/SSMSPworkshop.

Salish Sea Marine Survival Research Planning Workshop

In November 2012, Long Live the Kings and the Pacific Salmon Foundation convened a 3-day, U.S.-Canada workshop in Bellingham, Washington to:

> *determine the critical elements for a joint U.S.-Canada research program focused on identifying the primary factors affecting the survival of salmon and steelhead in the Salish Sea. Such information is vital to the recovery of wild salmon and steelhead and for managing sustainable hatchery and wild stock fisheries.*

There is increasing evidence that changes in the Salish Sea marine environment may be significantly affecting the overall survival of salmon and steelhead. Chinook, coho and steelhead survival in the marine environment has declined substantially: from the time they leave the freshwater as juveniles to when they return to their natal rivers or are harvested as adults (aka. marine survival). Many of these Salish Sea wild and hatchery stocks are experiencing marine survival rates less than one tenth of the levels experienced in the 1970's and 80's. At the same time, wild pink salmon adult return abundance has increased substantially since the 1990's and chum and sockeye abundance has varied extraordinarily over the past three decades. The commonality in patterns of survival and abundance among Salish Sea stocks compared to survival and abundance trends of stocks outside the region suggest that overall survival is strongly impacted when salmon and steelhead are in the Salish Sea.

Effective salmon and steelhead management requires an understanding of the primary factors controlling survival at each specific life stage. Current management and recovery efforts rely on understanding and addressing issues affecting freshwater productivity, but they are hampered by an inadequate and fragmented understanding of issues affecting productivity in the marine and estuarine environments. This is a critical knowledge gap since it is known that the marine life stages can be at least of equal importance as freshwater stages for salmon and steelhead survival, and the early marine phase is generally considered one of their most critical periods, where the fish are known to experience some of their most rapid growth and highest mortality rates.

While the focus of the workshop discussions was primarily on the marine survival of Chinook, coho and steelhead, all species were included to some extent given interspecies interactions and potentially shared survival drivers (e.g., by life-history types). Also, future research methods can readily evaluate multiple species simultaneously. The results of this workshop are intended to provide guidance to U.S. and Canadian scientists currently planning Salish Sea marine survival research. The scientists, and in the U.S., the project's Coordinating Committee, will review the results of this workshop and determine the next steps toward a collaborative research effort.

Over 90 participants representing multiple disciplines attended the workshop for the first two days, presenting and discussing hypotheses and research methods that help describe the salmon and the factors potentially affecting them (salmon biology/genetics/ecology, physical and biological oceanography, prey, predators, disease, toxins, toxics, and habitat). Facilitated discussions resulted in suggestions for how to improve upon the research recommendations provided by the U.S. Technical Team for Puget Sound and the scientists who developed the Pacific Salmon Foundation's Strait of

Georgia Chinook and coho research proposal.[1] The content of the workshop background materials, the workshop presentations, and the participants' suggestions were then discussed by an Advisory Panel on the third day, who provided more detailed recommendations for moving forward with a U.S.-Canada Salish Sea marine survival research program.

Advisory Panel Members

Richard Beamish (CA)	Retired, Senior Scientist, Department of Fisheries and Oceans, Pacific Biological Station
Dave Beauchamp (US)	Scientist, US Geological Survey & Professor, University of Washington, Aquatic and Fishery Sciences
Barry Berejikian (US)	Behavioral Ecology Team Leader, NOAA Northwest Fisheries Science Center
Eddy Carmack (CA)	Oceanographer, Department of Fisheries and Oceans
Ed Casillas (US)	Retired, NOAA Northwest Fisheries Science Center
Tracy Collier (US)	Science Director, Puget Sound Partnership
Ken Currens (US)	Hatchery Genetics Manager, Northwest Indian Fisheries Commission
Ed Farley (US)	Ecosystem Monitoring & Assessment Program Manger, NOAA Alaska Fisheries Science Center
Kurt Fresh (US)	Estuarine and Ocean Ecology Program Manager, NOAA Northwest Fisheries Science Center
Crawford "Buzz" Holling (CA)	Retired Ecologist
Mike LaPointe (CA)	Chief Biologist, Pacific Salmon Commission
Bill Peterson (US)	Oceanographer, NOAA Northwest Fisheries Science Center
Brian Riddell (CA)	President and CEO, Pacific Salmon Foundation
Rusty Sweeting (CA)	Scientist, Department of Fisheries and Oceans, Pacific Biological Station

Research Program Recommendations

The comments provided during the workshop and the recommendations of the Advisory Panel are described below. Four questions were asked directly of the Advisory Panel, and the workshop discussions were also guided toward determining the answers. Those are: **a) whether there is sufficient ecological and/or operational merit to warrant a collaborative international research program; b) whether a whole ecosystem study is needed; c) what factors should be investigated and research components implemented; d) what the resulting research program(s) should look like structurally and operationally.**

[1] *The Hypotheses and Preliminary Research Recommendations for Puget Sound and the Strait of Georgia Chinook and Coho Proposal are available at: http://www.lltk.org/SSMSPworkshop/meeting-materials.*

A) Is there sufficient ecological and/or operational merit to warrant a collaborative international research program?

