GULF OF ALASKA

INTEGRATED ECOSYSTEM RESEARCH PROGRAM

2009-2014

IMPLEMENTATION PLAN

SEPTEMBER 2008

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I. Introduction

The National Research Council (NRC) gave guidance for the 2005 North Pacific Research Board (NPRB) Science Plan and stated that the Integrated Ecosystem Research Program (IERP) concept is critical and without it, "…the NPRB will at best be a collection of loosely related projects, not a well-integrated program." The NRC believes that encouraging multidisciplinary, ecosystem-wide research can provide one of the most important, long-term legacies of the Board (NRC 2004). In developing an IERP, the NRC urged the Board to identify the most pressing management needs and questions, select a priority for a focused IERP, and then organize a workshop specific to that question, with the right participants and a clear mandate for the group to define what needs to be measured and where, and what hypotheses to test. The NRC noted that the Board, with its limited resources, should support development and use of complex biophysical/ecosystem models to focus research efforts and synthesize observations from long term monitoring projects and other historical data as available. The ultimate goal should be prediction of future ecosystem states in response to the combination of natural variability and human activities. Another important goal is to determine the limits of ecosystem predictability, all useful information for resource managers and policy makers.

Taking much of this advice to heart, the NPRB developed and implemented an Integrated Ecosystem Research Program for the Bering Sea that was launched in fall 2007, and which is currently completing its first field year. The NPRB is now revisiting the planning for the Gulf of Alaska IERP which was started more than two years ago and has already included the planning processes suggested above. Implementation of the GOA-IERP was put on hold in April 2007 in order to learn from the Bering Sea experience, look for partnerships, and to develop a program comparative in scientific merit and scope to that in the Bering Sea. After more development earlier in 2008, it is now ready for release as an initial call for pre-proposals and then a call for full proposals in 2009.

II. Gulf of Alaska Science

1. The Gulf of Alaska Ecosystem

The Gulf of Alaska is dominated by the strongest and most persistent currents found along either coasts of North America. These conditions reflect the influence of weather and climate and provide the link to efficiently transfer physical and biological "signals" from lower latitudes of the North Pacific Ocean into the northern GOA. The frequency and intensity of storms and the seasonal acceleration by fresh water establishes a "conveyor belt," carrying phytoplankton, zooplankton, larvae, juvenile fishes and climate signals north and west along the coast. During the summer, the conveyor belt slows in response to the onset of the North Pacific high-pressure system in the GOA. Some evidence suggests that climatologically, the small scale wind fields over the shelf in the northern Gulf of Alaska reverse, causing mid-shelf upwelling (See Chelton et al. 2002, *Science*). Such a reversal of the winds and hence conveyor belt over the outer shelf would allow deep water below the surface to overrun the shelf break at some locations, providing a crucial source of nutrients for coastal areas.

The Alaska Current and Stream and the Alaska Coastal Current are vigorous circulation features that extend across several domains within the GOA. As such, they represent alongshore pathways for planktonic organisms and contaminants. Exchange between the shelf and the basin may be mediated by frontal instabilities along the shelf break, large eddies passing along the continental slope (Fig. 1), flow-topography interactions, and cross-shelf Ekman transport within the surface and bottom boundary layers. Coastal waters in the GOA are considerably modified by heat exchange with the atmosphere, freshwater discharge from land, and cross-shelf transports (of freshwater, nutrients, heat, plankton, fish eggs and larvae) induced by winds, shelf break eddies, and changes in shelf bathymetry and coastline, and thus provide a changing environment for organisms moving through the region. These modifications are

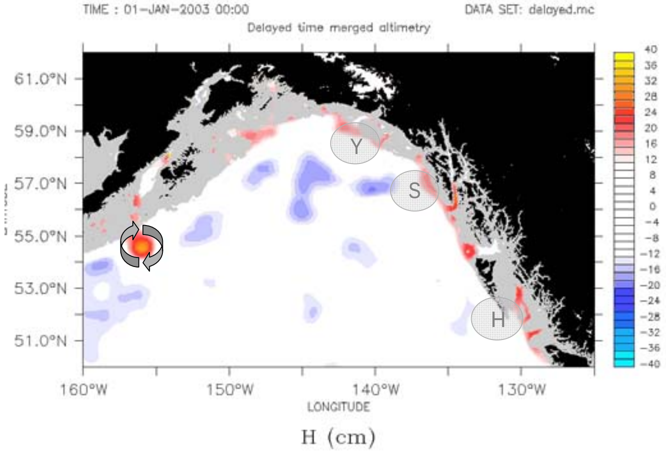

Figure 1. Eddy formation regions (Yakutat, Sitka, Haida) in the Gulf of Alaska (courtesy of Carol Ladd, NOAA)

especially evident in the areas dominated by the large embayment estuaries of the southeast island archipelago, Prince William Sound (PWS), Kenai Fjords, Cook Inlet, and Shelikof Strait. These unique ecosystems are critical components of the northern GOA in terms of providing nurseries and habitat for juveniles of many species of commercial and/or subsistence value. The structure and function of these systems are not well understood, but appear to be critically dependent upon abiotic and biotic exchanges between the adjacent shelf and slope.

Relatively little is understood regarding the mechanistic coupling between atmospheric and oceanographic (including nutrient fluxes) elements of this ecosystem and its secondary production. In the western GOA, shifts in atmospheric forcing (including small scale local winds) and oceanic forcing can impact transport and the presence of eddies in the Alaskan Stream, thus affecting the flux of nutrients and plankton onto the shelf and larvae off the shelf. Fluctuations of strength and eddy behavior of the Alaska Coastal Current may impact ecosystem dynamics, including recruitment of fish species. Enhancing our knowledge of the linkage from atmosphere to forage fish could provide the answer to why higher trophic level populations appear stable in some domains and not in others. For example, the positive or stable population growth of Steller sea lions, sea otters, crabs and other marine biota in the eastern GOA while similar populations are less vital in the western GOA and BSAI may merit further examination.

Fish fauna consists of a mix of temperate and subarctic species, resulting in a large gradient in species composition along the shelf from the eastern to the western GOA. The largest CPUE during summer typically occurs at or below the shelf break and there are strong cross-shelf gradients in species composition and diversity. In contrast, primary production is highest on the shelf and in coastal embayment and shows extreme variability with high standing stocks and productivity, and nutrient depletion, in the summer. Again, plankton composition has high spatial variability and distinct cross-shelf gradients. There are few reliable estimates for primary production for either the shelf or the central GOA. The nearshore areas serve as important spawning and nursery grounds for juveniles of numerous demersal and pelagic species, including salmon, pollock, cod, crab and over 20 species of flatfishes. The life history of many of these species is closely tied to the cyclonic boundary currents, which transport eggs and larvae and serve as important migratory pathways for juvenile salmon.

The system is also influenced from the top down, resulting in what has been described as the cascade hypothesis for the North Pacific Ocean. This hypothesis contends that the depletion of whales through hunting, and Pacific Ocean perch and herring through fishing, decreased the competition for prey for pollock (Springer et al. 2003, PNAS). As a result, pollock biomass showed large abundance increases throughout the 1970s, further extenuated by the 1976/77 regime shift. Larger predation by pollock may have increased predation on forage fishes, thus causing competition with marine mammals, such as the Steller sea lion. In the end, the possibility that whaling could have such far reaching effects in the ecosystem over many decades is sobering and illustrates our need to better understand the mechanisms and trophic interactions regulating marine populations (see also DeMaster et al. 2006, *PO*). Over the last decade, however, pollock has decreased again and arrowtooth flounder dominates many of the assemblages (Fig 2). The multi-factorial aspect of ecosystem forcing supports the notion that the pulsing of the system by perturbations, natural or anthropogenic, could result in different biological responses depending on the state of the system at that time (Spies 2007, *Elsevier*). Future predictions of ecosystem state and function become complicated by the fact that there is little evidence that regimes return to the same states after the perturbation has switched back to an earlier condition, as is very apparent with the cod fishery off the east coast of Canada. Several hypotheses of how this system ultimately functions have been proposed (see Mundy 2005, *Sea Grant* for a review) and the major elements that make up the GOA ecosystem have been previously identified (Fig. 3). Determining what upper trophic level population is regulated by what mechanism, and how this mechanism may react to future changes, is one of the large challenges of an integrated ecosystem program.

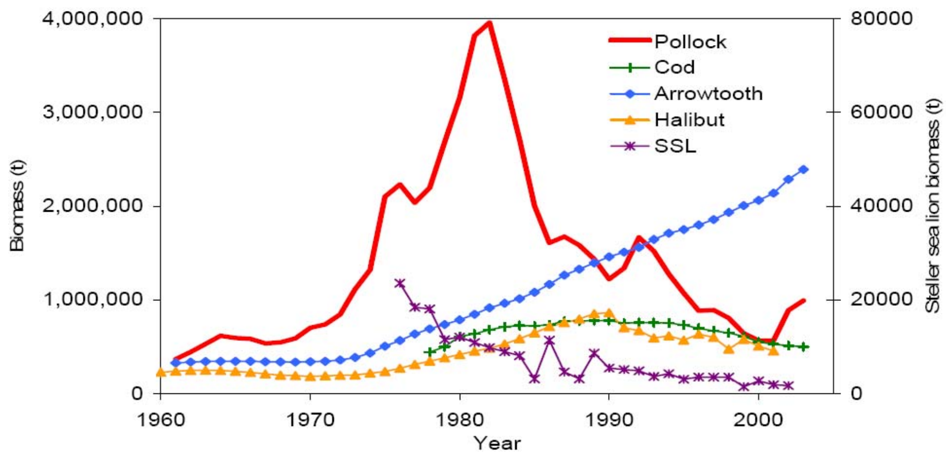

Figure 2. Biomass estimates of major GOA groundfish species (SAFE, 2007)

Figure 3. Physical and biological elements of the Gulf of Alaska ecosystem (courtesy of Phil Mundy, published in Mundy 2005)

2. Building upon existing knowledge

a. Programs

Although large gaps remain in our understanding of the Gulf of Alaska marine ecosystem, ocean research in the Gulf has been ongoing for decades and much data have been collected. Any new program needs to take a careful look at how to best build upon previous studies to capitalize on the existing knowledge and data. For example, a series of retrospective analyses of data collected in the Gulf of Alaska was funded under the Northeast Pacific GLOBEC program (Appendix 1). Many relevant datasets are available publically at their website http://globec.oce.orst.edu/data_access/data_index.html as well as at the PMEL metadata archive http://www.pmel.noaa.gov/np/mdb/index.htm. In addition, a large series of papers, especially on the oceanography, lower trophic level productivity, and factors influencing salmon productivity in the GOA, has been published in recent years (http://www.usglobec.org/issues.php). GLOBEC's investment in this region was $40M (1997-2008) with the goal to determine ecosystem processes regulating salmon populations. The program is currently in its synthesis phase, ending in 2010 (GLOBEC Report 21: Strategies for Pan-Regional Synthesis in U.S. GLOBEC).

