Exxon Valdez Oil Spill Trustee Council

Prince William Sound Integrated Herring Restoration Program

Exxon Valdez Oil Spill Trustee Council
441 W. 5th Avenue, Suite 500
Anchorage, AK 99501
907-278-8012
www.evostc.state.ak.us

Integrated Herring Restoration Program
DRAFT OUTLINE– September 3, 2008

Integrated Herring Restoration Program
DRAFT OUTLINE– September 3, 2008

PLEASE COMMENT

You can help the Trustee Council by reviewing this draft program and providing your comments. You can comment by:

Mail:	Exxon Valdez Oil Spill Trustee Council 441 W. 5th Avenue, Suite 500 Anchorage, AK 99501 Attn: PWS Herring Restoration Plan
Telephone:	1-800-478-7745 Collect calls will be accepted from fishers and boaters who call through the marine operator.
Fax:	907-276-7178
E-mail:	michael_baffrey@alaska.gov

Integrated Herring Restoration Program
DRAFT OUTLINE– September 3, 2008

Acknowledgements
I am pleased to acknowledge the hard work and dedication of the authors of this program: Stanley "Jeep" Rice, Doug Hay, Gary Fandrei, Vince Patrick, Evelyn Brown, Rob Campbell, Ross Mullins, Paul Herschberger, Scott Pegau, and Catherine Boerner. I would also like to extend my thanks to the members of the Herring Steering Committee whose commitment to the restoration of Pacific herring in Prince William Sound continues to drive this initiative.

Michael Baffrey, Executive Director

Integrated Herring Restoration Program
DRAFT OUTLINE– September 3, 2008

TABLE OF CONTENTS

Integrated Herring Restoration Program
DRAFT OUTLINE– September 3, 2008

Terminology

Recovery – Recovery is the return of the PWS herring population to some defined level. This can occur naturally or through restoration activities.

Restoration – Restoration is the recovery of the PWS herring population through human actions.

Intervention – Intervention describes the activity that attempts to either increase PWS herring birth rates or reduce PWS herring mortality.

Enhancement – The goal of restoring the herring population in a habitat that is capable of sustaining it.

Integrated program – An ecosystem based program organized around common goals/hypotheses determined and implemented through involvement by impacted communities and scientists to develop a teamwork that creates efficiencies, open communication, and inter-related activities that inform each other to achieve the program goals.

Supplemental production – the release of cultured herring to increase the existing herring population.

Intensive aquaculture – Rearing of herring using traditional hatcheries and artificial environments.

Extensive aquaculture – using natural habitats (bays) to rear herring

Recruitment - the process of older juveniles becoming sexually mature and joining the adult population. This definition is specific to Northeast Pacific herring.

Gamete - sperm or unfertilized ova, prior to release from adult fish

Egg – fertilized ovum, adhesive and sessile, within the inter-tidal and shallow sub-tidal zone, with developing embryo, and hatching in ~ 3 weeks

Larva – recently hatched embryo, living off yolk sac (~5 days) and feeding on small (~100 μm) zooplankton, living in surface waters (mainly top 20 m) and part of the zooplankton community, although most abundance in nearshore habitats. In general, larvae are long and thin, with little resemblance to adult forms.

Metamorphic – process of change between larval and juvenile forms (pigmentation beginning, physical change)

Juvenile – the stages between the larvae and sexually mature adult. Young juveniles begin to assume the adult form and develop silvery-colored scales. In general separate cohorts begin to aggregate together and form schools. In general the young juvenile stages are retained in nearshore habitats, but may venture into offshore (continental shelf areas) during their second or third years. The duration of the juvenile stages usually ends at age 3 or 4 when the fish are sexually maturing and joining adult schools.

Adult – the sexually mature stage, beginning at age 3 or 4 (36 – 48 months of age). Adults may form sub-populations that may, or may not migrate to shelf waters for summer feeding. In general adult herring form dense aggregations during winter months and remain relatively immobile and feed opportunistically.

Mass marking – the ability to place a physical or chemical mark on large numbers of fish in order to determine their place of origin

In-situ – taking place in the original environment; not moved

Carrying capacity - The maximum population of a particular organism that a given environment can support without detrimental effects

Otolith - Calcareous particles found in the inner ear

Integrated Herring Restoration Program
DRAFT OUTLINE– September 3, 2008

I. Executive Summary – This section will be completed after the IHRP Working Group workshop.

II. Introduction

The *Exxon Valdez* Oil Spill (EVOS) Trustee Council has classified the Prince William Sound (PWS) population of Pacific herring (*Clupea pallasi*) as a resource that has not recovered from the effects of the 1989 oil spill. The PWS herring population was increasing prior to 1989 with record harvests reported just before the spill. The 1989 year class was one of the smallest cohorts of spawning adults recorded, and by 1993, the fishery had collapsed with only 25% of the expected adults returning to spawn. The PWS fishery was closed from 1993 – 1996 but reopened in 1997 and 1998 based on an increasing population. Numbers again declined and the fishery remains closed today. Reasons for the population collapse and failure to recover remain largely unknown.

The main goal of this plan is to determine what, if anything can be done to successfully recover Pacific herring in Prince William Sound from the effects of the *Exxon Valdez* Oil Spill. In order to determine what steps can be taken, this plan will examine the reasons for the continued decline of herring in the Sound, identify and evaluate potential recovery options, and recommend a course of action for achieving restoration.

Based on the current information on Pacific herring in Prince William Sound, the Herring Steering Committee recommends the following recovery objective:

Restore the herring population in Prince William Sound (PWS) to a recovered status via a collaboration process between science and impacted communities:

- Develop a collaboration between science and impacted communities
- Determine the reasons for the lack of recovery of the PWS herring population
- Determine the social, economic and ecological feasibility of intervention
- Monitor and evaluate the success of restoration efforts
- Improve accuracy of population predictions with more reliable information

The population of PWS Pacific herring will be considered recovered when:

1. The spawning biomass has been above 43,000 metric tons for 6 to 8 years and;
2. There have been two “strong” recruitments of age 3 fish (≥220 million fish) in those 6 to 8 years, where strong is ≥ 220 million fish (or log deviation ≥ 5.67) and;
3. Spawning occurs in at least three regions of PWS (e.g. North, East and West).

1. Why Herring, Why Now?

Nineteen years have gone by since the Exxon Valdez Oil Spill and herring numbers are still too low to sustain a commercial fishery. More importantly, perhaps, is the fact that herring are an integral part of every inshore ecosystem on the northwest coast of North America and we cannot consider the Prince William Sound ecosystem recovered from the effects of the oil spill until herring abundance has been restored.

Herring are vital to many different species, man included. They are probably the most important species for transferring energy from zooplankton to upper level predators such as whales, sea birds and larger fish. It is their very placement in the food chain and the complex interactions between their food source, zooplankton, and their predators that makes the examination of herring restoration very challenging. Each step in their life cycle and the concomitant interaction with either food or predator could be the "bottleneck" point or limiting factor(s) prohibiting their recovery. Herring have not recovered naturally and it is time to make a concentrated and coordinated effort to identify the most likely limiting factors and to identify enhancement opportunities based upon rigorous science.

Scientific research has been conducted on all the injured species in Prince William Sound and the injured services have been examined in great detail. Several recovering species have direct links to herring and are a tangible measure of the importance of this keystone species to a full recovery of all species and the ecosystem as a whole. All recovering human services are in some way linked to the recovery of herring with commercial fishing having, perhaps, the most far-reaching implications. The economic effects of commercial fishing losses are felt across entire communities, from fisherman themselves to all the service industries.

There is urgency to looking at herring restoration now because there is still a viable, remnant stock from which to work. Additionally, a momentum has been developed and a partnership developed between the scientists and the affected communities which can carry this effort far.

2. The *Exxon Valdez* Oil Spill and Pacific Herring

The PWS herring population was increasing prior to 1989 with record harvests reported just before the oil spill (Figure 1).

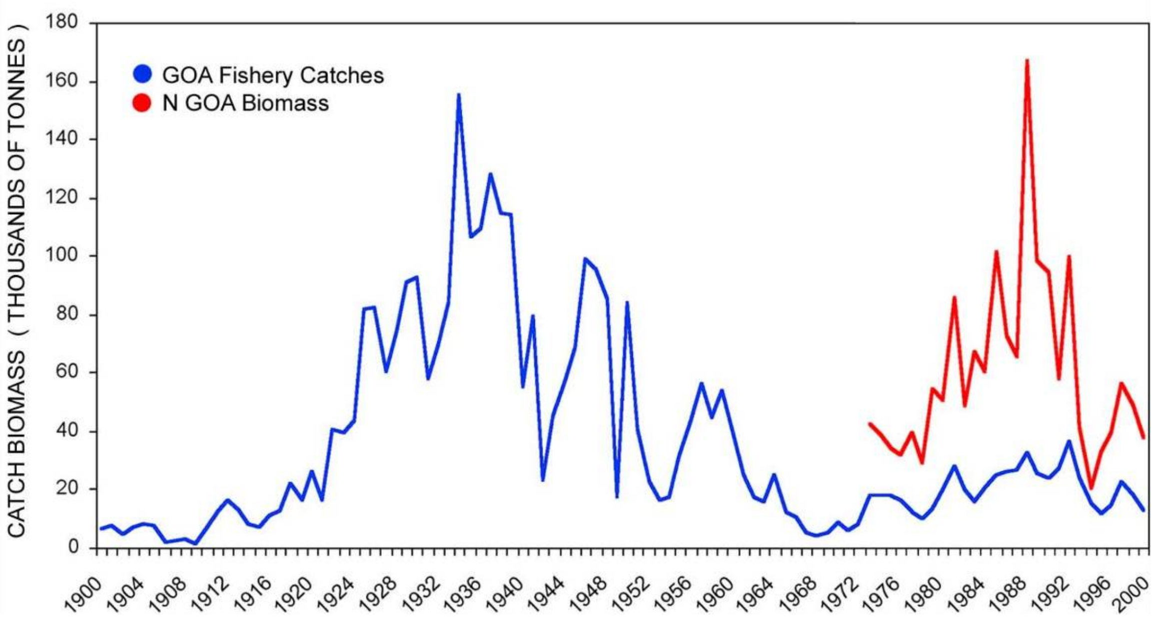


Fig. 1. Pacific herring fishery catches in the Gulf of Alaska (blue line) and estimated annual biomass of herring in PWS (red line) (Brown, 2007).

After the oil spill, the 1989 year class of herring was one of the smallest cohorts of spawning adults recorded, and by 1993, the fishery had collapsed with only 25% of the expected adults returning to spawn.

The population collapse stopped the commercial fishery, and ignited debate about the cause. Some are convinced that the spill was the cause; others believe it was caused by natural systems (Rice and Carls 2007). Unfortunately, we will never know with certainty what the cause was or when it started, as the there is a conflict between data interpretations (Hulson et al. 2008, Thorne and Thomas 2008). Unhealthy fish were detected at the same time as the crash, but disease surveillances were not underway in the previous years. Hydro-acoustic estimates of over wintering populations were initiated in 1993, after the decline in population was detected, and hence are not available during or prior to the decline or crash. The spill certainly affected the 1989 year class, as eggs and as larvae, resulting in one of the poorest recruitments ever observed. While oil continues to linger on some beaches in PWS, lingering exposures to new year classes is not suspected because there is little or no overlap of present day spawning sites with lingering oil. There is no known mechanism for continued oil exposures to this species. Direct oil effects were no longer detectable after 1990 in herring (Pearson, Elston et al. 1999; Carls, Marty et al. 2002) and strong recruitment of the 1988 year-class (in 1991) suggested that oil effects were restricted to the 1989 year class. No plausible oil-related mechanisms have been developed to explain a delayed response after intervening years of no response. Understanding the cause of the population decline or crash, and when it started, is no longer possible with certainty.