The workshop participants concluded and then the Advisory Panel confirmed that there is sufficient merit to move forward collaboratively between U.S. and Canada. The Panel suggests that the following inform where, how and the degree to which collaboration should occur:

1. Physical/biological information (how much do the systems have in common? Where is the greatest degree of overlap?).
   - Based upon the workshop presentations and discussions, the Strait of Georgia and Puget Sound respond simultaneously to large events such seasonal changes and large-scale climate and ocean changes.
   - Basic evaluations of Puget Sound and Strait of Georgia Chinook stocks suggest survival and abundance trends are similar and differ from the survival and abundance trends of stocks outside the region. This suggests that the primary factors affecting salmon and steelhead survival are common throughout the Salish Sea and driving survival from within the Salish Sea.
2. Existing assets or capabilities that are unique or have greater capacity on either side of the border.
   - The Canadian W.E. Ricker mid-water trawling cruises to capture juveniles offshore throughout the Salish Sea are a prime example.

The Advisory Panel also concluded that a unified, U.S.-Canada approach agreed to by numerous U.S. and Canadian scientists increases the likelihood that management and the general public will accept the outcomes of the research (the bar for information to influence policy is higher than the bar for publication).

B) Is a whole ecosystem study needed? C) What factors should be investigated and research components implemented? And D) What should the resulting research program(s) look like structurally and operationally?

Ultimately, the workshop participants and the Advisory Panel do not think a real-time understanding of the entire marine ecosystem (i.e., simultaneous data collection of all relevant environmental factors) is needed to determine how salmon are affected by the Salish Sea marine environment. The Advisory Panel instead recommends building from primary hypotheses based on existing evidence, and to strategically evaluate the other factors presented at the workshop, none of which could be discounted given the complexity of the salmon-marine environment relationship, potential cumulative effects of multiple factors, and the limited data available. They recommend including the multiple factors currently identified as potential stressors/survival drivers in a more comprehensive but simple retrospective analysis and modeling exercise, with the output of that exercise possibly resulting in a more limited list of factors to research. The Advisory Panel recommends certain data collection activities should be implemented immediately based upon known high priority data gaps (e.g., zoo/ichthyo- plankton prey availability with concurrent data on diet, size, growth, and subsequent survival of juvenile salmon in nearshore and offshore marine habitats). They also concluded that a well coordinated effort of simultaneous data collection is imperative. Ultimately, the Advisory Panel recommends that the primary focus continue to be on the salmon and steelhead themselves as they will likely be able to provide the greatest amount of information regarding what is driving their survival.

The Advisory Panel recommends developing a greater understanding of bottom-up processes as the foundation for a U.S.-Canada marine survival research program. First, the Advisory Panel agreed with evidence that indicates size-selective mortality is a prevalent force regulating the marine survival of **Chinook and coho** in the Salish Sea, suggesting factors affecting size and growth are most important. This is consistent with the findings of juvenile salmon ecology studies from the California Current and Alaska, indicating that size and growth during the first month or so in the marine environment explains a significant amount of the variation in overall marine survival to adulthood. Basically, fish that grow faster and larger tend to survive better. Food supply (including the quantity, quality, timing, and spatial extent of prey and the impact of competition on food availability) was considered the strongest likely mediator of size and growth.[2] Second, the physical evidence that the Puget Sound and Strait of Georgia respond similarly to outside forces, and that salmon survival and abundance trends are common throughout but unique to the Salish Sea support the idea that large-scale factors (e.g., increased water temperatures, change in wind patterns, etc.) may be having a distinct impact on Salish Sea salmon. And, several members of the Advisory Panel agreed that a logical link between larger-scale drivers and salmon survival is through bottom-up processes, focusing on the mechanistic linkages between climate change and prey abundance.

Ultimately, none of the other hypotheses presented at the workshop describing the factors that could be affecting early marine survival could be discounted with the information provided. Other factors may affect size and growth (e.g., increases in water temperature, toxics and/or disease), and factors such as nearshore habitat loss, climate change and ocean acidification may be influencing bottom-up processes. Also, large-scale factors such as temperature increases can lead to increased prevalence of and susceptibility to disease, resulting in mortality on a broad scale. Additional factors discussed during the workshop that may also be contributing to early marine mortality include: freshwater outmigrant timing/condition, limited diversity (genetic and/or life-history), the effect of Salish Sea residence duration, direct or indirect effects of harmful algae, and increased predation.

The Advisory Panel discussed predation as the ultimate source of mortality in some detail, in response to the lack of evidence suggesting fish are starving to death and the rapid mortality witnessed in steelhead acoustic telemetry studies. While predator abundance could drive predation, increased predation may also be associated with reduced size and growth, mediated by bottom-up processes, or as a result of a limited abundance of prey.[3] Ultimately, the Advisory Panel suggests predation as the other book end for the U.S.-Canada study given its significant potential role in mortality. Within this framework, the other factors discussed during the workshop can be evaluated.

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[2] REVIEWER COMMENT: *While growth is a characteristic that seems to influence survival, it doesn't tell us much as to what is killing the fish. An understanding of growth is an important component of a project aimed at understanding the factors affecting the success or failure of salmon runs; however, focused studies on the ultimate causes of mortality such as predation and those factors that increase the susceptibility to predation such as disease and physiological stress should be emphasized*.

[3] REVIEWER COMMENT*: Disease and physiological stress are also often linked to increased predation and should be evaluated*.