Also, NPRB has funded 108 projects, totaling just over $16M (http://project.nprb.org/), in the GOA between 2002 and 2008, from ecosystem modeling to oceanography, lower trophic levels, to fish, birds, mammals and humans, including a synthesis of knowledge specifically for Southeast Alaska (Eckert, project 406). Furthermore, the Exxon Valdez Oil Spill Trustee Council (EVOSTC) has funded ecosystem type projects particularly in PWS since 1994 (http://www.evostc.state.ak.us/Projects/SearchStart.cfm), including SEA and GEM, which focused on understanding and monitoring the physical and biological drivers of production of birds, fish (particularly herring and pink salmon) and mammals, especially for those species injured in the 1989 oil spill (Pearcy 2001, Mundy 2005). Some of the main conclusion from GEM and SEA/APEX are summarized in Appendix 2. In the last two years, EVOSTC has returned to a strong focus on factors regulating herring. The NOAA Alaska Fisheries Science Center maintains regular research (e.g. FOCI, SECM) and groundfish survey and assessment programs in the Gulf (http://www.afsc.noaa.gov), and a variety of coastal labs (Fig. 4) conduct smaller scale research program around the rim of the GOA ecosystem.

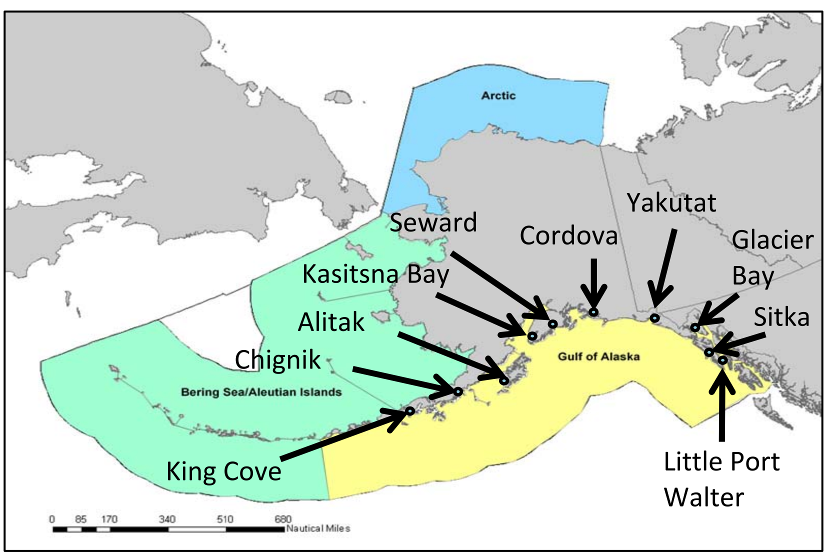

Figure 4. Location of coastal facilities and fishing operations in the Gulf of Alaska.

In summary, there is a substantial amount of data collection and integration that has occurred to date, and many ongoing projects that will provide essential pieces of information to help understand how this marine ecosystem functions. Integration and expansion of these existing datasets will assist in directing additional retrospective studies and field components so that adaptive sampling or long term monitoring can best inform forecast models (see below).

Below is a short summary of such ongoing efforts, specifically in terms of monitoring and modeling. Retrospective efforts were mentioned above, and potential process studies are further discussed in section III. These descriptions are not intended to be complete lists, nor are they meant to show that sufficient research is being conducted to not warrant more support. Rather, they mean to illustrate the past, present and future scope of work in this area in order to ensure collaboration and utilization of the foundations laid to date.

b. Monitoring

Data collected through long-term monitoring projects are key to addressing questions regarding ecosystem function and change. There is a series of ongoing monitoring efforts in the Gulf of Alaska. Some were started as part of GLOBEC (Fig. 5), including the Seward Line (NPRB Project 804). Others include the S-N, and E-W Continuous Plankton Recorder (CPR; supported by NPRB and EVOSTC, Fig. 6), oceanographic sampling from ferries (Fig. 7; NPRB Project 707), beached bird surveys (COASST, NPRB Project 612, Fig. 8), the AOOS demonstration project in PWS that combines monitoring, modeling and process (Fig. 9), as well as a variety of coastal monitoring projects as part of the coastal lab activities (Fig. 4). In addition, USFWS and USGS conduct seabird colony monitoring (Fig. 10), with a focus in the GOA on St. Lazaria Island, PWS, Barren Islands and Middleton Island, as well as ship board surveys for seabirds and mammals on ships of opportunity supported by NPRB (Project 637). Also, NOAA conducts regular monitoring of harbor seals, sea lions and commercial fish stocks throughout the area.

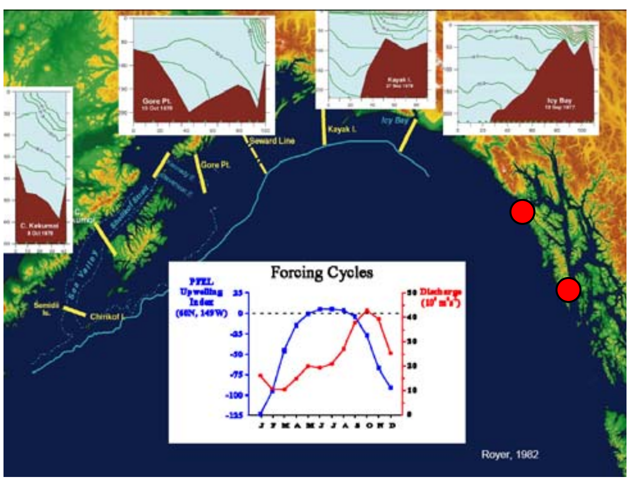

Figure 5: GLOBEC and other monitoring lines and NOAA buoys (red dots).

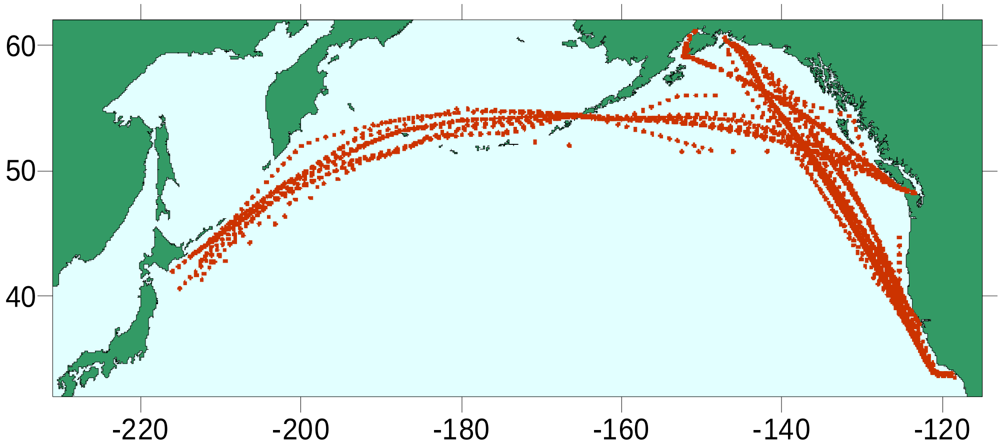

Figure 6: Continuous Plankton Recorder sampling 2000-2008 (Spring, Summer and Fall)

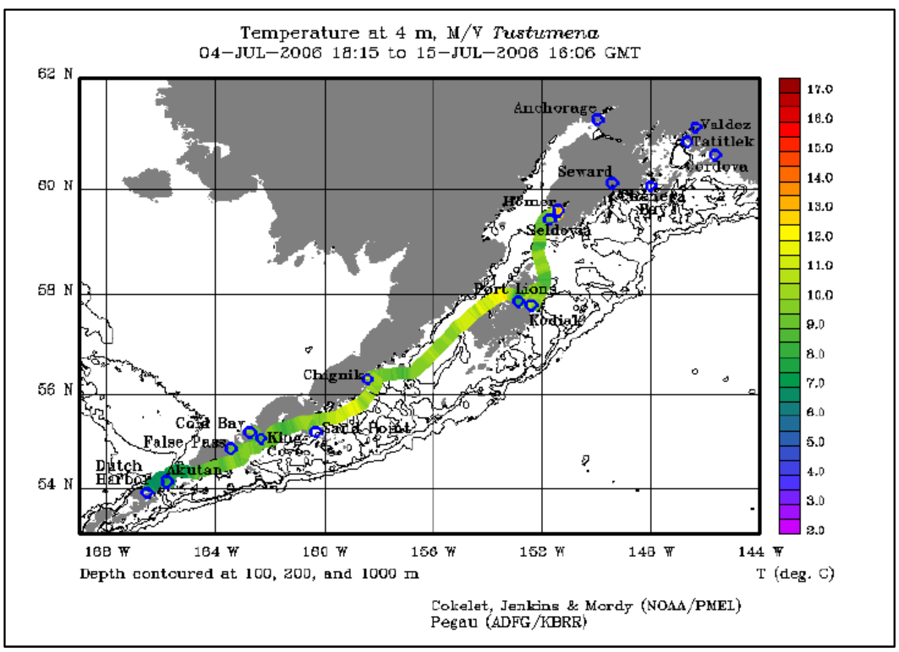

Figure 7: Near surface temperature sampled from the Alaska ferry *Tustumena* in October 2005.