3. Basic Herring Biology

The Pacific herring is one of 180 species of fish classified within the family Clupeidae and the order Clupeiformes. They occur in waters of the continental shelf from northern Baja California to arctic Alaska, westward to Russia and south to Japan and the west coasts of Korea. They also occur along the Arctic Ocean from the White Sea eastward to Ob Inlet (Hay 1985) (Figure 2).

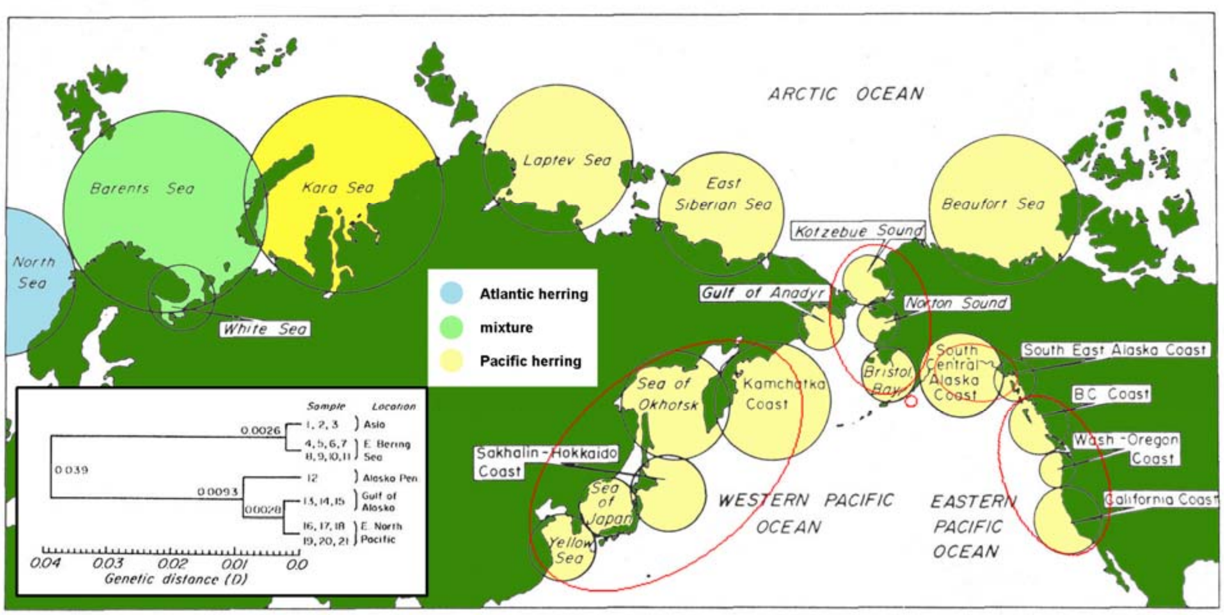


Fig.2. Global distribution of Pacific herring (adapted from Hay 1985)

The four Pacific herring life stages, eggs, larvae, juveniles and adults, are all found in PWS in various seasons and locations (Brown and Carls 1998). Spawning in PWS typically takes place in April and the spawning season varies from five days to three weeks. Pacific herring typically spawn along the same beaches each year, although the volume of eggs and shoreline distances varies (Brown and Carls 1998; Carls et al. 2002). For example, from 1994 to 1997, the annual spawning beach length ranged from 23.3 to 68.5 km (Willette et al. 1998). Figure 3 shows Pacific herring spawning beds located throughout PWS based upon 1973 - 2006 data from the Alaska Department of Fish and Game (Moffitt 2006, pers. comm.)

During spawning, the eggs attach to eelgrass, rockweed (*Fucus* sp) and kelp in shallow subtidal and intertidal areas. The eggs hatch in May, about 24 days after spawning depending on temperature (Hart 1973; Brown and Carls 1998). After hatching the larval herring migrate to the surface, congregate nearshore and continue to grow. Initially, the larvae have yolks that will last a few days, are poor swimmers and currents significantly affect their distribution. The larvae become juveniles in July, about 10 weeks after hatching. In the fall, the juveniles move into deeper water but nearshore habitat remains important for at least the first year, and they may spend up to two years in nearshore areas or bays before joining the adult population residing in deeper waters (Brown and Carls 1998).

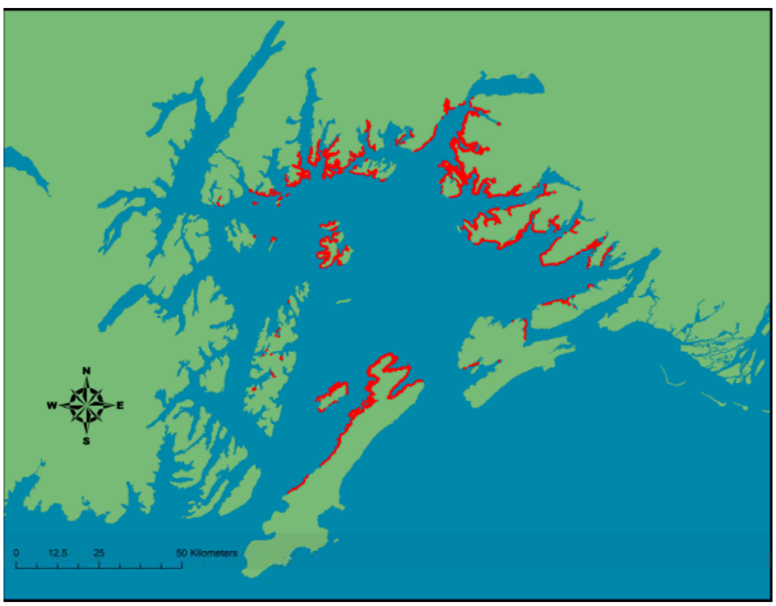


Fig.3 Pacific herring spawning beds located throughout PWS based upon 1973 - 2006 data from the Alaska Department of Fish and Game (Moffitt 2006, pers. comm.)

In PWS, adult Pacific Herring rarely spawn before their third year and may live up to 15 years. The average life span of a PWS herring is 9 years. After spawning in the spring, adult Pacific herring disperse from the spawning aggregations to multiple schools in deeper waters, presumably close to the entrance of PWS (Brown and Carls 1998). In the fall, adult and two year old fish return from summer feeding areas and over-winter in central and eastern PWS.

Newly hatched larvae carry a yolk sac that is typically depleted in the first week. The earliest larval stages begin feeding on invertebrate eggs and small zooplankton such as copepods. While the larval Pacific herring grow and congregate nearshore through their first summer, they continue to live mainly on copepods but may also eat other crustaceans, barnacle larvae, mollusk larvae or young fishes (Brown and Carls 1998). As they move into deeper waters, copepods remain an important food for both juvenile and adult pacific herring, but adults also feed on larger crustaceans and small fish. During winter, as temperature and light decrease, food supply becomes limited and both young and adult year classes stop feeding functionally. Survival of young herring through the winter depends on the amount of food that was available in the preceding summer and their ability to store sufficient lipid reserves to sustain them over the winter. For the older age classes, winter is less limiting on direct survival, but may affect their reproductive condition and spawning capacity in the spring (Carls et al. 2001).

III. Integrated Herring Restoration Program – Programmatic

1. Introduction

This section of the Integrated Herring Restoration Program (IHRP) will address the administrative and programmatic issues of maintaining the program. It will discuss how the Herring Steering Committee will communicate with the Trustee Council, Restoration office, researchers and project leaders, agency personnel and the public.

2. Integrated Herring Restoration Program Steering Committee

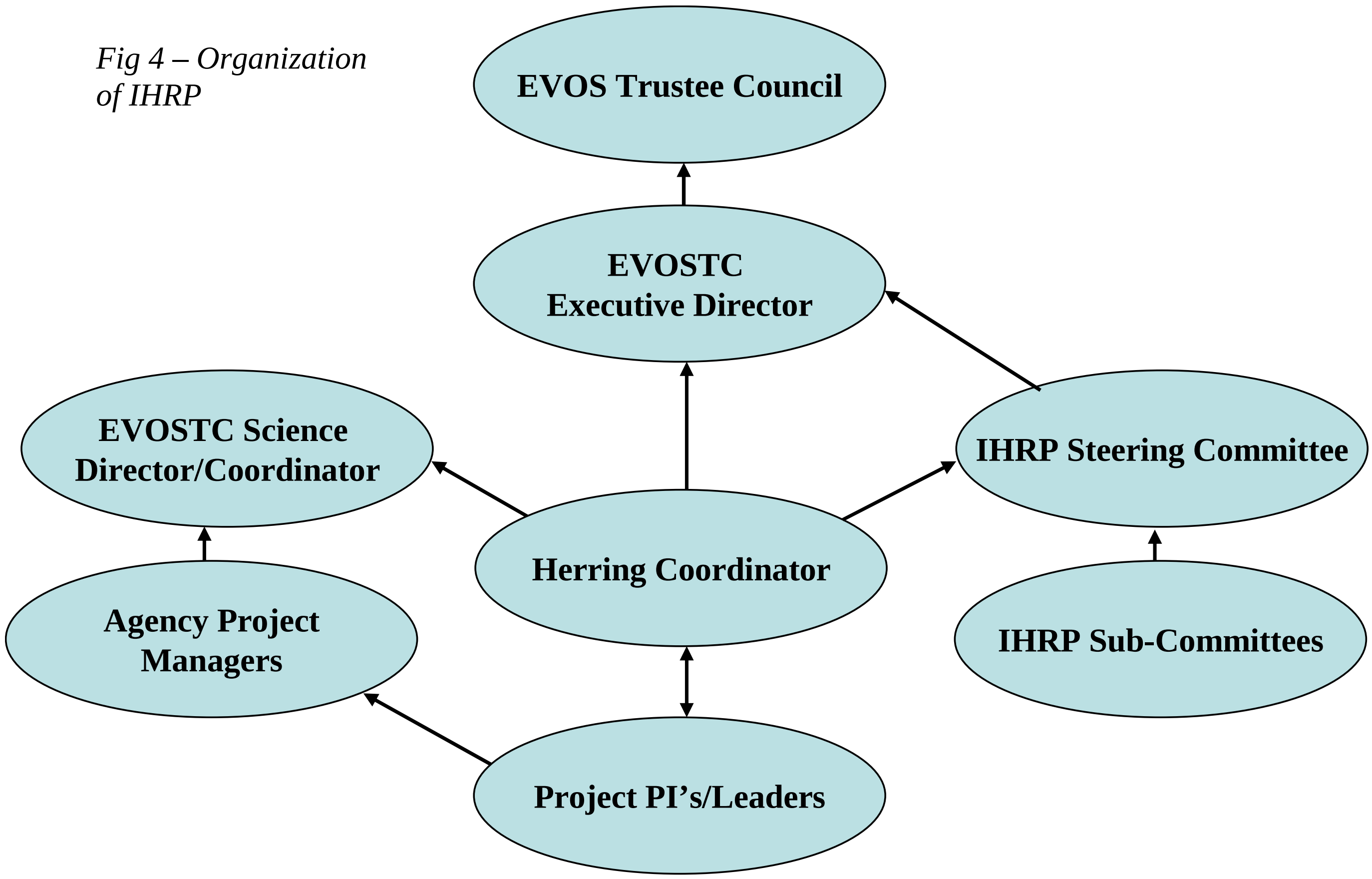
The Steering Committee consists of scientists, agency representatives, commercial fishermen, and members of the public. The Committee has been tasked with the creation and implementation of the Integrated Herring Restoration Program and is responsible for making recommendations to the Executive Director on project proposals, progress reports, and final deliverables. The group currently consists of 10 Steering Committee members and will meet on a bi-annual basis. Two temporary sub-committees have been formed for topic specific experts to address issues, including the writing of the IHRP and current marking technologies that may be applicable to PWS herring. Sub-committees will be formed as needed to address topics and members will be selected from both the Steering Committee at large and from national experts on specific topics. Sub-committees will not be permanent and will be called upon when needed. The main tasks of the Steering Committee will be to:

- Write and continually update the IHRP
- Make recommendations to the Executive Director on project proposals, progress reports, and final deliverables
- Identify the need for sub-committees to address specific topics
- Ensure open communication and data sharing between funded projects

a. Organization

The Steering Committee will provide guidance to the Executive Director and will work closely with the EVOSTC Restoration office and agency project managers to meet its identified goals (Figure 4).