Predation was hypothesized as the proximate, direct cause of the high mortality rates documented for steelhead in Puget Sound. Acoustic telemetry data have indicated that steelhead migrate through Puget Sound much more rapidly (approximately two to three weeks) than Chinook and coho salmon. The telemetry data do not indicate size-selective mortality of steelhead in Puget Sound. Rapid migration coupled with high mortality rates suggest that indirect mechanisms such as poor feeding opportunities, low growth rates, starvation, or disease are less important contributors to high mortality of steelhead than predation itself. A meta-analysis of segment-specific survival rates for other Puget Sound steelhead populations has recently been initiated and will help in identifying spatial patterns in mortality rates and further isolate potential hotspots. Equivalent data do not exist for steelhead in the Strait of Georgia.

The Advisory Panel strongly urges that efforts continue to focus on the fish[4] to help determine how the research effort should unfold over time (which factors to focus on and which to dismiss) and not get caught up in trying to "explain" the entire ecosystem. For example, answering specifics about primary productivity basin-wide may be beyond the scope of the effort. The most significant data gap is zooplankton and ichthyoplankton data as this is the basis of the juvenile salmon's food supply and the direct connection between salmon and bottom-up processes. The historical data for zooplankton is fragmented in both Puget Sound and the Strait of Georgia (inconsistent collection spatially, temporally and methodologically; and not tailored to evaluating food availability [e.g., supply, timing, quality, preferred prey] for the salmon species of interest). The Strait of Georgia has more data that is quantitative, but evaluations of long-term changes in the zooplankton population are confounded by changes in spatial and seasonal distribution of sampling, especially for comparisons before versus after 1994.[5] Zooplankton data have been periodically collected in Puget Sound since the 1970's from disassociated studies, resulting in data that are largely disparate. One long, largely qualitative data set (1975-95) also exists but has not been assessed for its utility. Ichthyoplankton data is very limited in both Puget Sound and Strait of Georgia.

Specific recommendations for improving the currently proposed research approaches for Puget Sound and the Strait of Georgia are as follows:

I. <u>Organize and better analyze existing data and create a modeling framework for analyzing the results of future field research</u>

One of the most repeated recommendations by the workshop participants and then confirmed by the Advisory Panel is to develop a modeling approach and begin retrospective analyses now versus waiting for new data to be collected. This should be done to: consolidate existing data, combine the effects of multiple factors/stressors, refine/increase the defensibility of hypotheses, better identify information gaps, potentially narrow the field of likely survival drivers, and provide a framework for future data inputs. This activity may also help identify immediate management actions. This exercise should include the factors identified by the Puget Sound and Strait of Georgia scientists who developed the research proposals leading up to the workshop, and adding measures of human population growth. Specific suggestions for this suite of activities are as follows:

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[4] *Build from factors directly impacting the fish outward to determine the factors ultimately driving survival*.

[5] *Based on a January 29, 2010 email written by Dave Mackas to Marc Trudel, subject, "Plankton in the Strait of Georgia".*

1. Refine the current evaluation of salmon and steelhead survival and abundance trends:
   a) Do a more precise evaluation of the coherence throughout the Salish Sea ecosystem and of the survival response by reviewing the marine survival or abundance trends among Salish Sea salmon and steelhead populations and their life histories.
      - Determine whether the system is connected and heterogeneous or disconnected and homogenous (Schafer and Carpenter 2003[6]).
      - Evaluate species/populations both that are doing well and those that aren't.

   b) Determine whether the survival of salmon and steelhead in the ocean can be quantified and separated from their survival in the Salish Sea to try to isolate the survival impacts of factors related to ocean processes versus those related to Salish Sea processes. Do this by comparing the marine survival trends of coastal stocks to Salish Sea stocks. Another approach to separating the effects of survival (and growth) within Salish Sea versus ocean life stages is to compare observed and back-calculated size structure of Salish Sea Chinook & coho sampled in Puget Sound and along the Pacific Coast[7] for known stocks of origin.

2. Develop a comprehensive modeling approach:
   a) Develop a taxonomy of the multiple models required. First, establish the questions to answer with models.
   b) Use models to facilitate early steps in research, utilizing retrospective data, but appreciate the existing information gaps (e.g., zooplankton data) when evaluating their utility.
   c) Use models as a powerful tool for incorporating and analyzing the salmon-Salish Sea ecosystem relationship with future assessment data from the field research implemented. Use the intensive sampling and assessment activities recommended in section II, below, as an opportunity to compare to and validate model outputs.
   d) Utilize multiple models for duplication (one model may be wrong, two better, etc.) and to address the multiple aspects that must be covered (physical processes, biological processes, adaptive management).
   e) Evaluate various modeling approaches, and begin with simple model exercises, working toward more complex approaches as needed. Determine whether existing models (diagnostic bioenergetics, life-history stage analysis, EcoSim with EcoPath for Puget Sound and the Strait of Georgia; ROMs, etc. for the Strait of Georgia) can be utilized, what basic first steps should be taken, and what more comprehensive models should be

[6] *Schaffer, M and S.R. Carpenter. 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. Trends in Ecology and Evolution. Vol. 18. No. 12*.

[7] *Via DFO's coastal trawl survey.*

developed (e.g., MoSSea[8] for physical and planktonic modeling, through zoo/ichthyoplankton, and Atlantis for enhanced food web modeling).[9]

f) Ensure models are spatially explicit.

g) Ensure models facilitate the evaluation of multiple stressors / cumulative effects.

3. Some additional recommendations for retrospective analyses and modeling are:

   a) Evaluate size and age-composition of juvenile salmon in the marine environment over time to help illuminate whether food limitations are occurring (e.g., DFO's W.E. Ricker midwater trawl data synthesized with existing nearshore, estuarine and smolt trap data).

   b) Use historical data and modeling to look for regime shifts.

   c) Evaluate correlations that once worked and now don't (pre-90s) vs. ones that work now (can also be done in association with monitoring).