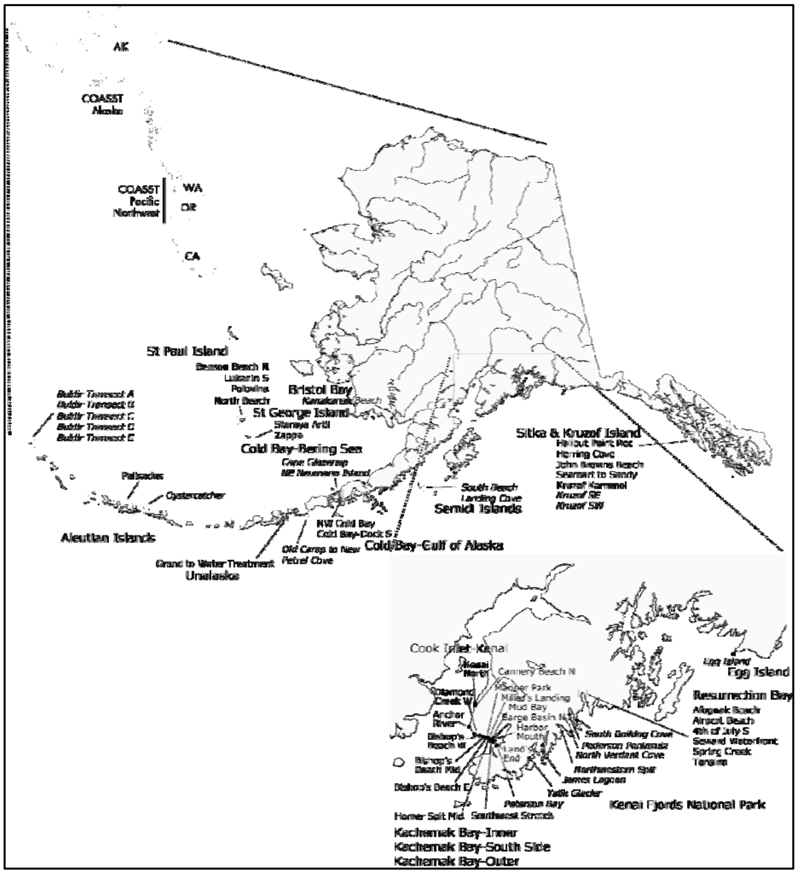

Figure 8: Location of COASST beaches in Alaska.

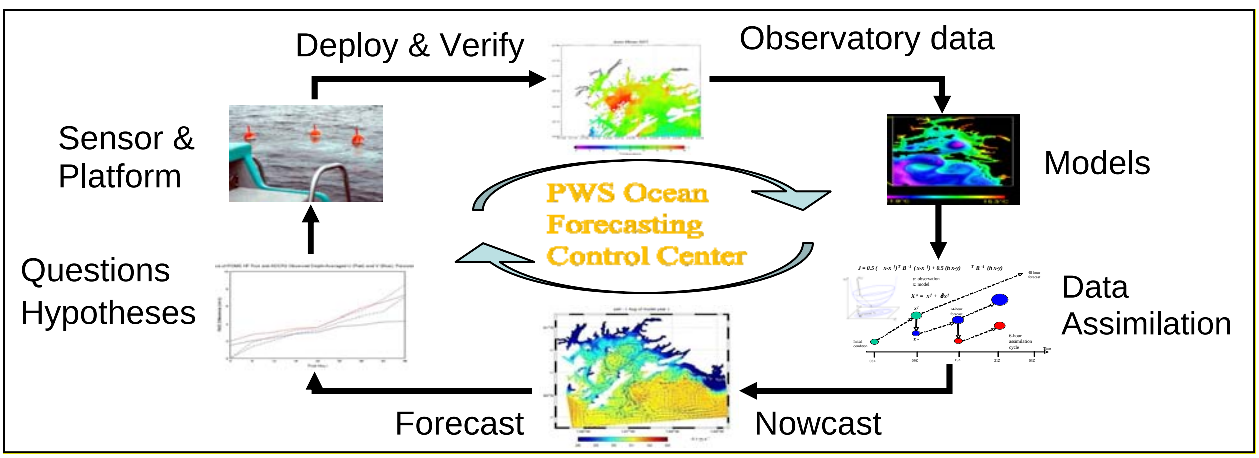

Figure 9: Schematic of AOOS Prince William Sound Demonstration Project. The field experiment is scheduled for summer 2009.

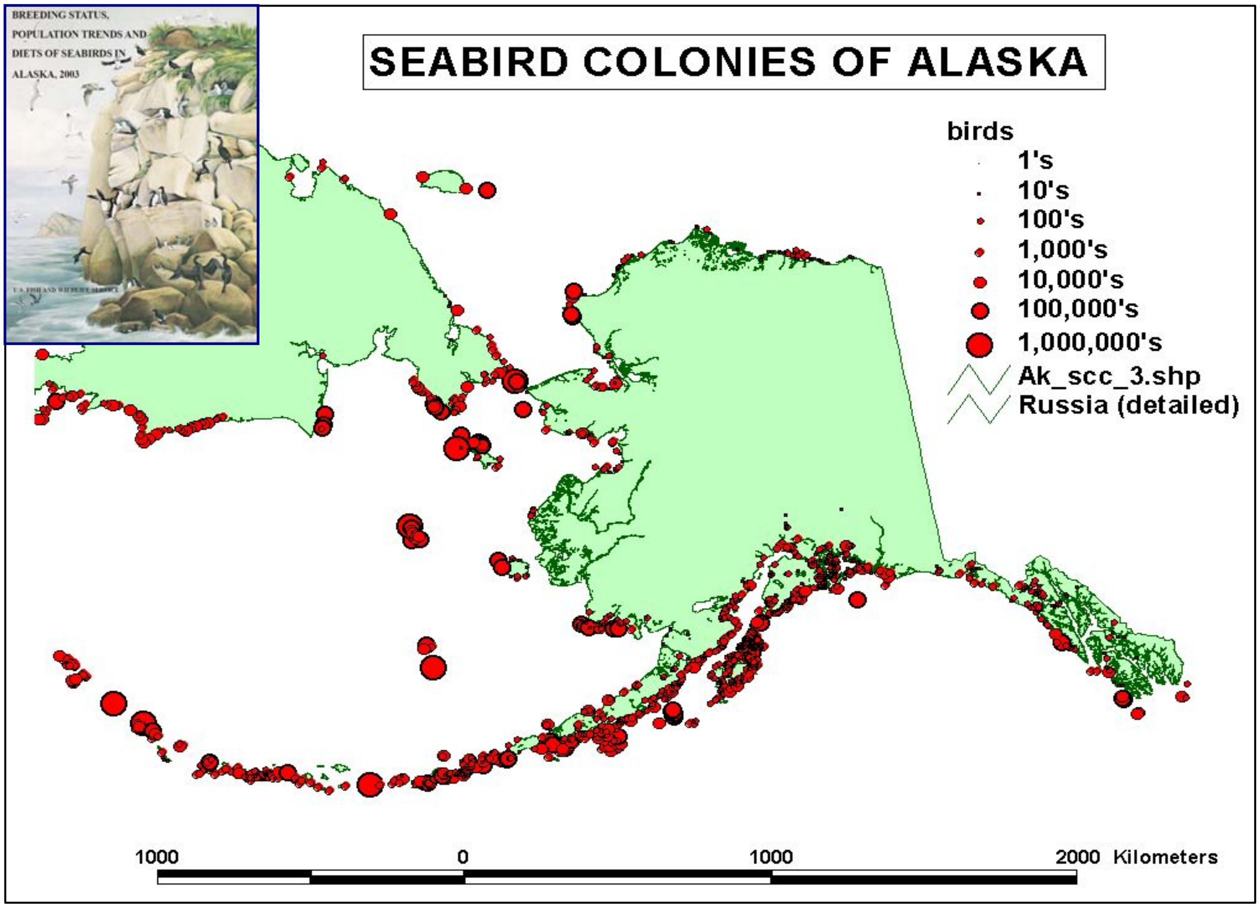

Figure 10: Seabird colony monitoring in Alaska (USFWS).

Finally, there is a substantial and increasing coastal population in the Gulf (132,000 people, excluding Anchorage, Fig. 11) whose population status as well as their dependence on the marine environment is monitored (Fig. 12), and which has changed significantly over the last few decades.

Any GOA IERP study should consider including a human element. Such a study element could potentially include establishing links between fisheries and community well-being, creating regional economic models of fisheries, analyzing alternative management strategies and the resulting socioeconomic impacts, evaluating community response to alternative management actions and ecosystem change, and measuring benefits, costs and the distribution of costs associated with consumptive and non-consumptive resource use (S. Kruse, pers. com).

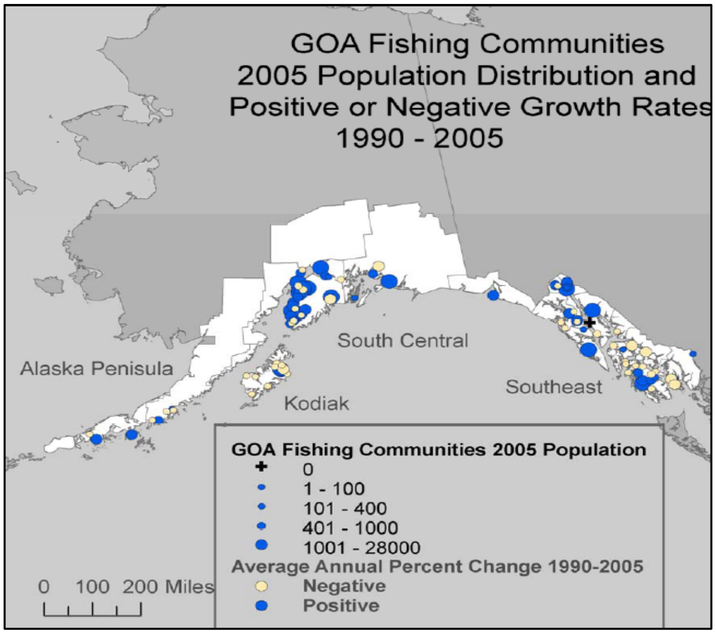

Figure 11: GOA fishing communities in 2005. Growth represents period of 1990-2005 (Boldt et al. 2007, SAFE).