Fig 4 – Organization of IHRP



b. Decision making

The IHRP Steering Committee will function on a majority vote basis and will make recommendations as a group. Any dissention in the group on a topic will be provided along with the majority recommendation to ensure that all information is available to the Executive Director and the Trustee Council prior to making any decisions. The group will convene as needed over the course of the fiscal year, but will have two standing meetings scheduled each year.

c. Internal review program

The review process for the IHRP Steering Committee will vary based on the topic for review. The following critical project stages will be reviewed using the following criteria:

Project Proposals – Upon receipt of project proposals, a meeting of the Steering Committee will be arranged to review and make recommendations on each proposal.

Confidentiality and non-disclosure agreements will be signed prior to distributing the full proposals to the Committee members. They will also receive any anonymous peer reviews received for each proposal for their review. The will also received any anonymous peer reviews received for each proposal for their review. Proposals that are received from a Committee member's agency, institution, or co-worker will not be shared with that Committee member and they must recuse themselves from any discussion or recommendation on that specific proposal(s).

After reviewing and discussing each proposal, the Committee will make recommendations to the Executive Director for each proposal based on its scientific merit, ability to answer questions identified by the Committee in the request for proposal, and how well the project will integrate with existing efforts. A majority vote will determine if a project is recommended for funding.

Project Progress Reports – Project progress on its identified objectives will be reviewed by the Committee at its bi-annual meetings. Each principal investigator (PI) will be responsible for providing a detailed report of the project's progress to both the Steering Committee and the assigned agency project manager 30 days prior to the identified Steering Committee meeting date. PI's may attend the meeting either in person or via telephone to aid in the discussion of the project's progress. The Steering Committee will make recommendations, if necessary, to the PI, Executive Director, and agency project manager for needed changes in scope, schedule, or level of integration. The Executive Director will be made aware of any projects that are not meeting their identified goals or are not working as part of the integrated team to allow for corrective action to be taken by the Trustee Council.

Project Final Reports/Deliverables – The Committee will review all final reports and deliverables for each project to ensure that the information gained is incorporated into the IHRP. The committee will provide feedback to the EVOSTC office staff that will be added to independent peer reviews and incorporated into each final report/deliverable.

d. Reporting structure

This section addresses the internal reporting structure of the Steering Committee, the reporting required of each PI to the committee, and how the committee will report to the Executive Director and Trustee Council.

Internal reporting – The Steering Committee will communicate between meetings through email, teleconferences, and a web-based forum. Two standing meetings will be scheduled during each fiscal year and other meetings will be scheduled as needed to address specific topics.

Principal Investigator reporting – Each principal investigator will be expected to provide an in-depth review of their project's progress 30 days prior to each of the two Steering Committee meetings. The review will be provided to their assigned agency project manager who will forward them to the EVOSTC Restoration Specialist for distribution to the committee. The report will detail each of the project's objectives and what work has been accomplished to date on each, an update of the project's schedule, and a summary of how local communities have participated or been made aware of their progress.

Reporting to the Executive Director – The Steering Committee will provide a written summary of each meeting to the Executive Director within 14 days of the end of the meeting. The summary will provide details of the discussion, recommendations of the committee based on the items reviewed, and a timeline for items that need action prior to the next meeting.

e. Herring coordinator

A herring coordinator has been recommended by the group to assist with logistics, internal and external communication, and to coordinate the efforts of the Steering Committee. The herring coordinator would be housed at the EVOSTC restoration office in Anchorage, Alaska and would report directly to the Executive Director. The main tasks of this full-time position would include:

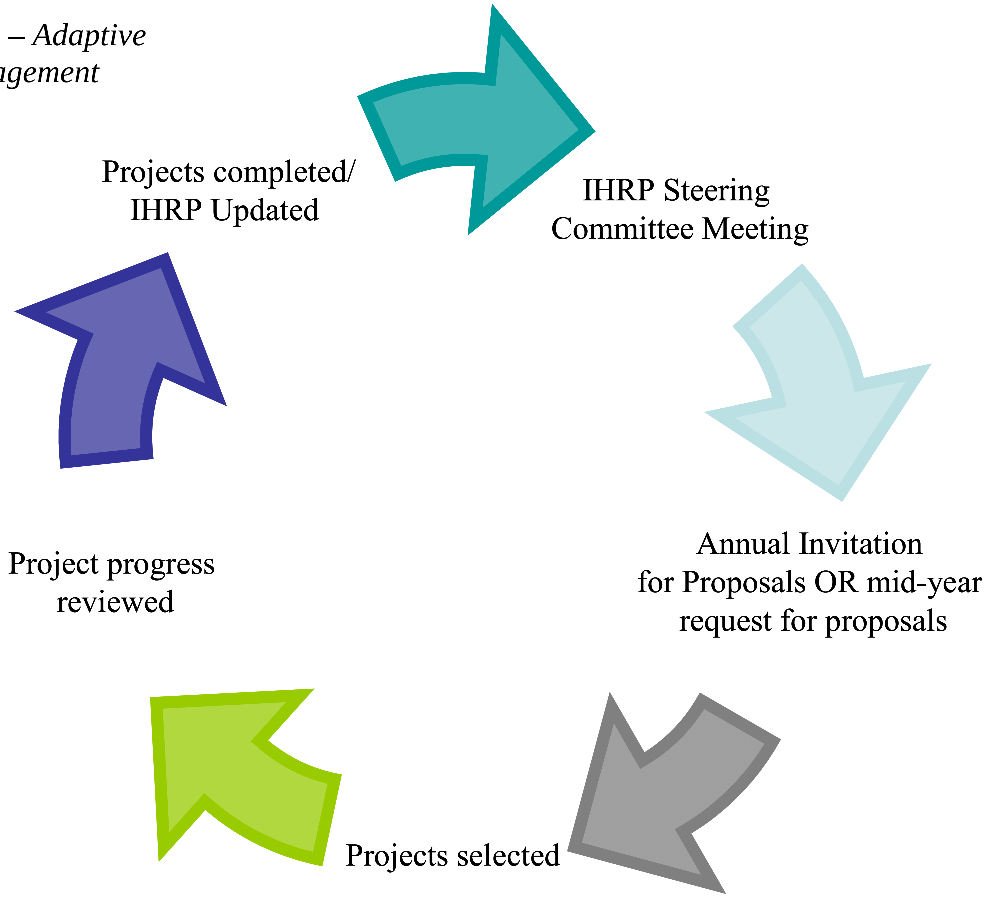
1. Coordination of all project logistics including vessel time, laboratory time (if appropriate), data transfer, and information sharing between the PI's.
2. Communication of the PI's and Steering Committee's progress to the Executive Director and the Trustee Council.
3. Scheduling of the bi-annual workshops and any necessary meetings throughout the fiscal year.
4. Updating of the Integrated Herring Restoration Program document under the guidance of the Steering Committee.
5. Updating of the herring information webpage on the EVOTC website.

f. Adaptive Management Cycle

The restoration program for PWS herring can be managed adaptively where the problem evaluation, policy decisions, research, monitoring and outcomes are all related in a way that leads to logical decision making and provides order and context for the various program activities. (Figure 5)

Flexibility will be key in determining the course of decisions for each fiscal year and the chart below illustrates the management cycle. At any point in the process, the Steering Committee can make the decision to begin back at the beginning of the cycle if necessary. An example of how the program can be adapted to meet particular goals would be if a project's progress is reviewed and it is determined that additional scope is needed or if a question has been raised in the research that requires a separate study. The Steering Committee can elect to meet again and begin the request for proposals cycle at any point in the year.

Fig 5 – Adaptive Management



3. Administrative Procedures

a. Semi-Annual Workshops

In order for the Steering Committee to make recommendations in a timely manner, two meetings per fiscal year will be scheduled as standing meetings and will include all members of the Steering Committee. The meetings will last approximately three-four days and will be held in Cordova, Alaska. Sub-committee and full Steering Committee meetings may be called throughout the year as needed and will be publicly advertised. All meetings will be open to the general public. The semi-annual workshops will serve to discuss proposals, project progress reports, and final reports and deliverables. The group will also discuss updates to the Integrated Herring restoration program document and determine if any corrective action is needed.

b. Logistics coordination

Prior to the appointment of a herring coordinator, the funded PI's will be expected to prepare a detailed schedule of any required vessel or laboratory time, required samples, and community involvement activities as part of their original proposal. At the first workshop of the fiscal year, this information will be shared with the group to assist in the sharing of necessary resources to minimize overall cost. As part of any project's progress report or final report, they must detail the coordination that has taken place with other funded projects.

c. Funding cycle

While the Steering Committee recommends the continued use of the annual invitation for proposal cycle, there is recognition that projects may be identified throughout the fiscal year to maintain the momentum of the IHPP. When these projects are identified by the Steering Committee, an invitation for proposals related to that specific project will be generated and reviewed by the Trustee Council, legal counsel, and agency liaisons prior to being made public. Recommendations for funding will be provided by the Steering Committee to the Trustee Council based on the proposals received for their funding consideration.

d. Data sharing Program

Open sharing of information, particularly collected scientific datasets and their associated metadata, between projects is a required component of the IHRP. Timely availability of collected datasets allows for helpful crosschecks, comparisons, and improved accuracy of research results for each project. It can also generate new ideas for needed research that are not currently anticipated.

The Trustee Council's Data Policy (revised March 17, 2008 and available at http://www.evostc.state.ak.us/Policies/data.cfm) remains in effect for all projects participating in the IHRP. Like all EVOSTC projects, IHRP projects are required to provide copies of final datasets for public distribution at the time the final report is completed, as outlined in the Data Policy.

In addition to the requirements of the Data Policy, principal investigators participating in the IHRP are required to make collected and processed datasets available to other IHRP projects within a reasonable timeframe after collection, allowing for necessary processing and turnaround time. Consistent with the Data Policy, such datasets will not be made publically available until the final report is completed at the conclusion of the project.

Beginning in the FY09 funding cycle, and in future fiscal years, proposals for IHRP projects must include a detailed schedule showing reasonable data collection, processing, and availability timeframes for each proposed year of the project. These timeframes will be reviewed, as part of the evaluation of the overall proposal, for reasonability and applicability to other projects. For projects that began in previous fiscal years and are continuing into FY09, the principal investigator must provide a detailed schedule of future data collection, processing, and availability timeframes to the EVOSTC Data Manager by November 30, 2008.