II. Implement specific, standardized field sampling and assessment activities

The Advisory Panel recommends that the research developers should not wait for the results of initial retrospective analyses and modeling to implement certain field sampling and assessment activities. There was strong agreement that a more rigorous marine fish sampling program is needed to address known information gaps and concurrence that a bottom-up sampling program should be implemented. These programs should be performed simultaneously and coordinated thoroughly. These programs should be finalized and implemented immediately and the samples collected should be preserved routinely. Standards and protocols should be developed for sampling activities so that data can be shared readily and utilized broadly in analyses. Data management should be coordinated and mechanisms such as data aggregators or a shared web site housing the data should be considered. Populations/life histories that are doing well versus those that aren't (within and among species) should be compared in the study. The Advisory Panel suggests beginning with a feasibility study based around specific populations and locations with multiple assessment approaches deployed concurrently, using the results to refine a broader program.

The following are specific recommendations from the Advisory Panel:

1. Zooplankton and ichthyoplankton prey availability data collection/analyses are the highest priorities since they are the direct link to salmon productivity and the most significant, current data gap. The Advisory Panel was not aware of local past or present ichthyoplankton research that would inform the development of an ichthyoplankton monitoring program. They recommend consulting with specialists outside of the region, such as scientist at NOAA's Alaska Fisheries Science Center, and consider implementing an ichthyoplankton

[8] *MoSSea – Modeling the Salish Sea is a modeling project of the U. of Washington designed to provide the first ever high-resolution, realistic hindcast simulations of the physical circulation in the entire Salish Sea region. A biological component is also available to couple with the hydrodynamic component to model bottom-up processes. http://faculty.washington.edu/pmacc/MoSSea/.*

[9] *REVIEWER COMMENT: Carefully evaluate the benefits and limitations of various modeling approaches, especially in the context of responses to simulated management strategies in ecosystem models*.

monitoring feasibility study. Some Advisory Panel members cautioned that the effort put into ichthyoplankton monitoring should be consistent with the need for that information, based upon the apparent role of ichthyoplankton in the salmon food web: as a food source or a competitor for food. Basic ecosystem modeling with existing utilities may help determine how sensitive salmon are to potential changes in ichthyoplankton. A comprehensive understanding of the Salish Sea planktonic (phyto and zoo) composition (species, food web structure, energy flow) is also valuable for determining to what extent the microbial environment is contributing to productivity at higher trophic levels (i.e., fish productivity) and how it may have changed over time.

2. Be cost-effective about physical and primary production data collection; however, be inclusive of methods for understanding how physical processes affect the distribution of production.
3. Initially, circulation models could help refine the spatial extent of fish and prey sampling. A better understanding of salmon feeding behavior (timing day/night, depth, etc) could also help refine sampling efforts.
4. Consider the entire year, not just the spring phytoplankton bloom, and vary the intensity of sampling based upon when the fish are in the system, especially during their first month of marine residence (predominantly February – October if including chum, pink and all life-histories of Chinook, coho, and steelhead). Evaluate the marine survival performance of salmon stocks that are released/outmigrate in the summer or fall compared to those that outmigrate in the spring to help determine whether food supply is an issue and the extent to which the spring bloom is playing a primary role.
5. Understand the condition of fish entering, and, if possible, leaving Salish Sea to determine if poor condition at these stages predetermines them for high mortality in subsequent stages (early marine residency and open ocean, respectively). Include other metrics in addition to size (e.g., energy, growth history from scales or otoliths). Make sure lipid content analyses are part of any monitoring program.

III. <u>Develop large-scale and targeted experiments</u>

Some Advisory Panel members suggested experimentation to isolate factors and evaluate their influence on survival. Some experiments were proposed in the Strait of Georgia Chinook and coho plan; however, they were largely not proposed as part of the Puget Sound preliminary research recommendations. The Advisory Panel recommends that the research developers further consider the utility of experiments. Some examples discussed were:

1. Hatchery manipulations, integrated on a Salish Sea – wide scale (composition [species and life-history], size, timing, numbers).
2. Mesocosm studies using net pens (varying mesh sizes resulting in varying degrees of access to various prey).
3. Net pen studies to evaluate growth rate restrictions in the marine environment.
4. Targeted acoustic studies to identify exactly where fish are dying (hotspots study).
5. PIT tag thousands of fish simultaneously and monitor seal haul-out sites and bird rookeries to evaluate predation.

6. Comparative survival studies: fish barged past potential hotspots vs. those not (especially for steelhead).
7. Control-treatment outmigrant studies re: barging fish through the system to avoid stressors like HAB, predators, and pathogens (e.g., *Nanophyetus, IHNv, Rennibacterium*); disease treatment such as *Vibrio* and *Rennibacterium* vaccinations; and chemical treatment for repelling sea lice.

Advisory Panel members also suggest that researchers look to changes in management over the past 30 years that could equate to large-scale experiments, such as some of the hatchery production changes that have occurred (e.g., 50% reduction in hatchery steelhead production in Puget Sound, the response to seal population reductions in Hood Canal from transient killer whales, etc.).