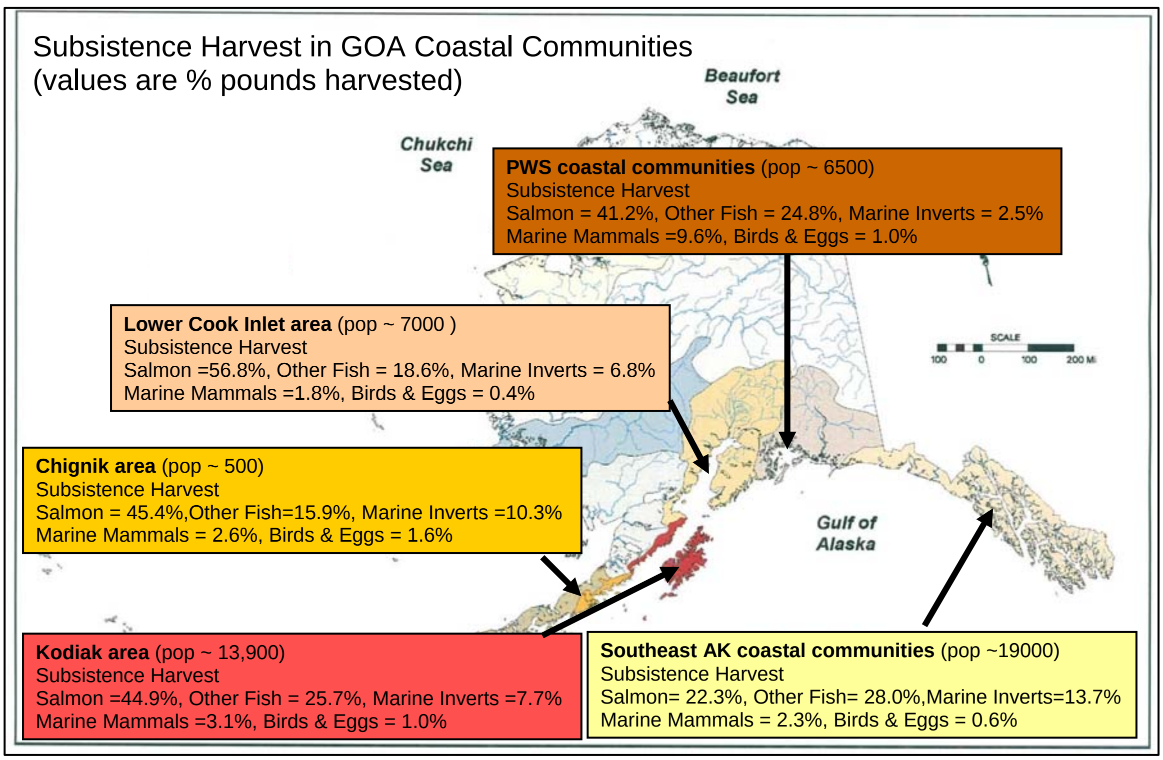

Figure 12: Subsistence regions and marine dependency in GOA (adapted from ADF&G).

c. Modeling

A variety of conceptual models has been proposed for the Gulf of Alaska marine ecosystem (e.g. Fig. 3, Fig. 13).

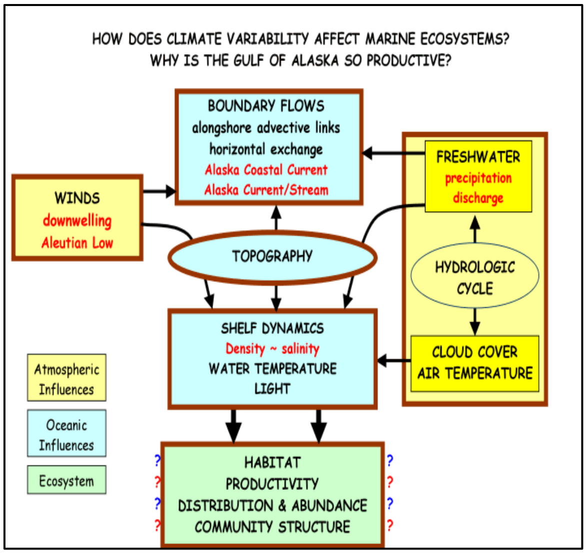

Figure 13: A model of bottom-up influence in the Gulf of Alaska Ecosystem (Beth Turner, GLOBEC).

In terms of physical modeling in the GOA, many advances have been made. A hydrology model has recently been updated and now includes detailed freshwater inputs (Royer, 2008 – NPRB Project 734). In terms of a Regional Ocean Model System (ROMS), two approaches (with and without data-assimilation) exist at a variety of resolutions (e.g. Fig. 14, but see also Rutgers ROMS, NPS POP, SODA POP, US NAVY NCOM).

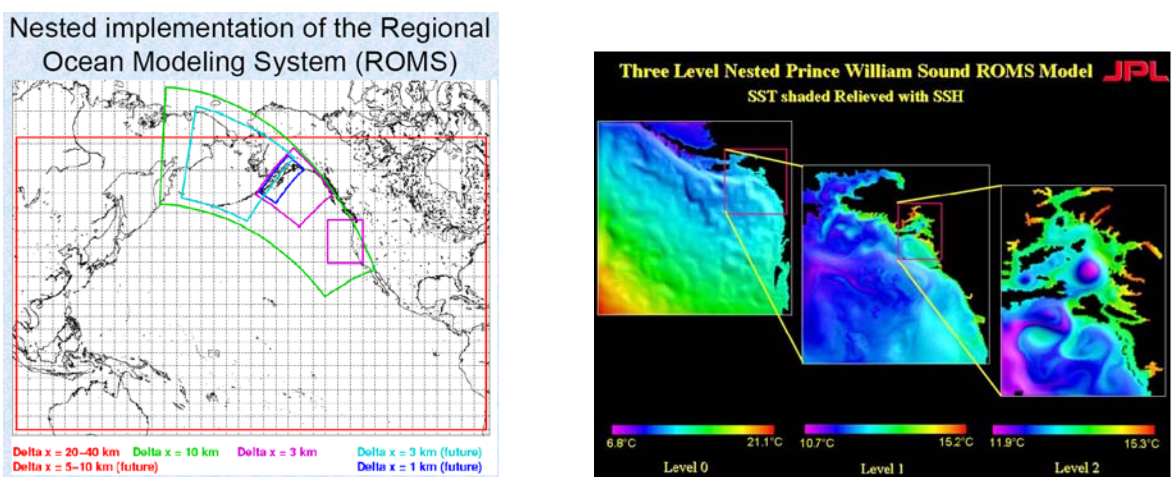

Figure 14: Existing ROMS model domains for the GOA (left from PMEL, right from JPL; where Level 0, 1, and 2 are 12km, 4km and 1.3km respectively).

It would seem to be a worthwhile effort to link the much improved existing hindcast-based models (1958-2004) with the data-assimilation forecast models, as well as to collect runs from all the GOA ROMS models and evaluate their skill and applicability in terms of biological processes (e.g. relevant vertical resolution). An interesting source of data validation, in addition to all the regular monitoring data, would be tracking data from animals equipped with CTD loggers (sea lions, fur seals, seabirds, sharks – see TOPP for more details http://www.topp.org/).

In terms of a lower trophic level model, GLOBEC funded an effort to develop an NPZ model (Fig. 15, Gibson, Coyle and Hinckley) which still has several outstanding issues to resolve, including temporal and spatial scale, and the large number of parameters (Batchelder, GOAIERP meeting, Feb 2007).

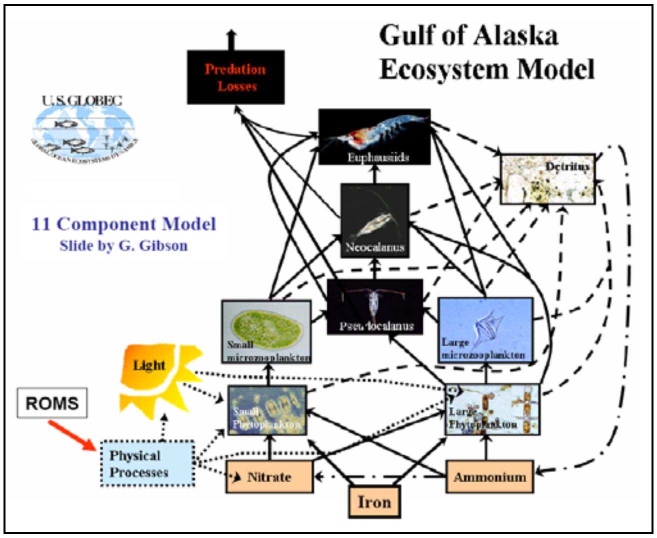

Figure 15: NPZ model for the Gulf of Alaska (Coyle, GLOBEC).

Nevertheless, it is a good basis to start from and it has been suggested that perhaps a web-based open source version of this NPZ model could be shared, using the same physics (or its run ensemble as discussed above), to further develop and evaluate and develop existing models - focusing on collaborative infrastructure rather than a single modeling group (e.g. NASA data & science team).

In terms of models that address process questions from zooplankton upwards, the choices and advancement beyond single-species stock assessments or mass balance models (e.g., Ecopath, Ecosim) are more limited. GLOBEC is attempting to link their efforts to salmon productivity, but otherwise it would appear that the rigorous efforts undertaken by the Ecosystem Modeling Committee (http://bsierp.nprb.org/meetings/emc.html) to set modeling standards, and a vertically integrated modeling approach like that funded under BSIERP (http://bsierp.nprb.org/modeling/index.html) should be applied based on the relevant already developed models. At the very least this approach and its insights should partially transfer to the Gulf of Alaska ecosystem.

III. GOA Integrated Ecosystem Research Program

Despite the programs, projects and products described above, several gaps remain in our functional understanding of the Gulf of Alaska marine ecosystem. Ultimately, the ability to accurately forecast the effects of climate variability, regime shifts, phase shifts, and anthropogenic activities on all higher trophic level organisms, including humans, depends largely on a better understanding of the key issues surrounding the life histories, behavior, sources of mortality, and the spatial and temporal distributions of key forage species and their response to the physical and biological environment. There is general agreement that there is currently inadequate information on this prey base to make meaningful forecasts of their abundances relative to changes in predator-prey relationships and climate variability.

For example, spatial variability in groundfish is poorly understood because seasonal monitoring and tagging programs have been limited. Small-scale variability in circulation and plankton dynamics have been examined through a number of meso-scale studies such as FOCI and GLOBEC in the central GOA. However, variability at the local to regional spatial scales and its effects on ecosystem dynamics remain poorly understood, although it may well be the most important scale of variability for nutrients, plankton and higher trophic level dynamics on the shelf.

It has been suggested that several eco-regions exist in Alaska (e.g. Fig. 16), and that inherent characteristics within those regions may be responsible for differences in demographic parameters among them. Even though they may not be understood, clear demographic differences among the same species between geographical areas within the Gulf of Alaska have been shown (e.g., crab and herring: Fig. 17; Steller sea lions: Fig. 18; harbor seals: Fig. 19; Black-legged kittiwakes: Fig. 20; pollock, arrowtooth flounder, and Pacific ocean perch: Fig. 21).