Principal Investigators must inform the Herring Coordinator and Data Manager as soon as possible if the dataset submission timeframes described in the proposal cannot be met so that an alternate delivery date can be arranged. It is the responsibility of each Principal Investigator to meet their data sharing obligations by making datasets available in a timely manner. The Data Manager will inform the EVOSTC Executive Director of projects consistently failing to provide datasets in a timely manner, and future funding for such projects may be withheld.

Datasets are to be shared with other IHRP projects using the web-based ProjectView application (available at http://www.evostc.state.ak.us/Projects/View/Login.cfm). ProjectView provides a secure method for sharing datasets and metadata between IHRP projects without making them available to the general public.

Investigators may upload datasets (and associated metadata) to ProjectView directly and share them with other IHRP projects, or provide them to the EVOSTC Data Manager by email, CD, or other agreeable method for uploading and sharing.

To reduce the probability of errors and preserve scientific integrity, it is recommended that only processed datasets be shared. Unprocessed (raw) datasets may also be shared (at the discretion of the principal investigator responsible for collecting the data) if requested by investigators from other projects. Any unprocessed datasets that are shared should be clearly marked as such in their description, and to distinguish them from other datasets, which are assumed to have been processed unless otherwise noted.

e. Use of technology for communication

Constructive communications between the parties involved is critical to the success of this Program. Participants are encouraged to use the discussion forum located at http://www.evostc.state.ak.us/forum to discuss projects or ideas and comment on important documents. The forum software preserves the comments made for future reference and makes them available to all participants immediately. Forums are available for members of the Steering Committee. Threaded discussions, document attachment, and email subscription capabilities are available to all participants.

f. Intellectual capital

The open discussion of project ideas and proposals is of some concern to the Steering Committee. In order to ensure that these discussions are as open as possible, each member of the Steering Committee will sign a non-disclosure and confidentiality statement at the beginning of the fiscal year.

g. Communication Plan

Recognizing the importance of this work to spill affected communities and the public at large, the Committee will provide for meaningful public involvement and regular updates on the development and implementation of an integrated Herring Restoration Program in PWS. This includes, but is not limited to:

- Provide routine notification of meetings and ensure meetings are open to the public, accessible in person or by teleconference with scheduled time for participation (as needed).

- Provide periodic updates to citizens (especially to spill affected local communities, native villages and corporations), PAC, TC, liaisons and Steering Team.
- Host community forums to report out on progress and solicit input.
- Brief TC members regularly. Arrange to brief elected officials with TC members and steering group members at key milestones.

h. Role of the EVOS Trustee Council Restoration Office

The EVOSTC restoration office will be leading this effort and will be the primary point of contact for the PI's, Steering Committee, and agency project managers. Since the Steering Committee is not a FACA (Federal Advisory Committee Act) group, they will make recommendations to the Executive Director. Prior to acquiring a herring coordinator, the Restoration Specialist will serve as the central point of contact and will be responsible for the coordination of the Steering Committee. The Restoration Specialist will work closely with the Executive Director, Environmental Program Specialist, Data Manager, and agency liaisons to ensure that the IHRP continues to serve the goals of the Trustee Council and to communicate its progress regularly.

i. Role of Agency project managers

The agency project managers will be responsible for keeping the Steering Committee updated on the progress of projects funded as part of the IHRP. The project managers currently use a quarterly update process, which is publicly available, to communicate scope and schedule progress. The agency project managers will also be required to alert the Steering Committee if a project is not meeting its identified goals and objectives.

4. Community involvement

Meaningful community involvement is defined as a substantive role for individuals, communities, and community-based organizations in the design and conduct of research, monitoring, and general restoration activities, in the analysis and application of the results, and in information-sharing in ways that ensure the information is both timely and easily understood.

The Trustee Council has determined that the IHRP will be community-based and will provide this meaningful participation by the local communities that continue to be injured from the loss of herring in the Sound. Community involvement can take many forms and can range from utilizing local vessel charters and guides to utilizing local citizens in the collection and analysis of project data.

Each proposal received as part of the IHRP will be reviewed for its level of community involvement prior to funding, during the course of the project, and in communicating its final deliverables. Assistance will be available to PI's and the Steering Committee through the Communication and Outreach Coordinator at the EVOSTC restoration office.

5. Opportunities for partnering

There are many state and federal agencies and non-governmental organizations currently funding research and restoration projects in Prince William Sound. Opportunities for partnering are numerous and would be mutually beneficial both financially and in the exchange of information. The following organizations are currently funding herring research and would be good candidates for partnering:

- Oil Spill Research Institute (OSRI)
- North Pacific Research Board (NPRB)
- Prince William Sound Science Center (PWSSC)
- Prince William Sound Regional Citizens Advisory Council (PWSRCAC)
- Alaska Ocean Observing System (AOOS)
- University of Alaska, Fairbanks (UAF)
- University of Alaska, Southeast (UASE)
- Alaska SeaLife Center (ASLC)

Each group will be contacted by the Executive Director to determine if a partnership will be beneficial and to determine the form of any potential partnerships. A memorandum of agreement will be signed between the Trustee Council and any interested groups that will detail the level of information and cost sharing. The Steering Committee may invite partners to any of its public meetings to discuss projects or upcoming opportunities.

IV. Integrated Herring Restoration Plan – Restoration Options

1. Factors Limiting Recovery

The effectiveness of any restoration alternative depends on applying that alternative to bypass or overwhelm some limitation in the natural recovery of the PWS herring population. This leads to asking a fundamental question, **what are the factors limiting herring recovery in Prince William Sound?** Several potential factors have been identified including disease, predation, oceanographic changes, contaminants in the habitat, competition, and a combination of factors that lead to poor recruitment.

Addressing the fundamental question requires a research program as part of the restoration plan. However, the fundamental question does not need to be fully understood before restoration activities can begin. As outlined above the integrated program relies on those activities to help address the fundamental question. Below we briefly describe potential limiting factors, then outline a series of research questions that need addressed, and following that describe the linkages to the other potions of this section of the plan.

Disease

A potentially significant factor in the inability of the Pacific herring population in PWS to recover is age-dependent mortality from three pathogens: mesomycetozoan Ichthyophonus hoferi, viral hemorrhagic septicemia virus (VHSV), and filamentous bacteria (associated with cutaneous ulcers). Beginning in 1993 with a severe outbreak of VHSV and ulcers, epidemics have cycled through the Pacific herring population in PWS about every 4 years with decreasing severity since 1993. However, epidemics of I. hoferi have been observed in more recent years.

The causes and effects of the sustained disease problems are not apparent. Unfortunately there are no long-term disease data sets for other herring populations, or other species with which to make comparisons. Immune suppression can be caused after acute exposure to oil, but no herring living today in PWS were alive and exposed in 1989, and no continuing exposure to lingering oil is suspected. An original hypothesis was that disease was a sporadic event associated with exceeding carrying capacity (Marty et al. 1998), but the 1998, 2001, 2002, and 2005 disease events occurred when the population was relatively low. How the current levels of disease and their interaction with other factors, such as predation or poor nutrition, affect mortality rates at the different life stages is unknown.

Predation

Previous research has not eliminated predators as a potential factor in limiting Pacific herring recovery in PWS. Herring are of great importance in the PWS ecosystem; as roughly second- or third-order consumers, they transfer energy from zooplankton to a wide variety of consumers including humpback whales, harbor seals, birds, and other fish. Herring may also significantly influence or control the grazing pressure exerted on lower trophic levels (Cole & McGlade 1998). The relationships between herring and multiple predators is complex, with ample opportunity for large or increasing predator populations to significantly deplete the herring population or prevent recovery.

Oceanographic changes

Pacific herring stocks have been shown to respond to climatic changes. Climatic changes can alter water temperatures thereby affecting the energetics of the fish. Climate changes can also alter the timing and location of productivity important to herring feeding. Changes in currents will alter the larval dispersal and their survival. Biological regime shifts associated with climate change can also alter the predators feeding on herring. Untangling the many threads linking climate variability and the lives of herring can be difficult, but large scale restoration efforts in a climate that is not favorable to herring survival will be futile.

Exactly what conditions are favorable to herring survival remain unknown. Brown (2006) found that the Gulf of Alaska populations have increased during the positive phase of the Pacific Decadal Oscillation, when the Aleutian low intensifies and warm water if found along the Alaskan coast. Although other investigators argue that herring do better during the negative phase of the PDO (Anderson and Piatt, 1999). Linking herring survival to a climatic index still does not indicate what aspects of that climatic index makes survival more likely.

Competition
With depressed population levels it may be possible that another species has filled some of the niches in the ecosystem that herring previously occupied. The competition for habitat or food at some life stage may limit the success of herring. Juvenile gadids, such as saffron cod or pollock, are often found in large numbers in the same habitats as juvenile herring. Although the Sound Ecosystem Assessment program found that there was no food competition between age 0 herring and pink salmon smolts (REF) there may be competition between the two at a different life stage or for a different resource. At least one recent modeling project suggested that hatchery released salmon smolt are responsible for maintaining the depressed herring populations (Deriso et al. 2008). What species the herring may be competing with and for which resource they are competing for is unknown.

Contaminants in habitat
The waters and majority of the PWS shoreline are among the cleanest habitats in the world. Polynuclear aromatic hydrocarbon loads in the water are very low (Carls et al. 2002). Less than 0.2% of the shoreline has evidence of oil contamination, the current and historical human habitation sites and areas where *Exxon Valdez* oil remains (Boehm et al. 2004; Short et al. 2002 report). Only trace concentrations of persistent organic pollutants (e.g., pesticides and polychlorinated biphenols) are detectable in intertidal areas (Short et al. 2006 report).

While oil continues to linger on some beaches in PWS, lingering exposures to new year classes is not suspected because there is little or no overlap of present day spawning sites with lingering oil. There is no known mechanism for continued oil exposures to this species. Direct oil effects were no longer detectable after 1990 in herring (Pearson, Elston et al. 1999; Carls, Marty et al. 2002) and strong recruitment of the 1988 year-class (in 1991) suggested that oil effects were restricted to the 1989 year class. No plausible oil-related mechanisms have been developed to explain a delayed response after intervening years of no response. Understanding the cause of the population decline or crash, and when it started, is no longer possible with certainty.

2. **Core Data Collection**
This item needs further development by the Herring Steering Committee.

    a. ADFG stock assessment program
    b. Stock assessment program supplement
        i. increased spatial and temporal scale of overwintering (fall & spring) surveys
        ii. evaluation of stock assessment techniques, especially spawn data input
        iii. evaluation of age at maturity (monitor gonad size & weight)
        iv. identification of stock structure (otolith chemistry, tags)
        v. Juvenile surveys (summer, fall, spring)
        vi. establish distribution
        vii. use tags or otoliths to determine spatial contribution

c. Tracking survival and recruitment
    i. impacts of seabird, marine mammal and fish predators and disease
    ii. evaluation of interspecific food competition of herring with pink salmon, sand lance and juvenile Pollock
    iii. evaluate interrelationship among predation, prey availability, competition, and disease
    iv. evaluate food limitation and key food/energy sources (outside or inside PWS) at juvenile and adult stages

3. Overview of Restoration Alternatives

It may be possible to restore herring populations in Prince William Sound through the use of direct restoration or intervention methods such as the moving of fertilized eggs to habitats more favorable for survival or the release of juveniles reared in hatcheries. However, the efficacy of these or other direct restoration methods need to be proven and may remain technically infeasible or too costly. Furthermore, the use of direct restoration activities may cause unintended adverse environmental outcomes such as the increase in incidence of disease to herring or other fishes. Well-designed pilot projects can be used to test the efficacy and provide an experimental platform with which to better understand the factors limiting herring recovery, which must be accounted for in the implementation of full scale restoration activities.