IV. Operational Recommendations

The Advisory Panel provided the following operational recommendations:

1. Develop an international management and public engagement strategy.
    a. The Pacific Salmon Foundation and Long Live the Kings should continue to help identify and coordinate the appropriate parties and facilitate the process.
    b. Strategically engage and utilize relevant groups, forums, etc. (e.g., Pacific Salmon Commission, Puget Sound Partnership, etc.)
2. Develop international workgroups to refine and begin implementing research components. The workgroups should be multi-disciplinary as appropriate and created to satisfy the specific research components:
    a. retrospective and modeling
    b. experiments
    c. diagnostic studies and monitoring
    d. collaboration, communication, and data standardization and sharing
3. Establish an international equivalent to the U.S. Coordinating Committee to help identify and secure funding and ensure management cooperation, buy in and guidance.

V. Challenges and Opportunities

Specific challenges and opportunities were identified over the course of the workshop. Those that were more salient are listed below:

Challenges

- The current funding environment is poor, requiring creative, strategic thinking and targeting various funding sources for different components of the future research program.
- Retrospective work is typically not easy to fund, and the historical record is patchy.

- As agency budgets continue to shrink, there are concerns about the longevity of existing programs that contribute to our understanding of salmon marine survival.
- Careful study design is imperative to ensuring that short- and long-term research efforts will inform management. To achieve this, experiments and process/diagnostic studies must be carried out within a larger monitoring and assessment framework. Short-term studies should focus on narrowing the field of factors affecting survival and provide a mechanistic context for their influence on survival. The results of these short-term studies will contribute data to longer time series and help refine the monitoring and assessment design. And, long-term time series analyses (via modeling, regressions, etc.) can be used to evaluate the utility of the mechanistic relationships over longer periods of environmental variability, and to determine whether changes to certain factors explain salmon and steelhead survival trends.
- The Endangered Species Act has “take” limitations that could affect the extent of sample collection. There are only a few salmon and steelhead populations with marine (outmigrant-to-adult) survival data in the Strait of Georgia, inhibiting the evaluation of factors affecting their survival.

Opportunities

- Citizen/community science to accomplish some of the spatially extensive monitoring likely required.
- Other retrospective data sources (e.g., fishermen’s logs, First Nations data sets).

Next Steps

The U.S. and Canadian scientists currently planning Salish Sea marine survival research are reviewing the results of this workshop in the context of their planning efforts and are working on the next steps to develop a comprehensive, collaborative research program. A revised research planning framework will be implemented that utilizes U.S.-Canada workgroups to complete the research components that will benefit from transboundary collaboration. Fundraising is also a high priority. Long Live the Kings and the Pacific Salmon Foundation are working with the research developers and agency leads to establish a fundraising strategy. Sources of funding will be identified for the various components of the research, and a high-level proposal will be drafted for participating managers to lobby for the project at the federal/Congressional level.

Ecosystem Indicators for Forecasting Adult Salmon Returns

In February 2011, fisheries co-managers associated with the North of Falcon Process met with John Stein, Director of NOAA Fisheries' Northwest Fisheries Science Center, to discuss their concerns over declining salmon stocks in Puget Sound. An increasing concern is the inability to consistently predict reasonably accurate freshwater and marine survival rates (unique by species and by stock) used in salmon recovery efforts and to forecast adult abundances for the annual fisheries planning processes. This issue applies to the entire Salish Sea region, where observed adult returns have declined considerably in recent years for many species and have varied by orders of magnitude for some species and stocks, even from year to year. Without advance indications of what to expect for the annual freshwater and marine survival rates, the abundance forecasts for many Salish Sea stocks essentially utilize recent marine survival trends. As there appears to be increasing instability in marine survival rates, assuming constant or average historical survival rates poses an increasing risk in overforecasts, potentially resulting in harvest beyond sustainable rates. Poor forecasts present a serious management challenge because they impact treaty rights and may drive future listing decisions of salmon populations as well.

Monitoring programs like those conducted on the Washington and Oregon coasts, which produce ecosystem indicators used to forecast adult returns of Chinook and Coho salmon to the Columbia River system and Washington Coast, are not consistently conducted in the Strait of Georgia by Canada's Department of Fisheries and Oceans (DFO) or the Puget Sound by NOAA or any other governmental group. A unified indicators program in the Salish would improve the ability of harvest managers to accurately forecast adult salmon returns, reduce the risk of over-harvest, and improve the likelihood of meeting recovery goals for ESA-listed species. These issues were addressed with a workshop organized to improve ecosystem indicators used in forecasting. In recognition of the large topical overlap with that of the Salish Sea Marine Survival Workshop, this two-day meeting followed the Marine Survival workshop, with a large degree of cross-participation by organizers, speakers, and attendees.

The goals of the Ecosystem Indicators workshop were to:

- identify a suite of ecosystem indicators that could be used to improve forecasts of returns of the numerous species and stocks of salmon in the Salish Sea,
- determine a plan for monitoring promising indicators and closing spatial or temporal gaps in existing indicators,
- identify important monitoring programs at risk, and
- improve ways to share and synthesize data, standardize data collection methods, and coordinate efforts.

This workshop therefore differed from the Marine Survival workshop in several ways. First, it considered the potential utility of ecosystem indicators in both freshwater and marine systems. Second, it focused on the application of scientific findings that would be a logical outcome of the plan for research developed at the Marine Survival Workshop. Third, it emphasized the importance of long-term monitoring that is needed for fishery management and salmon recovery efforts and will persist beyond the 5-10 year timeline specified by the Marine Survival research plan.