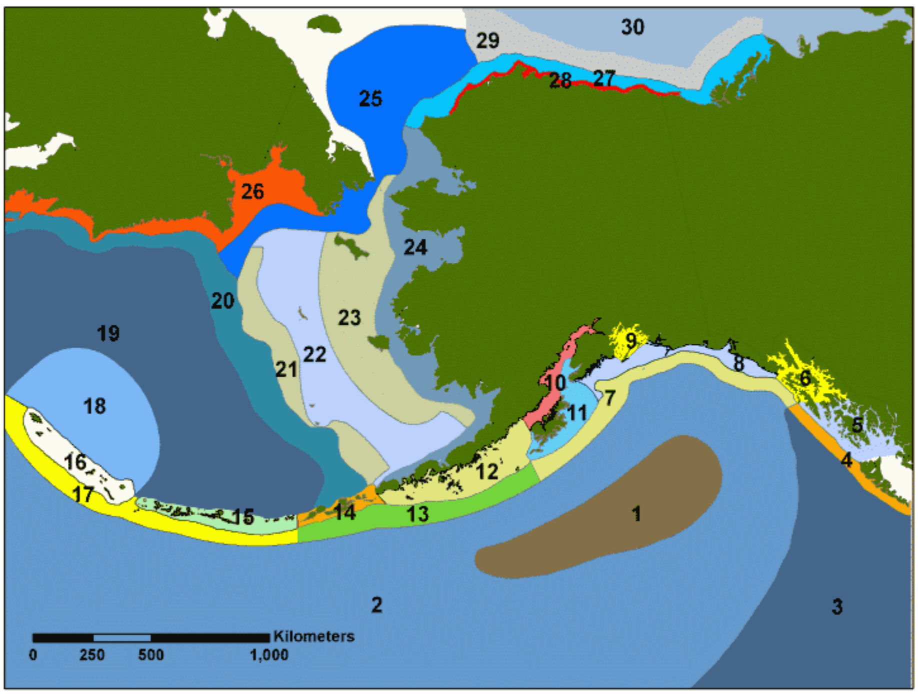

Figure 16: Proposed Eco-regions for Alaska (Piatt and Springer 2007).

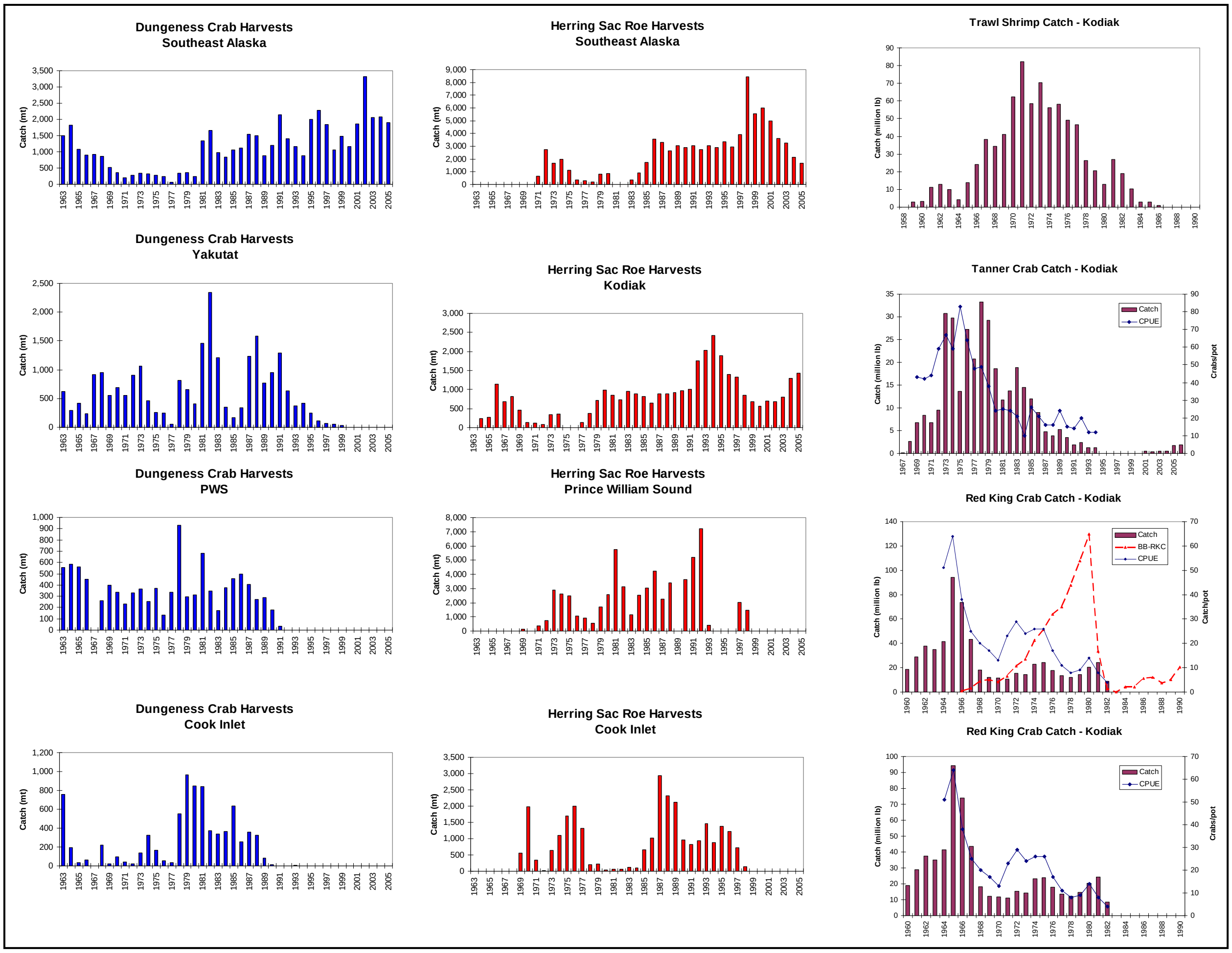

Figure 17: Catch records of crab, herring and shrimp 1960-2005 throughout the Gulf of Alaska (D. Woodby pers. comm.).

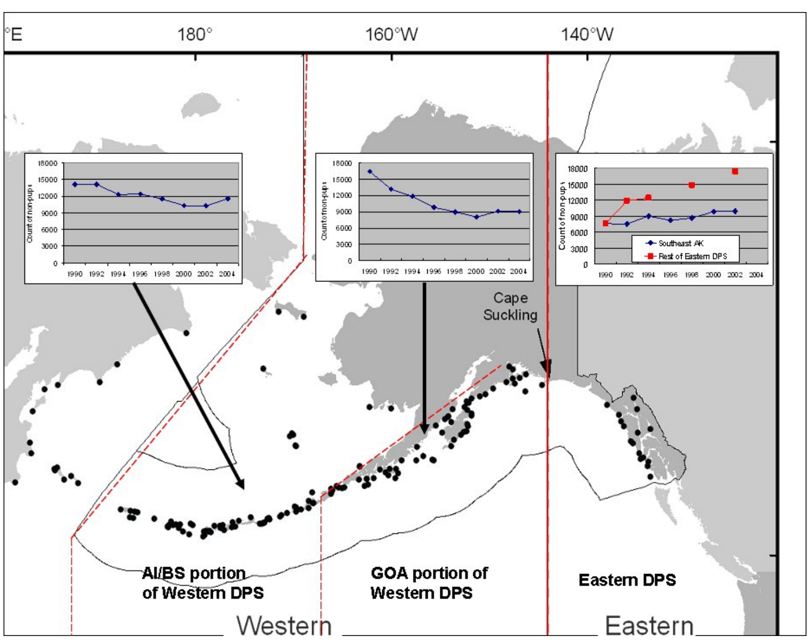

Figure 18: Trend of non-pup counts in 3 regions in Alaska (adapted from NMML).

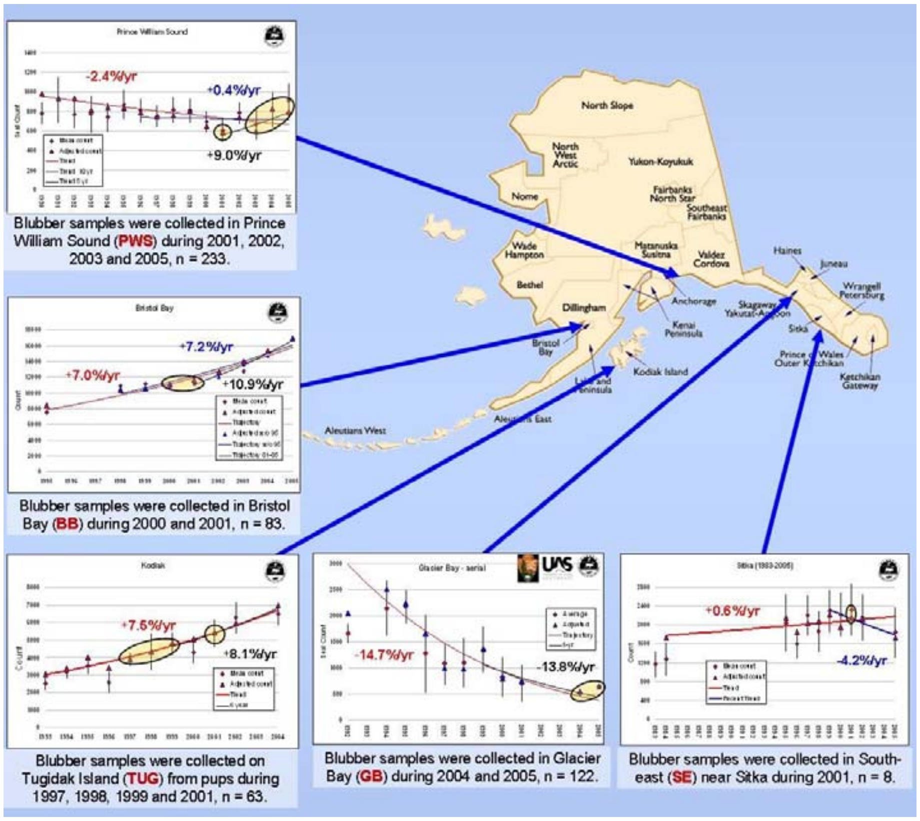

Figure 19: Trend of harbor seal populations at 5 locations in Alaska (adapted from ADF&G).