The issue of restoration through intervention and particularly enhancement of marine fish populations is controversial. There is part of the fisheries science community, mainly from the ecological side, that is steadfastly opposed to the concept of marine finfish enhancement. There is another component who are comfortable with the concept. However, even the detractors of the concept suggest that the activity may be warranted when all other conventional management procedures fail. Even then there are reservations about the efficacy of the approach if density-dependent factors regulating recruitment occur after the release of cultured fish.

A decision to investigate the feasibility of a particular intervention alternative does not necessarily mean that the EVOS Trustee Council is committed to implementation of a large-scale intervention program. Instead, the intention is to examine the implications of the concept, as it applies to herring in Prince William Sound. Full scale intervention activities would require several years of preparation, mainly to develop and determine some technological issues, such as mass marking of fish. Mass marking and other technological activities are fundamental pre-requisites of intervention activity. Therefore, because the development of these technological issues will take time, it is important that some investigations begin immediately. It also is important to understand that these investigations also could result in a definitive conclusion that the restoration activities are impractical or far too expensive.

The Integrated Herring Restoration Plan Steering Committee discussed and prioritized several restoration alternatives. The alternatives are introduced here in a general manner and will be outlined in more detail later in the plan. The alternatives are presented in the order that they were prioritized. Each alternative has advantages and disadvantages that should be considered when designing pilot and full scale programs. Because it is not clear what is the limiting factor to herring recovery it is not possible to predict the efficacy of any alternative so a plan to test the efficacy is essential to the development of that restoration approach.

Regardless of which intervention alternatives are developed, monitoring and research will play an important role in the restoration process. Monitoring will be required as part of any active restoration program to evaluate the efficacy of various active restoration methods, the status of recovery, and the potential occurrence of unintended adverse impacts. Research will be needed to support the particular activity and to identify if limiting factors elsewhere in the herring life cycle will prevent the restoration activity from being effective.

4. **Restoration Options**
   a. **Supplemental Production**
      A supplemental production program is an enhancement activity designed to release cultured herring to supplement natural recruitment so as to assist recovery or restoration of the population to historical levels. Depending on the specific approach taken the effort can bypass early life stage mortality caused by larval drift, food availability, habitat competition, predation, and disease. The herring could be released into nursery habitats after a few months when they reach the juvenile stage. The juvenile herring may also be maintained through the end of the first winter to allow feeding through this potential bottleneck. The cost of the program depends on the length of time that the herring are maintained. All fish released must be marked to allow the efficacy of the program to be determined. With a well designed mark-recapture set of programs it may be possible to address the fundamental questions regarding the factors limiting recovery. There is also the potential for controlling the release site environment in a manner that can inform the efficacy of other restoration alternatives.

      The desired program would provide the information needed for developing a full scale in-situ herring rearing program. Advantages of this alternative include that it directly adds fish to the ecosystem, technology exists for rearing hearing, large numbers of juveniles can be raised past one or more potential limiting factors, and the degree of manipulation should permit marking of all fish. Disadvantages include the higher costs associated with the length of time herring must be cared for and the potential for the release of diseased or inferior stock.

      1. **Action Steps**
         a. Pilot project
            i. Create a project plan
               1. Estimate total pilot project costs by phase
               2. Create a collaboration plan with potential partners

3. Determine population enhancement objectives

ii. Design an operational plan including:
    i. Egg acquisition methods
    ii. staffing/observation schedules
    iii. release timelines
    iv. disease control protocols
    v. caging/netting/tank structure
    vi. feeding protocols (if necessary)
    vii. Permitting (EIS requirements)
    viii. lessons learned from salmon enhancement
    ix. equipment required (Ships, nets, divers, etc.)
    x. program for evaluating outcomes

iii. Develop disease surveillance program in and around the vicinity of the supplementation facility.

iv. Develop safe and effective biosecurity procedures including:
    i. Disease prevention procedures in the supplementation facility.
    ii. Methods to prevent the spread of pathogens from the rearing facility to wild fishes.
    iii. Standard Operating Procedures (SOP's) to implement in the event of disease outbreaks in the rearing facility / locality.

v. Develop procedures to prevent exacerbation of disease resulting from comingling of released fish with wild cohorts.

vi. Based on results of pilot project, if it is decided to proceed
    i. Create a project plan
        1. Estimate total project costs by phase
        2. Create a collaboration plan with potential partners
        3. Evaluate population enhancement objectives
    ii. Design an operational plan including:
        1. Egg acquisition methods
        2. staffing/observation schedules
        3. release timelines
        4. disease control protocols
        5. caging/netting/tank structure
        6. feeding protocols (if necessary)
        7. Permitting (EIS requirements)
        8. lessons learned from salmon enhancement
        9. equipment required (Ships, nets, divers, etc.)
        10. program for evaluating outcomes

2. Science Necessary

a. Year 1 Steps

i. Supplementation hypotheses, objectives, & strategies (intensive vs. extensive)
    11. Cost/Benefit Scale Study
ii. Evaluate the feasibility of marking and recapture technologies
    12. Mark/recapture detectability threshold & interpretation
    13. Maintain the mark/recapture program
iii. Design a program for disease evaluation/control
    14. Evaluate the effect of stress on disease outbreaks
    15. Maintain disease control program
iv. Identify potential egg acquisition, rearing, & release locations
v. Evaluate the carrying capacity/natural food availability in each candidate bay
vi. Evaluate the grow out age/release condition
    16. bio-energetic model
vii. Evaluate the survival, condition, & distribution of post-release juveniles
    17. within nursery area
    18. outside nursery area
viii. Evaluate the effect of juveniles released on natural populations
ix. Evaluate the optimal release cycles
x. Basic understanding of disease kinetics and exacerbation factors including effects of rearing density, temperature, and nutritional status.
xi. Adaptive management strategies intended to mitigate disease.
xii. Expanded diagnostic tools for rapid diagnosis of pathogens and diseases
xiii. Efficacious, long lasting, and safe vaccines that can be easily administered to reared herring.
xiv. Develop required permitting.

3. Technologies Required

a. Mass marking and recapture techniques
    iii. sub-group batch multiple marking
b. Feeding methodologies
c. Food production/composition
d. Containment systems (nets, pens, etc.)
e. Survey techniques

b. Predator Management

Predator Management looks to reduce mortality by controlling the level of predation on herring. Because herring are a popular prey item of fish, birds, and mammals it is quite possible that at the current low levels of herring biomass it is not possible to satiate the predators and herring are stuck in a predator pit. The control of predation on adult fish should decrease mortality leading to increased spawning biomass. The approach looks to reduce predation through the use of fisheries on primary predators, such as walleye pollock, hazing techniques to remove the predators, or protecting fish through the use of barrier systems.

Predator management is very likely to be a controversial approach with the simplest approach being to develop a fishery for some of the dominant predators. More controversial would be the hazing of marine mammals or birds. It has the disadvantages of having no manner to directly test the efficacy, some of the predators are endangered species, and relying on reduction fisheries practices.

1. **Action Steps**
    a. Removing/hazing/barring predators
2. **Science Necessary**
    a. Determine the predators that need to be included
        i. seabirds
        ii. pollock
        iii. marine mammals
            a. sea lions
            b. whales
            c. harbor seals
        iv. flatfish
                iv. arrowtooth flounder
        v. salmon (chum, coho)
    b. Complete overwintering density surveys at:
        i. entry to bay system (beginning of summer)
        ii. leaving bay system (late summer)
        iii. joining adult schools (fall)
        iv. recruitment
    c. Determine energetics models for predators/prey
    d. Complete census of predator/prey fields
    e. Determine time varying age structure of herring (maybe predators also)
    f. Determine time varying distribution of predator/prey movement pathways
    g. Surveys to determine success
3. **Technologies Required**
    a. Active acoustic detection and alarm technologies
    b. Mass marking and recapture techniques
    c. Accurate census of juveniles

c. Egg Relocation

Egg relocation involves moving eggs stranded on the shore back into the water to improve their viability or moving them to another location believed to be more favorable for survival. This approach attempts to reduce mortality at the egg and through the larval drift stages of life. Advantages of the approach are that the manipulation of eggs may allow them to be marked, and the cost is relatively low since handling is minimized. Disadvantages include potential harm to existing eggs during the collection process, the low likelihood of being able to manipulate enough eggs to detect an effect in the population, and it bypasses very few potential bottlenecks in herring recovery so it has a lower likelihood of success.

1. **Action Steps**
   a. Return windrow eggs to the water
   b. Relocation of naturally spawned eggs, on natural or artificial substrate, to more favorable nursery bays
2. **Science Necessary**
   a. Create operational plan for moving/gathering eggs
   b. Create a monitoring plan for moved eggs to determine success
   c. Survey to determine windrow egg quantity (variable in space and inter-annually)
   d. Determine the mortality rate of moving eggs
   e. Determine permitting requirements
   f. Determine hatching success on artificial and natural substrates
   g. Determine effects (if any) of stress on eggs
   h. Determine spatially diverse egg destinations using a larval drift analysis (probability map)
   i. Determine larval carrying capacity/natural food availability
   j. Determine the affect on natural populations
   k. Identify ideal nursery habitats
   l. Determine the larval disease prevalence/exposure
3. **Technologies Needed**
   a. Technology for marking & recapture for evaluation
   b. Circulation model for larval drift analysis

d. Altering carrying capacity by over-winter feeding

Juvenile herring have very limited reserves to make it through their first winter. By feeding fish at this stage it may be possible to significantly decrease the mortality at this critical point in their life. The approach depends on being able to identify the location of overwintering juveniles and providing an appropriate feed for them. It is important that any such program not attract predators or competition for the food resources. A full scale program may require repeat feeding at several locations within Prince William Sound. Advantages of this approach are that cultured herring are known to eat commercial feed, the cost is likely to be moderate, and it may be possible to mark the fish using the feed. Disadvantages include needing to identify appropriate feeding locations, feeding the target species without creating more predation or competition, and ensuring the fish can metabolize the food.

1. **Action Steps**
   a. Provide food
   b. Fertilize
2. **Science Necessary**
   a. Determine what equipment is needed
   b. Determine the appropriate artificial/natural feed
   c. Determine required permitting
   d. Determine bays where juveniles are overwintering
   e. Evaluate overwintering Energetics
   f. Determine the natural survival level in each bay
   g. Determine the predation rates in each bay
   h. Compare herring results with competitor fish
   i. Evaluate efficacy of process
   j. Determine in-situ food availability
   k. Determine oceanographic conditions in each bay
3. **Technologies Needed**
   a. Feeding methodologies
   b. Food production/composition

e. Managing Competition (habitat (space) & food source)

Herring survival at early life stages may be heavily influenced by competition for space or food. Juvenile pollock and some species of cod are known to use the same nursery habitats. It has also been suggested that competition with hatchery salmon may be keeping the herring from recovery. It is even possible that adult and juvenile herring compete for food resources at different points throughout the year. This approach would use fishery management practices to reduce the quantity of fish competing for resources with juvenile herring. Disadvantages include affecting salmon fisheries, not being able to directly measure the effect of the program, and the potential need to develop new reduction fisheries to remove competitors.

1. **Action Steps**
   a. Remove competitors
   b. Cull herring
2. **Science Necessary**
3. **Technologies Needed**

f. Disease Mitigation

Traditional disease management strategies involve an integration of infection prevalence and intensity monitoring with mitigation strategies including prevention with prophylactics, treatment with appropriate therapeutics, and adaptive disease management practices that are evaluated by continued disease monitoring. Although this proven process typically process works extremely well in hatchery situations, where fish are monitored and manipulated under semi-controlled conditions, the traditional disease management process is not appropriate in situations involving populations of wild marine fish, including Pacific herring in Prince William Sound. For example, administration of prophylactics and therapeutics to populations of wild marine fish are complicated by issues involving ecosystem scale and fish community dynamics, and are typically not considered appropriate for populations of wild fishes. These complications have historically prevented the advancement of disease management in populations of wild fish; however, the field of disease ecology has recently emerged and is offering creative ways to mitigate and manage diseases in wild populations.