Workshop Process and Results

In the two days of the workshop, participants heard from 18 speakers who have collected or utilized data on promising ecosystem indicators, broadly grouped into abiotic processes (climate, freshwater, estuarine, and marine habitat processes), population metrics at juvenile life stages (e.g., freshwater outmigrants, abundance within Puget Sound or the Strait of Georgia), and trophic interactions (predators, prey, and individual condition). During the second day of the workshop, participants discussed these findings in light of the goals of the workshop, focusing on three general issues:

A. what are the most promising ecosystem indicators for forecasting adult returns of the six salmon species found in the Strait of Georgia?,

B. what indicators require new monitoring programs to fulfill, and is there a logical lead entity or entities to perform them?, and

C. given the existence of multiple entities collecting information, how should responsibility for data synthesis be shared, and is there a common and acceptable platform or framework for sharing data?

A) What are the most promising ecosystem indicators for forecasting adult returns?

This question was addressed in the context of breakout discussion sessions, with participants joining one of three groups: 1) abiotic indicators, 2) prey and growth, or 3) abundance and predators. There was significant agreement that ecosystem indicators would depend largely on the species of interest, and in many cases, on individual stocks of that species. In the tables below, relevant indicators for each species are noted with a dot, and were considered in the contexts of freshwater, estuarine, within the Salish Sea, or within the Strait of Juan de Fuca (SJDF) and off the Pacific Coast. Much of the discussion was focused on identifying potential indicators, rather than restricting the number of relevant indicators without better data analysis to determine which indicators best predict variation in adult salmon returns. Nevertheless, some species-specific winnowing of potential indicators was possible.

The abiotic indicators subgroup considered a variety of indicators across habitats (Table 1), and noted several variables with data that were limited (*) spatially or temporally. It was also noted that hydrodynamic models can be used to predict some abiotic variation (e.g., temperature in estuaries) and that, as a major habitat type, estuaries have the sparsest data coverage.

The prey and growth subgroup discussed numerous potential data sources (Table 2) including some that focused on productivity of the system (e.g., nutrients, chlorophyll, and growth in geoducks) as well as diet and growth of individual fish. Subgroup members noted that many potential indicators lacked time series with any spatial resolution, so linking these datasets with adult returns is in some respects just getting started for the Salish Sea. Hence, while some measurements could be specified by habitat type, little species-specific information is available. For the long term, an exploratory approach for discovering the most useful indicators was recommended. Meanwhile, most participants agreed that food supply probably mediates salmon survival in most years, and there is a notable lack of zooplankton and ichthyoplankton data. Therefore, zooplankton and ichthyoplankton data collection should commence immediately along with intensive coordinated fish sampling. The group also noted that fiscal vulnerabilities are a big consideration for sampling. For example, the W.E. Ricker midwater trawling effort (run by Canada's DFO in the Strait of Georgia and Puget Sound), which effectively samples most species and provides good diet, size, and some growth data, may lack funding for additional work in

Table 1. *Potential abiotic ecosystem indicators. Starred (*) indicators indicate limited sampling across years or space.*

Potential Indicator	Chinook	Coho	Steelhead	Sockeye	Chum	Pink
Freshwater						
Average river flow	●	●	●	●	●	
Low flows		●	●	●		
Peak flows	●	●			●	●
Temperature (winter & summer)*	●	●	●	●	●	●
Turbidity*	●	●	●		●	●
Snowpack	●	●	●	●	`●	●
Estuarine						
Estuarine temperature*	●	●			●	
Dissolved oxygen*	●	●			●	
Salinity*	●	●			●	
Within the Salish Sea, the SJDF & off the Coast						
pH	●	●	●	●	●	●
Temperature (e.g., DFO lighthouse data)	●	●	●	●	●	●
Salinity	●	●	●	●	●	●
Wind direction	●	●	●	●	●	●
Climate indicators (e.g. PDO, ENSO)	●	●	●	●	●	●
Cloud cover	●	●	●	●	●	●
Dissolved oxygen	●	●	●	●	●	●
Stratification	●	●	●	●	●	●

[1]PDO = Pacific Decadal Oscillation, ENSO = El Nino/Southern Oscillation

Table 2. *Potential prey and growth ecosystem indicators. Starred (*) indicators indicate limited sampling across years or space. Location of sampling is indicated by F = Freshwater, N = Nearshore, O = Offshore, and All = All habitat types.*

Potential Indicator	Chinook	Coho	Steelhead	Sockeye	Chum	Pink
Individual size and size change (All)	●	●	●	●	●	●
Outmigrant timing (F)	●	●	●	●	●	●
Body condition (e.g., lipid content, stable isotopes)* (All)	●	●	●	●	●	●
Growth (e.g., IGF)* (All)	●	●	●	●	●	●
Stomach Contents (All)	●	●	●	●	●	●
Disease* (All)	●	●	●	●	●	●
Oyster condition (N)	●	●	●	●	●	●
Crab CPUE, abundance (N,O)*	●	●	●	●	●	●
Geoduck growth rates (N)	●	●	●	●	●	●
Nutrients (N,O)	●	●	●	●	●	●
Chlorophyll (contributions by taxa*) (N)	●	●	●	●	●	●
Zooplankton density & biomass (N,O)*	●	●	●	●	●	●
Lipid and fatty acids of zooplankton (N,O)*	●	●	●	●	●	●
Phytoplankton sedimentation rate (N)*	●	●	●	●	●	●
Forage fish biomass (N,O)	●	●	●			

Puget Sound or be directed to address emerging priorities in other regions of the ocean unless creative means are found to fund it independently.