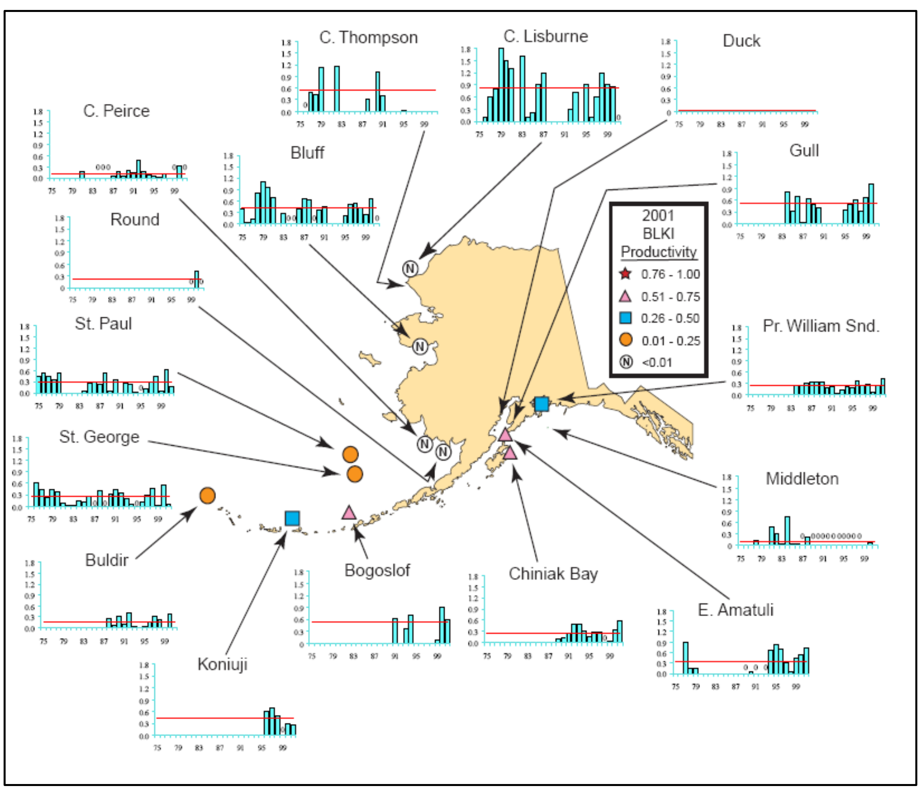

Figure 20: Productivity trends of Black-legged Kittiwakes in Alaska (Dragoo et al. 2003).

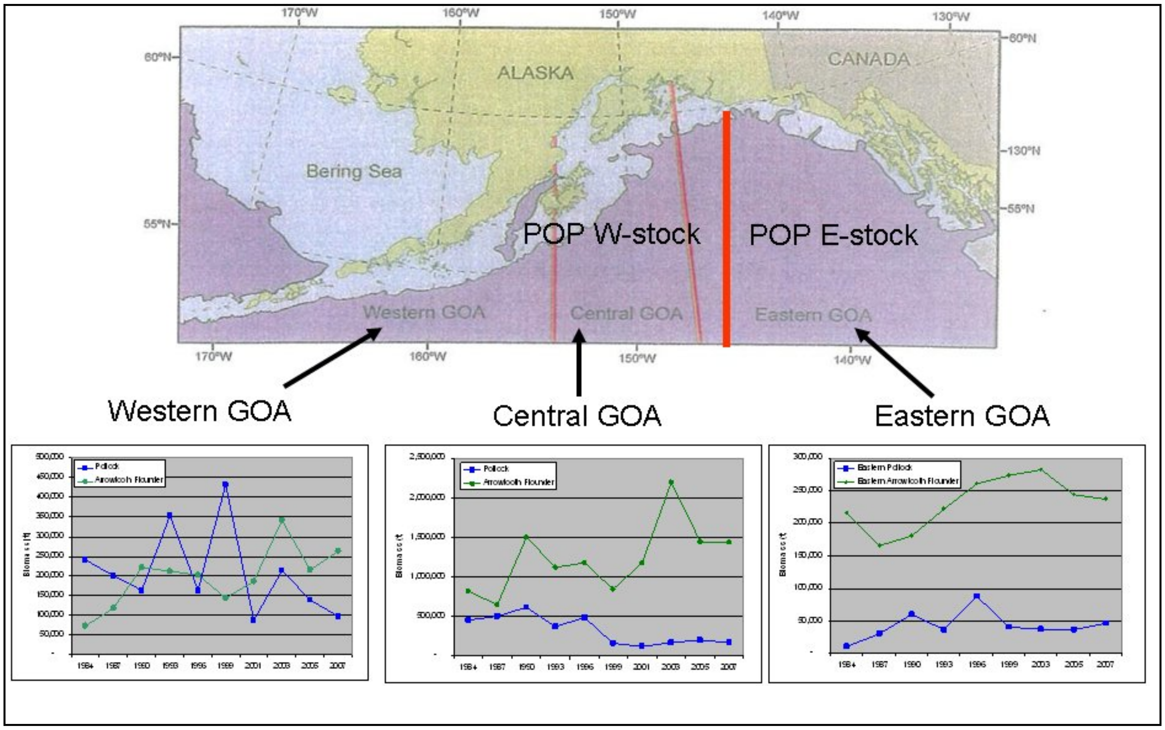

Figure 21: Trends of biomass of pollock and arrowtooth flounder in 3 regions of Alaska (AFSC pers. comm.). Thick red line indicates a genetic boundary for POP populations in the Gulf of Alaska (NPRB project 512).

In the absence of a clear understanding of the mechanisms driving the demographic differences between regions, precautionary management measures such as area or gear specific closures are in effect (Fig. 22). Clearly, these could become more effective in terms of conservation and less intrusive for the fisheries if our mechanistic understanding was better.

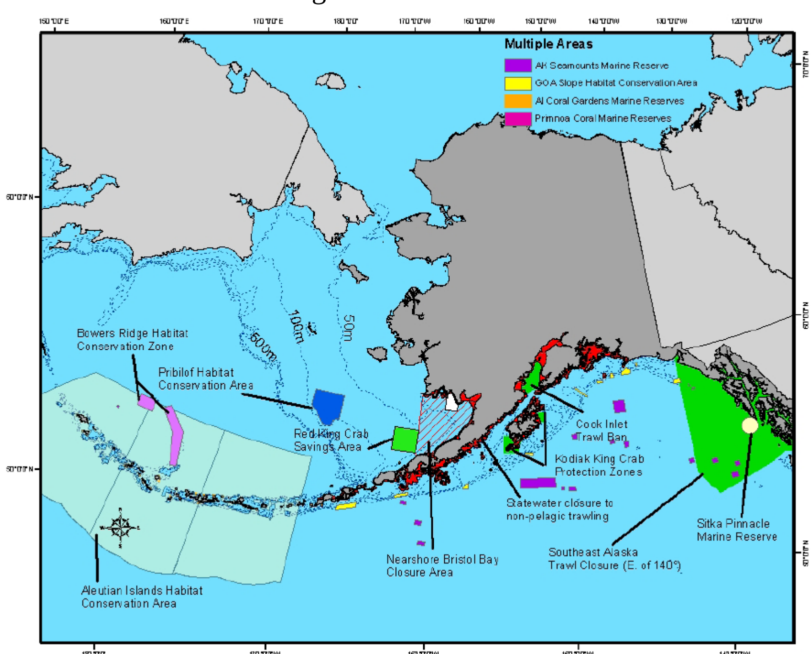

Figure 22: Year-round groundfish closures in Alaska's EEZ (NPFMC)

1. GOA IERP Scope

The Gulf of Alaska Integrated Ecosystem Research Program revolves around the following overarching question:

How do environmental and anthropogenic processes, including climate change, affect various trophic levels and dynamical linkages among trophic levels, with particular emphasis on fish and fisheries, marine mammals and seabirds within the Gulf of Alaska?

In the first instance, the goal is to ***determine and quantify the processes driving upper trophic level populations and to better understand observed and potential future variability therein as they affect key management issues in the North Pacific.*** To do so, clearly all four research approaches (monitoring, modeling, retrospective and process studies) will need to be employed and integrated. Based on the above examples, a study designed in a comparative fashion is encouraged as these geographical differences in various upper trophic level populations, at the regional scale, will likely be the most effective in helping elucidate the critical mechanisms controlling their demographic manifestations.

There are two general research concepts potentially couched within this geographical comparison which seem attractive and could be explored. The first deals with functional ecosystem resilience and the second with match-mismatch. Different from a conservation approach for a particular commercially targeted species or a species group focus (e.g. groundfish, seabirds, marine mammals) is an approach with a focus on functional groups (i.e. collections of species that perform a similar function, irrespective of their taxonomic affinities) and the key ecosystem processes undertaken by them (e.g. Hughes et al. 2005 *TREE*). Such a concept is more concerned with general ecosystem function and how it is impacted by natural and anthropogenic activities, rather than worrying about a single species or group. High species richness confers greater resilience to marine ecosystems (assuming species within the functional group respond differently to natural or anthropogenic pressures), affording a degree of ecological insurance against ecological uncertainty. This idea is also linked to the concepts of ecological versus biological extinction; as well as invasive species, which can affect species richness (and thus possibly resilience) and correlated extinction of native species, and provoke multiple effects which involve overall ecosystem functioning (material flow between trophic groups, primary production organic decomposition, benthic pelagic coupling; Occhipinti-Ambrogi 2007, *MPB*). Both ideas could be explored as part of such an IERP.

The second concept deals with match-mismatch. It is quite possible that geographic differences are not brought about by different characteristics in the system, but rather critical differences in the timing of the same processes. Such an investigation could also be extremely informative and be explored in terms of temporal (e.g. Stenseth 2002, *NAS*), spatial (e.g. Gremillet et al. 2008, *JAE*) or intensity (Durant et al. 2005, *Ecol. Letters*) match-mismatch.

Temporal scale is clearly an issue to be addressed by any of these studies, and in this regard, much discussion has focused around regime shifts. Evidence suggests there were climate regime shifts in 1977, 1989, and perhaps also in the late 1990s in the North Pacific. Ecosystem response to these shifts in the GOA were strong after 1977, but weaker in 1989 (e.g., Fig. 2, Cianelli et al. 2005 *PRCB*, Litzow and Cianelli 2007, *Ecol. Letters*), perhaps due to the geographic location of the GOA in relation to the spatial pattern of climate variability in the North Pacific (Boldt et al 2007, *SAFE*). Transitions between ecosystem states are often triggered by sudden perturbations, but are also typically preceded by relatively long periods of declining ecosystem resilience, which is defined as the ability of an ecosystem to absorb perturbation while remaining in its current state (Litzow 2006, *ICES*). Developing the ability to understand factors determining resilience, how to measure and consequently monitor them, especially in systems that are subject to rapid climate change, would thus appear critical for fisheries management.