A disease ecology approach is similar to that employed by the World Health Organization (WHO) and Centers for Disease Control (CDC), and involves a three tiered process involving:

1. Establishment and continuation of infection prevalence and intensity monitoring and surveillances. This component is required to monitor changes that signal the emergence of future epizootics and to evaluate the efficacy of future disease management strategies.
2. Incorporation of empirical studies intended to determine the basic epidemiological relationships between environmental and biological factors influencing infection / disease prevalence.
3. Development of predictive tools, based on known epidemiological relationships, which will be useful in forecasting the potential for future disease epidemics.

Combined, this three-tiered approach will provide the basic epidemiological information necessary to develop and validate adaptive disease management strategies intended to mitigate the effects of future herring disease outbreaks in PWS; these adaptive management strategies can then be evaluated and adjusted through continued monitoring for infection prevalence and intensity. A very clear advantage of this approach over that employed by the WHO and CDC involves utilization of the natural host (Pacific herring), rather than mammalian surrogates for humans, in empirical manipulation studies.

1. **Action Steps**
    a. Develop harvest management strategies to mitigate disease
        i. Culling the population before or during an epizootic
        ii. Curtailing fishing
    b. Maintain population herd immunity

2. **Science Necessary**
    a. Basic understanding of disease kinetics and exacerbation factors
    b. Predictive tools that forecast disease potential
        i. Genetic / molecular tools

c. Bank of herring immune response genes
d. Immunological tools
    ii. Fin ex-plant cultures
e. Epidemiological tools
    i. Processes involved in ickthophonus
f. Evaluate success of the tools and harvest management strategies
g. Annual monitoring
    i. Infection prevalence and intensity monitoring
    ii. Monitoring for susceptibility and disease potential
    iii. Evaluate epizootics
h. Determine cause through sampling
i. Develop vaccines and determine efficacy
j. Develop required permitting

g. Harvest Strategies

The recovery goal outlined in this plan requires a biomass above that currently used to open the fisheries. Therefore, changes to harvest strategies may be needed to allow full rebuilding of the stock. Such changes may include protecting spawning areas from staging and anchoring boats to reduce disturbance to the eggs, changing the fishery threshold, and restricting practices that tend to induce disease. Advantages of the approach include low costs to implement and potentially improved sustainability of the fishery. The disadvantages include not being able to implement until the fishery is reopened and no direct measure of how the changes affect the population.

1. **Action Steps**
    a. Restrict or eliminate fishery gear types that tend to induce disease
        i. Increase or revisit fishery threshold
        ii. Improve accuracy of stock assessment/ASA to minimize risk of over-fishing
    b. Create protected area for spawning
2. **Science Necessary**
    a. Develop predictive tools to forecast future abundance
    b. Maintain existing stock assessment
    c. Strengthen stock assessment monitoring to evaluate effectiveness including egg deposition and GSI (gonad somatic index) & LSI (liver somatic index)
    d. Understand the role of spatial integrity in stock management
    e. Identify characteristics of productive spawning beds
    f. Model reproductive energetics and efficiency
    g. Determine larval drift
    h. Establish/verify predator prey relationships
    i. Establish disease relationships
    j. Determine if immunity can be introduced in-situ
    k. Determine carrying capacity
3. **Technologies Needed**

a. Otolith chemistry for stock identification

h. No action – Allow Natural Recovery

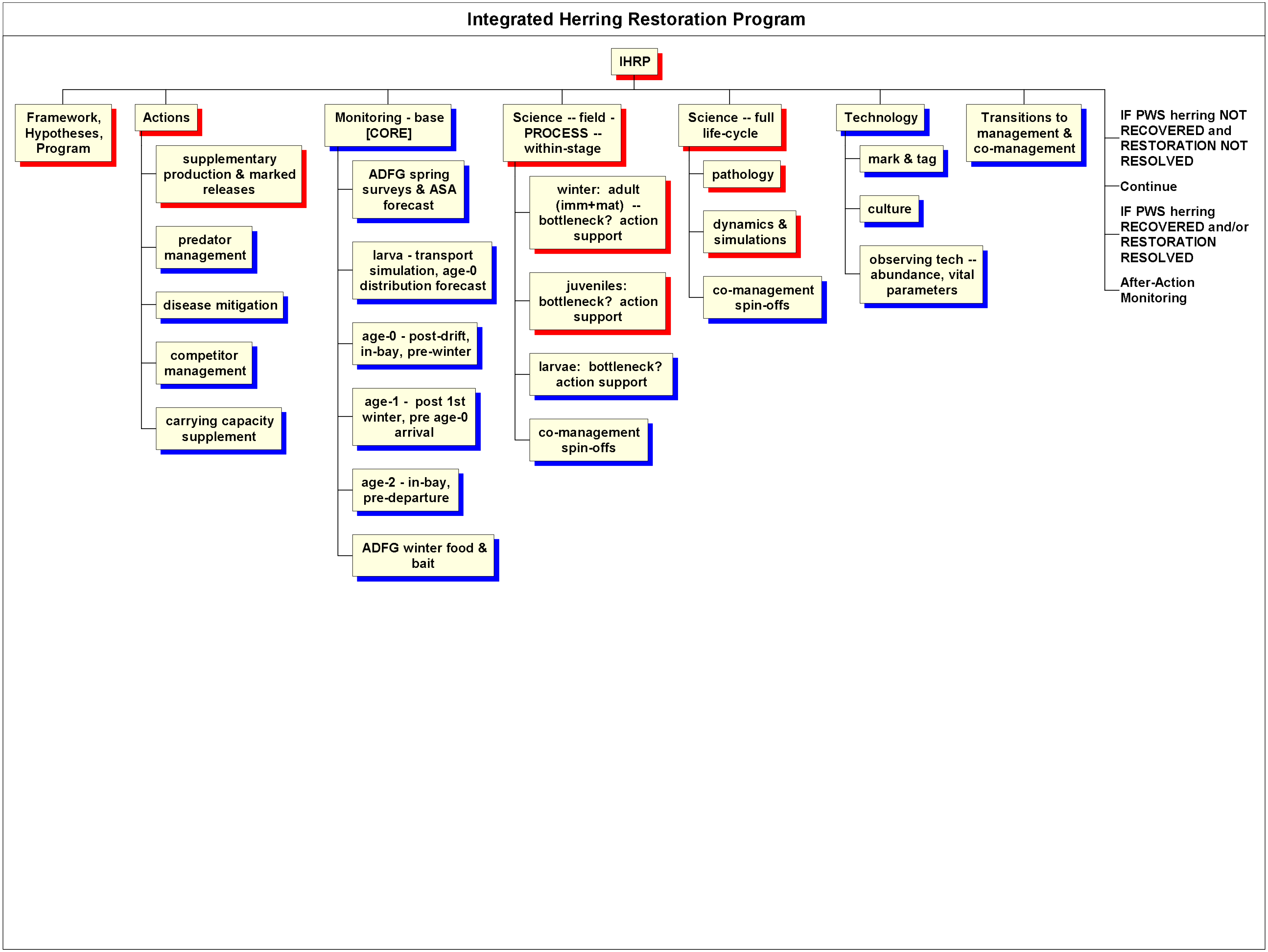
If direct restoration activities are found to be impractical, too costly, or too risky, then monitoring and research may be the only viable means of understanding the natural recovery of the herring populations, or the mechanisms that prevent natural recovery. For example, monitoring and research might lead to a better understanding of the role of disease, predictability of disease outbreaks, and disease management practices that reduce disease impacts. Monitoring of herring populations and critical life-history attributes might also allow for the development of better predictive models of herring stocks, more protective fisheries management practices, and longer-term sustainability of the stock. Furthermore, monitoring and research might reveal unknown sources of human-induced impacts on herring that, if identified, could be ameliorated and removed as an impediment to natural recovery. The tools and understanding developed by monitoring and research would be expected to provide fisheries managers with better predictions of herring populations allowing for more adaptive management practices that will be needed even if active intervention is implemented. The greatest advantage is that no ecological manipulation is required. The disadvantage is that it does nothing to restore herring populations.

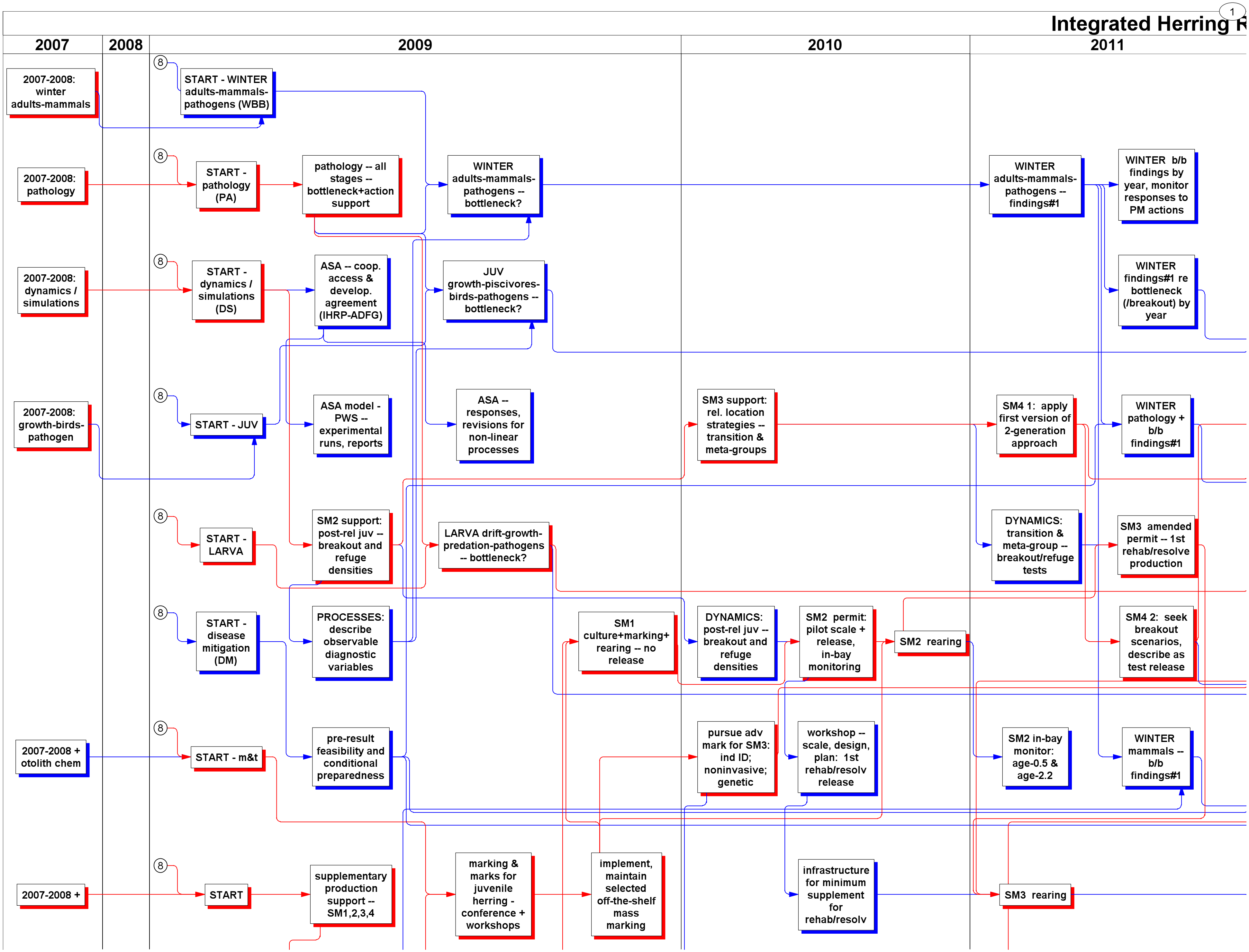
5. Recommendations

During the first year of the program, the Steering Committee would recommend that the Trustee Council pursue the science required to determine the feasibility of the Supplemental Production option.