The abundance and predators subgroup considered the few potential datasets on predators of juvenile salmon, and the many datasets on salmon abundance (Table 3). Potential predators include piscivorous fish, seabirds, and marine mammals. These are generally long-lived species with populations that do not show strong interannual fluctuations that could readily inform yearly variation in salmon returns. However, seabird densities and activities of pinnipeds and orcas could conceivably be useful in forecasts.

Numerous abundance metrics are measured for juvenile salmon during their life cycle. Freshwater abundances include returning adults (including jacks and kelts), eggs, and outmigrants (including production from hatcheries). Many of these measurements (particularly outmigrants) are well represented in Washington but not in Canada. A variety of techniques exist for sampling juvenile salmon in estuarine and nearshore habitats, although coverage is limited in space and time for most of these measurements. The longest time series include fyke trapping, beach seining, shoreline counts, and neritic sampling in the Skagit River estuary and, to a lesser extent, in the Snohomish estuary. In addition, midwater trawling by the W.E. Ricker in the deeper waters of Puget Sound and the Strait of Georgia has continued for 11 years. All these programs are vulnerable to funding cuts or to shifting priorities. Even

Table 3. *Potential predator and abundance ecosystem indicators. Starred (*) indicators indicate limited sampling across years or space.*

Potential Indicator	Chinook	Coho	Steelhead	Sockeye	Chum	Pink
Predators indicators – Nearshore						
Seabird abundance	●	●	●	●	●	●
Pinniped activity	●	●	●	●	●	●
Orca activity	●				●	
Abundance indicators – Freshwater						
Pre-spawn mortality	●	●	●	●	●	●
Adults*[1]	●	●	●	●	●	●
Jacks	●	●				
Eggs (adults * fecundity)	●	●	●	●	●	●
Juvenile outmigrants (NOR & HOR[2])*	●	●	●	●	●	●
Hatchery production	●	●	●		●	
Early survival of HOR groups	●	●	●		●	
Abundance indicators – Estuarine						
Cumulative density*	●	●			●	
Abundance indicators – Within the Salish Sea						
Shoreline counts*					●	●
Beach seining density*	●	●			●	●
Neritic density*	●	●			●	●
Midwater CPUE*	●	●		●	●	●
Purse seine CPUE*	●	●	●	●	●	●
Abundance indicators – SJDF and off the Coast						
Pelagic CPUE	●	●	●	●	●	●
Pattern of offshore migration	●	●	●	●	●	●

[1] Adult data is limited for major salmon populations in British Columbia.
[2]NOR & HOR are abbreviations for natural-origin recruits and hatchery-origin recruits, respectively.

sampling as fundamental as counts of adult returns has witnessed declines in funding over the last ten years.

Many sampling programs are species-specific. For example, shoreline counts are effective for measuring only pink and chum fry. Outmigrant sampling in many places can provide good estimates of chum, coho, and Chinook, but not steelhead smolts because they can avoid traps. In the nearshore, steelhead are particularly difficult to sample because of their size, speed, and rapid outmigration. It was suggested that a purse seining monitoring program would provide useful sampling for all salmon species as long as it was done at the appropriate times, frequencies, and locations. Purse seining, which is used in the Lower Columbia and in the Strait of Georgia, is less harmful for the fish and thus more consistent with reducing the take of listed species.

B) What indicators require new monitoring programs to fulfill, and by whom?

A number of indicators noted in the list above would likely be new in particular oceanographic basins. New indicators will be a challenge to use for predicting adult returns simply because they lack an annual time series, so choice of these new techniques should be based on existing work elsewhere in the Pacific Northwest, or based on analysis of spatially or temporally sparse local datasets. For example, many of the potential new monitoring programs follow from Bill Peterson's Ecosystem Indicators list. Workshop participants discussed these potential activities and provided logical lead entities for data collection. Many of the sampling programs conceivably could be performed locally by multiple groups, and could be incorporated into a comprehensive sampling effort that could offset the fiscal challenges of a large sampling program. Participants agreed that analysis leading to usage of data as indicators of adult

Table 4. *Potential new monitoring activities that could provide useful indicators, and the logical entities for data collection.*

Activity	Logical entities for data collection
Purse seining	NOAA,DFO, Tribes, academia
Genetic stock ID	WDFW, DFO, Tribes, academia
Phytoplankton	All
Zoo & Ichthyo plankton	All
Condition factors (stomach contents, lipids, growth, size, IGF)	NOAA, DFO, WDFW, Tribes, USGS, academia
Disease field monitoring and empirical studies	WDFW, Tribes, USGS
Sediment traps	All
Forage Fish Biomass/age structure	NOAA, DFO, WDFW, Tribes, USGS, academia
Stable isotopes (N, C)	All
Seabirds	WDFW, Environment CA, USGS, Audubon/community groups, academia
Marine mammals	NOAA, DFO, Tribes, community groups
Standardized adult monitoring (spatial gaps exist)	Tribes, WDFW,DFO
Outmigrant trapping (Strait of Georgia gaps, addtnl options in Puget Sound)	DFO, Tribes, WDFW
Age and growth in geoducks	Tribes, Industry, WDFW, DFO, academia

returns should be performed by tribal, academic, state (WDFW) and federal (NOAA, DFO) entities. and could be incorporated into a comprehensive sampling effort that could offset the fiscal challenges of a large sampling program. Participants agreed that analysis leading to usage of data as indicators of adult returns should be performed by tribal, academic, state (WDFW) and federal (NOAA, DFO) entities.