Finally, it should be noted that freshwater discharge is a major determinant of salinities in the upper water column within the ACC and is important to the timing and strength of stratification in the spring and summer. It has a downstream effect for the Bering Sea as the ACC is its single largest freshwater input (Fig. 23). Coupled with wind mixing patterns and water temperatures, freshwater discharge also, in part, controls the mixed layer depth and thus the amount of nutrients in the mixed layer for primary and subsequent upper trophic level productivity. Implementing an IERP in the Gulf of Alaska in the light of having an ongoing program in the Bering Sea permits the opportunity to explore this larger scale downstream effect.

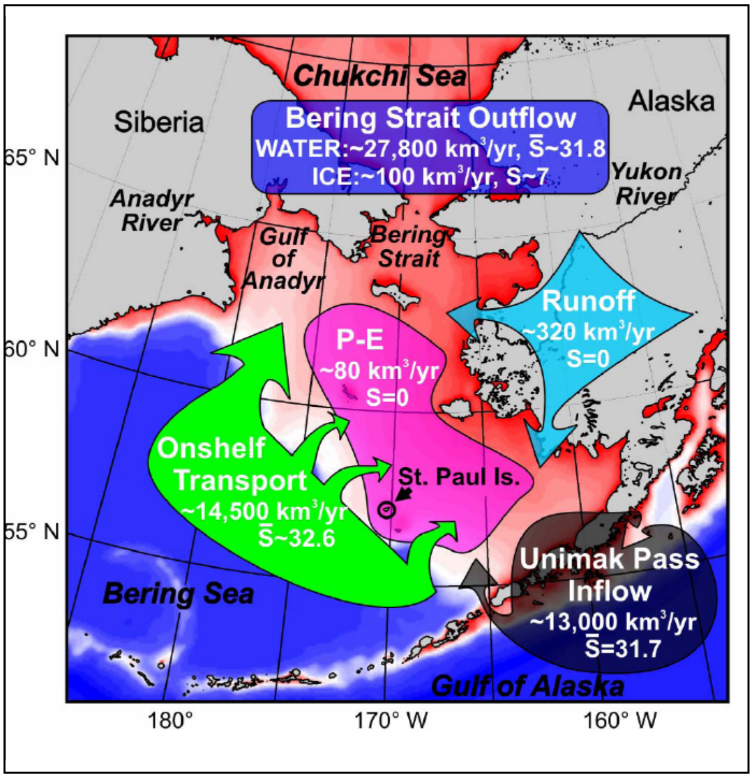

Figure 23: The Gulf is the single largest source of freshwater for the Bering Sea and, by extension, a major source for the Arctic Ocean (Aagaard et al., 2006)

2. GOA IERP Implementation

Staying within the financial boundaries set by the NPRB (see RFP for details) will require successful IERP proposals to demonstrate a thorough understanding and maximum leveraging of existing observational, process and modeling programs. Such a leveraged program will employ the major research activities (monitoring, process, retrospective, and modeling) to the extent they are necessary to elucidate relevant patterns and trends, and their associated causal processes and mechanisms. ***The critical aspect is vertical integration.*** Given the focus on quantitative predictions, continuous communication between field work results and modeling will play a crucial role.

Implementation Approach

To facilitate implementation of the GOA IERP with the current level of funding available ($8 Million), and to build on knowledge gained through the Bering Sea IERP implementation process, the following modular implementation approach has been adopted.

The modular approach will be based on four concurrent components to be competed separately with full vertical integration across all trophic levels occurring after proposal selection within each component. Specifically, the first component will focus on one or more upper trophic level species, at least one of which must be a fish species of commercial importance. The second component will focus on the forage base and resources which influence the productivity of the top level predator(s) chosen. The type, quality and quantity of food resources, its timing and location, are all critical to understanding higher trophic level responses. Thus, the ecological breadth and scope of the new work funded under the second component are expected to be somewhat larger than other components. The third component will focus on the biological and physical oceanographic parameters on which this portion of the ecosystem is based. Finally, a strong vertically-integrated modeling component as the fourth part of this program will be essential to describe and predict the responses (and variability therein) of this portion of the GOA ecosystem to environmental and anthropogenic processes, including climate change.

This approach will be implemented through a call for pre-proposals for the upper trophic level component only in October 2008. Middle and lower trophic level components, as well as the integrated modeling component, will be competed via full proposals after selection and invitation for full proposals for the upper trophic level component has been completed in March 2009. The pre-proposal documents from the selected upper trophic level component(s) will be made publically available (without salary information) so that teams proposing to the three other components will be aware of the relevant upper level specie(s) of interest and can make contact with those principal investigators.

Vertical integration across all trophic levels is a key requirement of a properly developed IERP. Using this modular approach, full vertical integration across all trophic linkages will be achieved *after* the selection of all components through intensive focal meetings in fall 2009 and spring 2010. It will be the goal of these post-selection meetings to establish vertical linkages and build cooperation between all four components. A scientific leadership group made up of the lead PI from each of the four components, in coordination with NPRB staff, Science Panel, and Ecosystem Modeling Committee, will be established and responsible for overall project management and integration.

Funding and Timeline

A total of eight million dollars (including overall data and program management, as well as Education and Outreach) may be made available for this GOA IERP starting in fall 2009 and ending in 2013 or 2014 (see details below). The NPRB is reserving $500K for overall IERP program management as well as $200K for IERP Education and Outreach. The remaining funds ($7.3M) will be distributed between the four integrated components as follows: i) Upper Trophic Level Component: $2.8 million, ii) Forage base Component: $2 million, iii) Lower Trophic Level and Physical Oceanography: $1.5 million and iv) Ecosystem Modeling Component: $1 million. Details of how funds may be allocated by year can be found in the RFP.

Programmatically, the GOA IERP is expected to include one full planning year (FY2010), two or three major field years (FY 2011, 2012 and potentially 2013), followed by one or two analysis and synthesis year(s). Project proposals will have the flexibility of determining how many field years are required to meet the objectives of the study but must stay within the funding boundaries detailed in the RFP.

Proposal and Project Selection Timeline

Action	Tentative Timeline
Call for Pre-proposals for upper trophic level component	October 3, 2008
Pre-proposal Submission Deadline	January 28, 2009
Science Panel meeting	February 11-12, 2009
NPRB meeting	February 24-25, 2009
Invitation for Full Proposals for upper trophic level component	March 6, 2009
RFP Release for full proposals for all other components	March 6, 2009
Full proposal Submission Deadline (all components)	July 2, 2009
NPRB Funding Decisions	September 2009
Notification to PIs	October 2009

Appendices

Appendix 1. Survey of U.S. GLOBEC NEP Retrospective Projects

NAME OF PROJECT:

Retrospective analysis of growth rate and recruitment for sablefish, *Anoplopoma fimbria*, from the Gulf of Alaska and the California Current System.

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

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LIST OF PROJECT'S OTHER INVESTIGATORS:

Dudley B. Chelton, co-PI, William Pinnix, Graduate Research Assistant (both at OSU)

SUMMARY OF RETROSPECTIVE WORK - YEAR 1:

Geographic area being studied: West coast of the US from central California to Vancouver Island, and the Gulf of Alaska from Queen Charlotte Islands through Prince William Sound.

Time periods being studied: Approximately 1940 - present

Types of data or derived indices being analyzed: We are accessing archived sablefish otoliths that have been collected since the early 1980's for use in stock assessments. Large numbers of sablefish otoliths (>20,000 pairs) have been aged from both west coast and Gulf of Alaska stocks. We are retrieving these otoliths and will develop a time series of juvenile sablefish growth for each year class beginning in the 1940s, based on the relationship between otolith size at the first annulus and fish length. Growth and recruitment indices for each year class will be analyzed relative to prevailing environmental conditions. Oceanographic and climatological datasets include sea surface temperature (SST), North Pacific hydrography, sea level pressure (SLP), surface wind, comprehensive ocean-atmosphere data set (COADS), coastal sea level, larval fish and zooplankton abundance and hydrographic data from the California Cooperative Oceanic Fisheries Investigations (CalCOFI).

Progress Anticipated at the end of year 1: A large collection of sablefish otoliths have been identified and associated size and age data have been collated for several collections from the Gulf of Alaska and the west coast. At the end of year 1 we will have retrieved and processed approximately half the target samples from the Gulf of Alaska (approximately 1400 otolith pairs). The relationship between otolith size and fish length at age will be completed and statistically evaluated and compared across collections (otoliths have been collected and aged by different laboratories and agencies). The potential effect of aging error will be tested and preliminary models developed under a variety of possible aging error scenarios. Preliminary models relating juvenile growth to subsequent adult recruitment will be developed for the Gulf of Alaska stock. All available west coast otoliths will have been located and associated data entered into a comprehensive dataset. We will have begun, but not completed, similar measurements and analyses for west coast sablefish. If sufficient progress has been made, we will begin preliminary comparisons of growth and recruitment between stocks within a year class and within a stock among years. We will begin analyses of biological responses to large scale (decadal or longer) climatic events.

NAME OF PROJECT:

Analysis of Ichthyoplankton Abundance, Distribution, and Species Associations in the Western Gulf of Alaska.

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

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LIST OF PROJECT'S OTHER INVESTIGATORS:

Kevin Bailey, Ann Kiernan, Miriam Doyle, AFSC, NOAA, Seattle

SUMMARY OF RETROSPECTIVE WORK- YEAR 1:

Geographic area being studied: Main focus on Western Gulf of Alaska (GOA) but some data from Bering Sea, eastern GOA, and West Coast will be included.

Time period(s)being studied: Main focus from 1981 to 1996 but data from the 1970s including some prior to the Regime Shift will be examined.

Types of data or derived indices being analyzed: Yearly and seasonal abundance and distribution patterns of egg and larval stages of 41 species of marine fish, species associations of ichthyoplankton.

Progress anticipated at the end of year 1: Much effort during the first year will be devoted to cleaning up and standardizing the AFSC ichthyoplankton data base and to producing a geographic atlas of the abundance and distribution patterns of the eggs and larval stages of the dominant species. To this end, we have hired on a database specialist and GIS mapping specialist and detailed maps should be available for about 41 species which will be available in color plates and on our web site by the end of the year. In addition to the data we proposed to analyze, we have added a number of years prior to 1981 and some parallel collections in the Bering Sea and along the US West Coast for comparison. We now anticipate that 105 cruises will be available for analysis. We have begun to examine the distribution of select taxa for the presence of an El Niño signal in our data and hope to have some results by the fall.