V. Integrated Herring Restoration Plan - Short and Long Term Plan

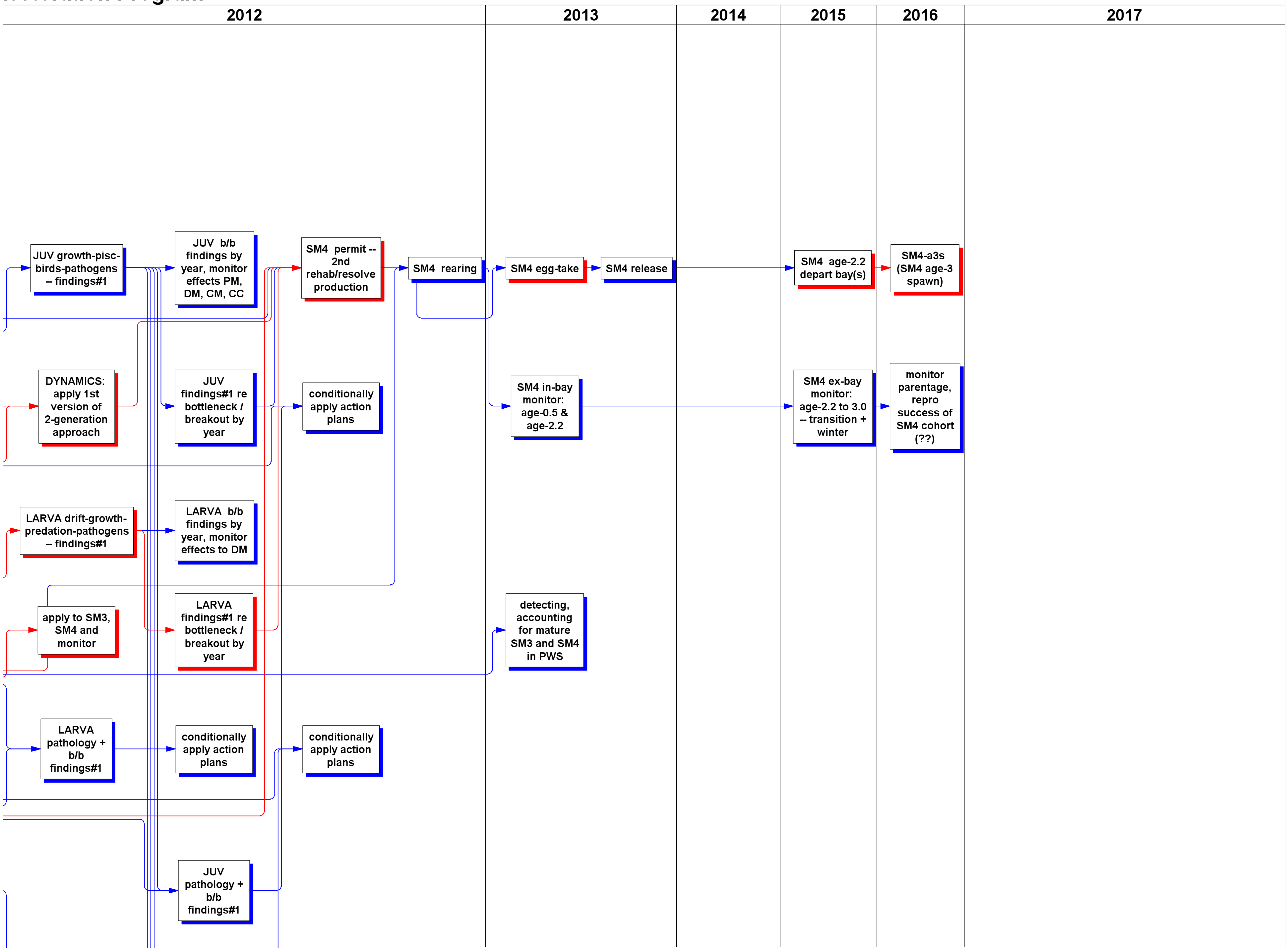
1. Year 1 –
   This will be completed at the Herring Working Group workshop September 8-10
   a. Administrative needs
   b. Recommended project list
2. Year 2
   a. Administrative needs
   b. Recommended project list
3. Year 3
   a. Administrative needs
   b. Recommended project list
4. Year 4
   a. Administrative needs
   b. Recommended project list
5. Year 5
   a. Administrative needs
   b. Recommended project list
6. Long-term Plan
   a. Need for long-term monitoring

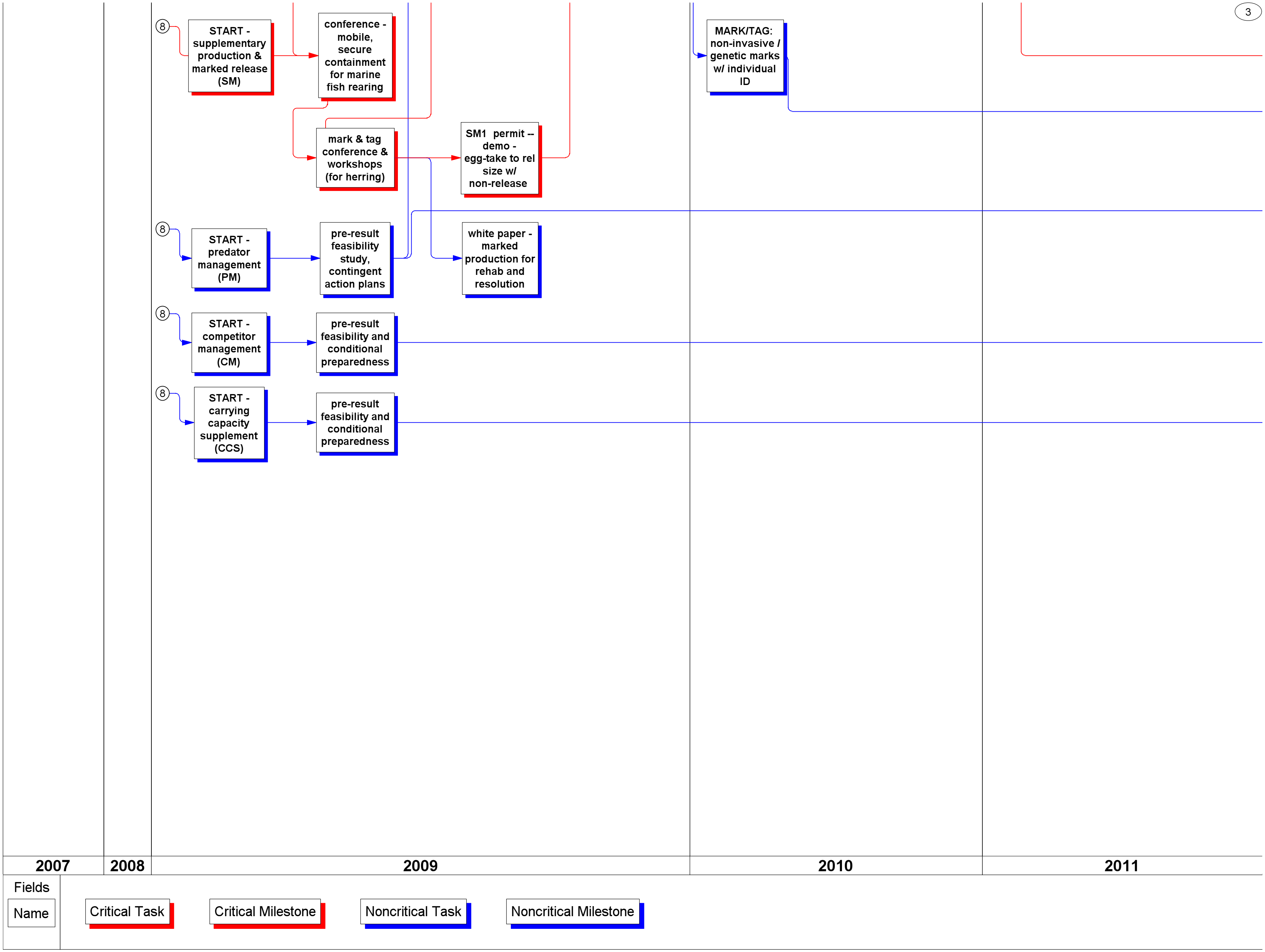

Integrated Herring Restoration Program
IHRP
Framework, Hypotheses, Program
Actions
supplementary production & marked releases
predator management
disease mitigation
competitor management
carrying capacity supplement
Monitoring - base [CORE]
ADFG spring surveys & ASA forecast
larva - transport simulation, age-0 distribution forecast
age-0 - post-drift, in-bay, pre-winter
age-1 - post 1st winter, pre age-0 arrival
age-2 - in-bay, pre-departure
ADFG winter food & bait
Science -- field - PROCESS -- within-stage
winter: adult (imm+mat) -- bottleneck? action support
juveniles: bottleneck? action support
larvae: bottleneck? action support
co-management spin-offs
Science -- full life-cycle
pathology
dynamics & simulations
co-management spin-offs
Technology
mark & tag
culture
observing tech -- abundance, vital parameters
Transitions to management & co-management
IF PWS herring NOT RECOVERED and RESTORATION NOT RESOLVED
Continue
IF PWS herring RECOVERED and/or RESTORATION RESOLVED
After-Action Monitoring