C) How should responsibility for data synthesis be shared, and on what type of platform?

Data sharing platforms include NANOOS, SalmonScape, the Juvenile Migrant Data Exchange and Nearshore Data Exchange, and cloud-based platforms. Logistics of managing such a diverse database are difficult and require planning and resources. Major issues include database development and maintenance, data sharing agreements, data synthesis – who does it and how is it shared – and timeliness. Products need to be available on a schedule that allows co-managers to use them in forecasts, and monetary support is essential if this is to take place. Furthermore, standards for data collection, analysis and sharing need to be agreed upon to support both timely forecasts and longer-term peer-reviewed publications.

Workshop participants agreed on the need for a centralized point of data access for research data sets and for annual indicators and other synthesized products. Given existing efforts by NOAA and DFO on production of indicators, many participants agreed that NOAA and DFO should take the lead in developing indices and the stoplight tables that inform predictions. However, methods still need to be developed with the co-managers and standardized among NOAA and DFO, particularly in how the red-yellow-green forecast categories are determined.

Recommendations and Next Steps

Several clear recommendations emerged from the presentations and discussions of the Ecosystem Indicators workshop:

- A number of different indicators at several spatial scales (watershed, oceanographic basin, entire region) need monitoring in order for an ecosystem indicators approach to successfully be integrated into forecasts of adult salmon returns in the Salish Sea.[10]
- Because of inherent differences in the biology and ecology of different salmon species, different sets of ecosystem indicators will likely need to be developed for each species.
- Monitoring plans need to address how existing gaps in indicators will be filled across space and time and how existing monitoring programs at risk can be maintained in the face of budget limitations.
- Several indicators, including zooplankton, individual size and growth, outmigrants, and midwater trawling are especially critical to initiate or maintain. Purse seining should be considered for increasing the capability of examining steelhead and other rapid salmon outmigrants and fish predators.

[10] *REVIEWER COMMENT: Another important conclusion of the workshop is the need to be realistic in terms of the precision that can be achieved at predicting adult returns with ecosystem indicators, and the need to better convey the level of precision of forecasts to managers and the general public.*

- Indicator development can be phased to take advantage of the variability of available time series. For example, numerous abiotic datasets that have good temporal and spatial representation could be used to produce an initial set of Ecosystem Indicators, and additional indicators could be added as more information becomes available.
- A number of indicators are amenable to distributed data collection efforts by Tribes, community groups, and other organizations. Collection of data in this manner will be facilitated by standardized data collection and management protocols.
- Links to the most commonly used abiotic indicators across the Salish Sea have been compiled as a product of this workshop, and these need to be incorporated into a database with a nested structure.
- Existing monitoring datasets will need to be managed in ways that facilitate both annual updating and timely availability for use by multiple co-managers charged with producing stock forecasts with seasonal deadlines.
- NOAA and DFO will coordinate the production of summaries of ecosystem indicators to facilitate forecasts of adult returns among major regions in the Pacific northwest (e.g., Columbia River system, Pacific Coast, and the Salish Sea).

Discussions on the second day of the workshop revealed that additional work needs to be done to coordinate monitoring, data management, and analysis tasks, particularly in light of the overlap with the proposed activities for the Salish Sea Marine Survival research program. Members of the Ecosystem Indicators group will work with the Marine Survival technical team workgroups to follow the workshops' major recommendations regarding long-term monitoring, data management, and analysis. Concurrently, meetings will be planned for NOAA and DFO researchers to discuss coordinating progress on ecosystem indicator development.

Marine Survival and Ecosystem Indicators Programs Overlap and Coordination

The workshop participants and, concurrently, the scientists and managers involved in developing the plans for both the Salish Sea Marine Survival and Ecosystem Indicators programs, believe there is significant merit in continued, strong collaboration between the two efforts. The Salish Sea marine survival research will help isolate the primary factors affecting survival in the marine environment. A strategic ecosystem-based approach will be employed, and the focus will be on narrowing the field of factors most significantly affecting survival and providing a mechanistic context for their influence on survival. This work is primarily intended to determine what factors have caused the long-term declines of Chinook, coho and steelhead witnessed in the Salish Sea. However, it also informs the development and application of ecosystem indicators to improve adult return forecasting: returns that vary significantly on an annual basis. While factors, or the combination thereof, affecting the long-term decline may be different from factors/indicators that describe inter-annual variation, the mechanistic context for a factor's influence on survival will remain the same.

The Ecosystem Indicators program represents the direct application of research activities and outcomes to management. A broad suite of ecosystem indicators to improve adult return forecasting can be roughly identified now based on current knowledge, to be tested and refined over time, and will include both freshwater and marine components. Those marine indicators not adequately measured will be included as part of a comprehensive monitoring program that also satisfies marine survival research program needs. Also, retrospective analyses and modeling needs are in many ways shared, to help narrow the field of potential survival drivers and inform indicator development.

Below is a diagram describing the programs and how they overlap. The initial phase of the marine survival program has been proposed to last 5 years. An additional 5 year increment is identified as the time it will likely take to continue to narrow the field of appropriate ecosystem indicators. It is assumed that the marine survival and ecosystem indicators programs will continue beyond the 5 and 10 year phases in some form, and that continuous monitoring and modeling, and periodic diagnostic studies and experiments will occur under the umbrella of the long-term effort.

Marine Survival Project and Ecosystem Indicators Program Process Overlap (Over time)