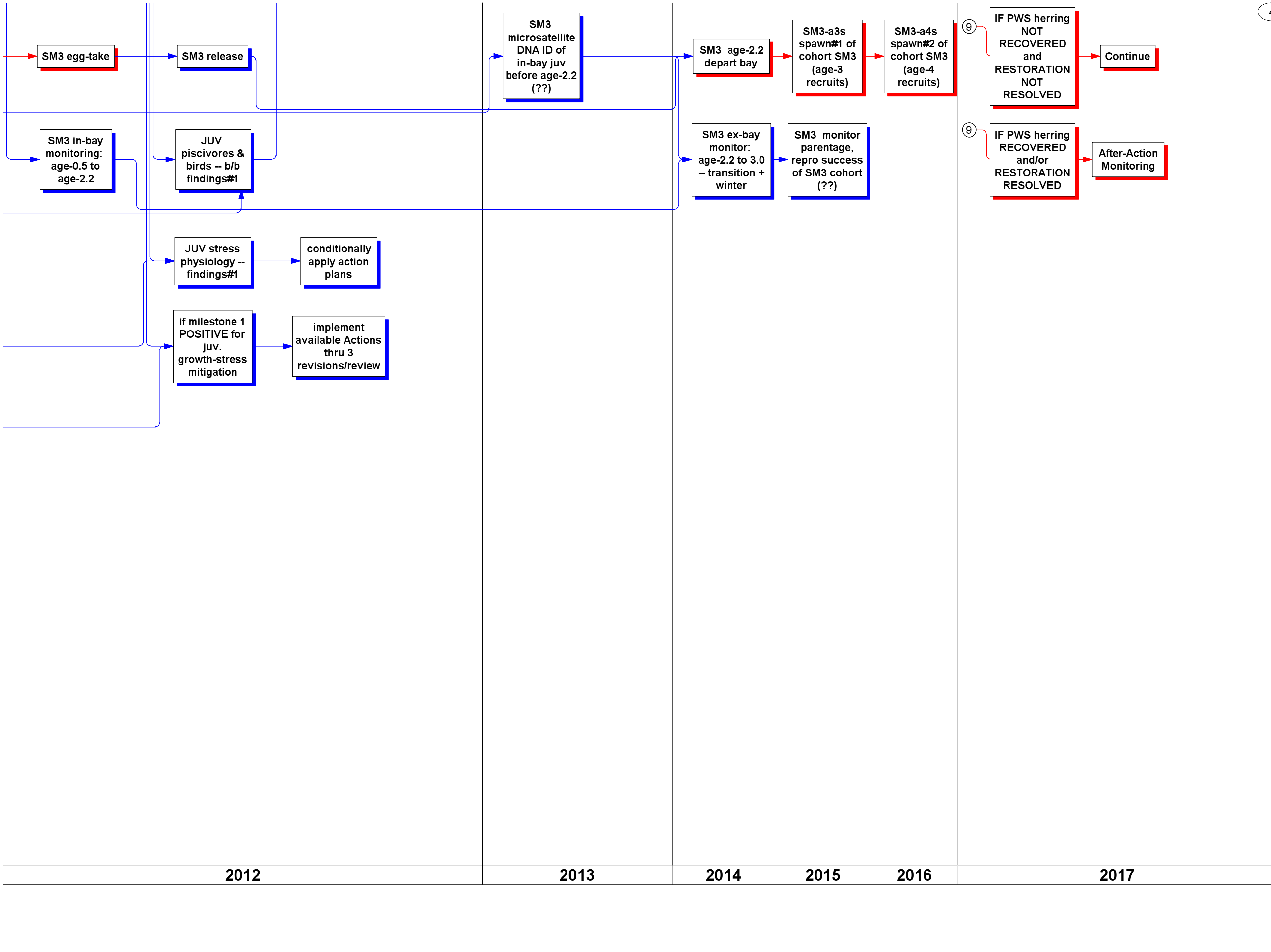


Integrated Herring R
1
2007
2008
2009
2010
2011
2007-2008: winter adults-mammals
8
START - WINTER adults-mammals-pathogens (WBB)
2007-2008: pathology
START - pathology (PA)
pathology -- all stages -- bottleneck+action support
WINTER adults-mammals-pathogens -- bottleneck?
WINTER adults-mammals-pathogens -- findings#1
WINTER b/b findings by year, monitor responses to PM actions
2007-2008: dynamics / simulations
START - dynamics / simulations (DS)
ASA -- coop. access & develop. agreement (IHRP-ADFG)
JUV growth-piscivores-birds-pathogens -- bottleneck?
WINTER findings#1 re bottleneck (/breakout) by year
2007-2008: growth-birds-pathogen
START - JUV
ASA model - PWS -- experimental runs, reports
ASA -- responses, revisions for non-linear processes
SM3 support: rel. location strategies -- transition & meta-groups
SM4 1: apply first version of 2-generation approach
WINTER pathology + b/b findings#1
START - LARVA
SM2 support: post-rel juv -- breakout and refuge densities
LARVA drift-growth-predation-pathogens -- bottleneck?
DYNAMICS: transition & meta-group -- breakout/refuge tests
SM3 amended permit -- 1st rehab/resolve production
START - disease mitigation (DM)
PROCESSES: describe observable diagnostic variables
SM1 culture+marking+ rearing -- no release
DYNAMICS: post-rel juv -- breakout and refuge densities
SM2 permit: pilot scale + release, in-bay monitoring
SM2 rearing
SM4 2: seek breakout scenarios, describe as test release
2007-2008 + otolith chem
START - m&t
pre-result feasibility and conditional preparedness
pursue adv mark for SM3: ind ID; noninvasive; genetic
workshop -- scale, design, plan: 1st rehab/resolv release
SM2 in-bay monitor: age-0.5 & age-2.2
WINTER mammals -- b/b findings#1
2007-2008 +
START
supplementary production support -- SM1,2,3,4
marking & marks for juvenile herring - conference + workshops
implement, maintain selected off-the-shelf mass marking
infrastructure for minimum supplement for rehab/resolv
SM3 rearing

Restoration Program




3
8
START - supplementary production & marked release (SM)
conference - mobile, secure containment for marine fish rearing
mark & tag conference & workshops (for herring)
SM1 permit -- demo - egg-take to rel size w/ non-release
MARK/TAG: non-invasive / genetic marks w/ individual ID
8
START - predator management (PM)
pre-result feasibility study, contingent action plans
white paper - marked production for rehab and resolution
8
START - competitor management (CM)
pre-result feasibility and conditional preparedness
8
START - carrying capacity supplement (CCS)
pre-result feasibility and conditional preparedness
2007
2008
2009
2010
2011
Fields
Name
Critical Task
Critical Milestone
Noncritical Task
Noncritical Milestone


SM3 egg-take
SM3 release
SM3 microsatellite DNA ID of in-bay juv before age-2.2 (??)
SM3 age-2.2 depart bay
SM3-a3s spawn#1 of cohort SM3 (age-3 recruits)
SM3-a4s spawn#2 of cohort SM3 (age-4 recruits)
9
IF PWS herring NOT RECOVERED and RESTORATION NOT RESOLVED
Continue
SM3 in-bay monitoring: age-0.5 to age-2.2
JUV piscivores & birds -- b/b findings#1
SM3 ex-bay monitor: age-2.2 to 3.0 -- transition + winter
SM3 monitor parentage, repro success of SM3 cohort (??)
9
IF PWS herring RECOVERED and/or RESTORATION RESOLVED
After-Action Monitoring
JUV stress physiology -- findings#1
conditionally apply action plans
if milestone 1 POSITIVE for juv. growth-stress mitigation
implement available Actions thru 3 revisions/review
2012
2013
2014
2015
2016
2017

VI. References

Batten, S.D. 2007. Acquisition of Continuous Plankton Recorder Data. Restoration Project 070624. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 22 pp.

Bickford, N.A., B.L. Norcross. 2007. Herring Restoration in PWS: Identifying Natal and Nursery Habitats. Restoration Project 070782. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 34 pp.

Bishop, M.A., K.J. Kuletz. 2007. Seabird Predation on Juvenile Herring in Prince William Sound. Restoration Project 070814. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 48 pp.

Boehm PD, Page DS, Brown JS, Neff JM, Burns WA. 2004. Polycyclic aromatic hydrocarbon levels in mussels from Prince William Sound, Alaska, USA, document the return to baseline conditions. Environmental Toxicology and Chemistry 23:2916-2929.

Brown, E.D. and M.G. Carls. 1998. Restoration notebook: Pacific herring (*Clupea pallasi*). Exxon Valdez Oil Spill Trustee Council, Anchorage, AK. 8 pp.

Carls, M.G., G.D. Marty, and J.E. Hose. 2001. Synthesis of the toxicological and epidemiological impacts of the Exxon Valdez oil spill on Pacific herring in Prince William Sound, Alaska. Restoration Project 99328. *Exxon Valdez Oil Spill Trustee Council Final Report*, Anchorage, AK. 86 pp.

Carls, M. G.; Marty, G. D.; Hose, J. E. 2002. Synthesis of the toxicological impacts of the *Exxon Valdez* oil spill on Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska, USA. *Canadian Journal of Fisheries and Aquatic Sciences*, 59, (1), 153-172.

Cole, J., McGlade, J. 1998. Clupeoid Population Variability, the Environment and Satellite Imagery in Coastal Upwelling Systems. Reviews in Fish Biology and Fisheries 8:445-471

Gay, S.M. 2007. Project 070817. Physical oceanographic factors affecting productivity in juvenile Pacific herring nursery habitats. Restoration Project 070817. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 20 pp.

Gay, S. M., Vaughan, S.L. 2001. Seasonal hydrography and tidal currents of bays and fjords in Prince William Sound, Alaska. Fisheries Oceanography 10: 159-193

Hart, J.L. 1973. Pacific fishes of Canada. Bulletin 180. Fisheries Research Board of Canada, Ottawa, Canada. 740 pp.

Hay DE. 1985. Reproductive biology of Pacific herring (Clupea harengus pallasi). Can J Fish Aquat Sci 42(Suppl 1):111-126.
Herschberger, P., J. Hansen, D. Elliott, E. Emmenger, R. Kocan, G. Kurath, S. LaPatra, J. Winton. 2007. Restoration Project 070819. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 77 pp.

Hulson, J.F., Miller, S.E., Quinn, T.J., Marty, G. D., Moffitt, S. D., Funk, F. 2008. Data conflicts in fishery models: incorporating hydroacoustic data into the Prince William Sound Pacific herring assessment model. ICES Journal of Marine Science, January 1, 2008; 65(1): 25 - 43.

Kiefer, D.A., E. Brown, V.M. Tsontos. 2007. An Ecosystem Model of Prince William Sound Herring. Restoration Project 070810. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 50 pp.

Lindeberg, M.R. 2007. *ShoreZone* mapping for Prince William Sound. Restoration Project 070805. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 32 pp.

Matkin, C. 2007. Monitoring, Tagging, Feeding Studies, and Restoration of Killer Whales
in Prince William Sound/Kenai Fjords in 2007. Restoration Project 070742. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 25 pp.

Meuret-Woody, H. 2007. Identification of Essential Habitat for Pacific Herring (Clupea Pallasi) in Sitka Sound for Comparison to Prince William Sound i.e. Source vs. Sink Habitat. Restoration Project 070834. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 32pp.

Moffitt, S.D., R. Bochenek. 2007. Herring Data and Information Portal. Project 070822. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 24 pp.

Otis T, Heinz R, Bickford N. 2007. Using otolith chemistry to discriminate Pacific herring stocks in Alaska. Restoration Project 070769. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 18 pp.

Pearson, W. H., R. A. Elston, et al. 1999. Why did the Prince William Sound, Alaska, Pacific herring (Clupea pallasi) fisheries collapse in 1993 and 1994? Review of hypotheses. Cananadian Journal of Fisheries and Aquatic Sciences 56: 711-737.

Rice, S., Heintz, R., Moran, J., Quinn, T., Straley, J. 2007. Significance of Whale Predation On Natural Mortality Rate of Pacific Herring in Prince William Sound. Restoration Project 070804. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 51 pp.

Thorne, R. E., and Thomas, G. L. 2008. Herring and the "Exxon Valdez" oil spill: an investigation into historical data conflicts. ICES Journal of Marine Science, 65: 44–50.

Vollenweider, J.J., Heintz, R.A. 2007. Are Herring Energetics in PWS a Limiting Factor in Successful Recruitment of Juveniles and Reproduction Investment of Adults? Restoration Project 070806. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 27 pp.

Willette, T.S., Carpenter, G.S., Hyer, K. and J.A. Wilcock. 1998. Herring natal habitats. Restoration Project 97166. *Exxon Valdez Oil Spill Trustee Council Final Report*, Anchorage, AK. 257 pp.

Weingartner, T. 2007. Long-Term Oceanographic Monitoring of the Alaska Coastal Current. Restoration Project 070340. *Exxon Valdez Oil Spill Trustee Council Project Proposal*, Anchorage, AK. 32 pp.