NAME OF PROJECT:

GLOBEC Northeast Pacific Retrospective Study: Long-term Variability in Salmon Abundance in the Gulf of Alaska and California Current Systems

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

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LIST OF PROJECT'S OTHER INVESTIGATORS:

Anne Beesley (Graduate student-UAF)

SUMMARY OF RETROSPECTIVE WORK- YEAR 1:

This project is utilizing analysis of sediment cores from sockeye salmon nursery lakes to reconstruct past changes in sockeye abundance. Reconstructions are based on stable isotope analysis (N-15 and S-34) combined with standard paleolimnological techniques. See GLOBEC proposal for details regarding the basis of this technique. Several sites have been selected in each of two regions, one influenced by the California Current Systems (CCS; Washington, Idaho, Oregon), and the other adjacent to the Gulf of Alaska (GOA; Kodiak Island, Alaska Peninsula). The time period the study is focused on is the last 500 years, with anticipated time-resolution of about 5 years. In addition, sites in Alaska will be studied to examine trends over a longer timescale, the past 2000 years. Data from sites will be compared within and between regions to assess the similarity of trends. Reconstructed trends in salmon abundance will also be compared to paleoclimatic data to determine relationships between salmon abundance and climate change. For the GOA sites, cores are in hand and the data is being finalized for period of the past 500 years; a manuscript should be submitted for review by the end of the year. Analysis of the 2000 year record is in progress, and should also be completed by the end of the year. Fieldwork for the CCS sites will take place this summer, and preliminary results should be completed by the end of the year. As part of this project, all relevant data on paleoclimatic and paleoceanographic variability of the North Pacific will be synthesized over these time-periods. The data generated by this project will help evaluate key GLOBEC hypotheses regarding relationships between climate and production regimes in the CCS and GOA.

Geographic area being studied: Gulf of Alaska and California Current (primarily WA state).

Time period(s) being studied: 500 to 2000 years BP

Types of data or derived indices being analyzed: Estimates of past sizes of runs of adult sockeye salmon. Information on paleoclimate. Anticipated time-resolution is on the order of 2-5 years.

Progress anticipated at the end of year 1: For GOA, cores are in hand and salmon population estimates are in progress for 6 individual systems for the past 300 - 600 years, and for 2 systems over the past 2000 years. A MS on GOA results should be submitted by the end of the year For the CC system, fieldwork will begin this summer, and preliminary information should be available by the end of 1998.

NAME OF PROJECT:

A Retrospective Study of Top Predator Trophic Positions, Productivity, and Growth in the Gulf of Alaska for 1960-75 and 1975-90

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

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LIST OF PROJECT'S OTHER INVESTIGATORS:

Keith Hobson, Canadian Wildlife Service, John Piatt, Biological Research Division, US. Dept. Int.

SUMMARY OF RETROSPECTIVE WORK- YEAR 1:

Geographic area being studied: Gulf of Alaska
Time period(s) being studied: 1960-75 and 1975-90
Types of data or derived indices being analyzed:

- Trophic position from delta-N stable isotope analyses of sea lion teeth, seabird feathers, fish scales and otoliths
- Sea lion growth from measurements of tooth fine structure
- Population status from population surveys of sea lions, sea birds, and fishes
- Oceanographic state from various indices (e.g, NEPPI)

Progress anticipated at the end of year 1:

- Analysis materials in hand for all species
- Stable isotope analyses begun for all species
- Growth measurements for sea lions completed
- Population data gathered

NAME OF PROJECT:

Long-term Changes in California Current Zooplankton Assemblages: A Retrospective Analysis

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

Name: Mark Ohman (or David Checkley; on sabbatical at present)
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LIST OF PROJECT'S OTHER INVESTIGATORS:

David Checkley (dcheckley@ucsd.edu), Bertha Lavaniegos (berlav@cicese.mx), Ginger Rebstock (grebstock@ucsd.edu), Gregory Rau (rau4@llnl.gov)

SUMMARY OF RETROSPECTIVE WORK- YEAR 1:

Geographic area being studied: (1) Extended S. California Bight and (2) Offshore Monterey Bay

Time period(s) being studied: 1949 to present; with particular focus on springtime patterns (March-April)

Types of data or derived indices being analyzed: Zooplankton samples collected by bongo nets in the CalCOFI program are being enumerated. All holozooplankton taxa are enumerated to some taxonomic level; several taxa (esp. copepods, salps, doliolids, hyperiid amphipods, euphausiids by E. Brinton) to the species level. Stable isotope content of 2 species of particle-grazing copepods is being analyzed in relation to El Nino and lower frequency climate signals.

Progress anticipated at the end of year 1: We have completed analyses of all holozooplankton taxa from 10 of the springtime CalCOFI cruises during the period 1951 to 1997. Detailed reconstructions of zooplankton biomass, by taxonomic group, suggest that the biomass of some major taxa (e.g., copepods, euphausiids) has remained relatively constant over this 47-year period, despite the 70% decline in total zooplankton biomass. Other taxa (e.g., hyperiid amphipods and some of their gelatinous hosts such as doliolids, salps, and hydromedusae) show great interannual variability, but appear to have declined significantly in more recent years. Species-specific analyses reveal that the dominance structure within some taxa has occurred, despite relative constancy of biomass. E. Brinton found a persistent increase in abundance of a warm-water, coastal euphausiid (*Nyctiphanes simplex*) dating from the 1976-77 Regime Shift, while other euphausiid taxa show no long-term changes. The species diversity of hyperiid amphipods also appears to have changed at the time of the Regime Shift, a further indication of altered availability of their gelatinous hosts. Preliminary results from analysis of the 15N composition of *Calanus pacificus* off Monterey Bay with G. Rau suggest that the copepods became isotopically heavier during the El Nino events of 1958 and 1982; we await analyses of the 1998 event.

NAME OF PROJECT:

Patterns, Sources and Mechanisms of Decadal-Scale Environmental Variability in the Northeast Pacific: A Retrospective and Modeling Analysis

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

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LIST OF PROJECT'S OTHER INVESTIGATORS:

Gregory Monterey, Richard Parrish, Roy Mendelssohn (all at PFEL) and Tom Murphree (Naval Postgrad. School)

SUMMARY OF RETROSPECTIVE WORK- YEAR 1:

Geographic area being studied: entire North Pacific basin, with emphasis on coastal ecosystems of California Current and GOA

Time period(s) being studied: comparing two decades, 1966-75 and 1977-86

Types of data or derived indices being analyzed: Gridded 2-degree fields (monthly averages for each decade and climatology) and monthly time series for selected geographic regions (1946-present) from two data sets:

- COADS surface observations (wind, SST, SLP) and derived fields (wind stress and curl, integrated transport, upwelling)
- World Ocean Atlas (WOA) subsurface observations at standard depths, and derived fields (temperature, salinity, mixed layer depth, dynamic topography).

Progress anticipated at the end of year 1: The overriding objective of this project is to examine interdecadal ocean variability in the North Pacific using retrospective analysis of environmental data sets with innovative statistical modeling techniques, combined with numerical modeling. The goal is to describe and understand the characteristic modes of oceanic variability that may affect the distribution, abundance and production of marine animals. During year 1 of this project, we will develop the data bases and data extraction methods to generate time series and gridded fields of surface and subsurface variables. Analysis will begin on gridded fields of monthly and seasonal climatologies of key environmental variables (SLP, wind, SST, and quantities derived from these), and on decadal averages for two periods (1966-75 and 1977-86), to describe changes due to the 1976 climate shift. Gridded surface and subsurface fields will also be developed for forcing a numerical ocean circulation model. These data sets and extraction methods will be available to other NEP investigators and the oceanographic community by the end of this year.

NAME OF PROJECT:

Retrospective analysis of Northeast Pacific microzooplankton

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

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LIST OF PROJECT'S OTHER INVESTIGATORS:

none

SUMMARY OF RETROSPECTIVE WORK- YEAR 1:

Geographic area being studied: Ocean Station P (50N, 145W) and Line P extending from Vancouver Island to Station P

Time period(s) being studied: 1987, 1988, 1993-1998 (inclusive)

Types of data or derived indices being analyzed: Microzooplankton samples; Samples from winter, spring, and late summer seasons are available for nearly all years, and will be used to evaluate seasonal and interannual variation in this planktonic group. Microzooplankton are known to be the major trophic link between primary producers and higher trophic levels in oceanic subarctic waters, and may play an equally important role in coastal ecosystems. Retrospective analysis of this key trophic link will be combined with data on meteorology, ocean physics, and plankton biology to provide a window onto the mechanisms by which climate shifts may alter food web structure and function.

Progress anticipated at the end of year 1:
By the end of year 1 we expect to have analyzed all samples microscopically and be well into data work-up. Specifically, data on abundance, size structure and taxonomic composition of the microzooplankton community will be available for most if not all samples. During year 2 of this two-year project we will focus on relating shifts in the above microzooplankton parameters to shifts in plankton biology and climatology of the northeast Pacific. Note that sample collection is on-going and should continue at least through the year 2000.

NAME OF PROJECT:

Remote Sensing of the NE Pacific: Retrospective and Concurrent Time Series Analysis Using Multiple Sensors on Multiple Scales

POINT OF CONTACT FOR RETROSPECTIVE COMPONENT:

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LIST OF PROJECT'S OTHER INVESTIGATORS:

Corinne James and Mark Abbott (OSU); Andrew Thomas (Univ. of Maine); Jan Svejkovsky (Ocean Imaging, Inc.)

SUMMARY OF RETROSPECTIVE WORK:

Geographic area being studied: North Pacific Basin - East of 170W **Time period(s) being studied:**

- AVHRR SST: (1981)--1985--2000
- Altimeter SLH: 1987--1988; 1993--2000
- Sat. Ocean Color: 1997--2000
- Tide Gauge SLH: 1957--2000

Types of data or derived indices being analyzed:

- Satellite SST - 1 km absolute temperature, cloud masked. Approximately 19N--56N, from the coast out to 132W-138W. 1-4 images per day
- Satellite SST - Pathfinder 9 km absolute temperature, cloud masked
- Altimeter - TOPEX, ERS-1 data: a subset of along track height anomalies, covering the eastern basin. 1-2 images per day
- Ocean Color - OCTS, SeaWiFS over the eastern basin, when available
- SAR Imagery - selected scenes off Newport OR during cruises
- Tide Gauge SLH: From stations along the west coasts of N. and S. America, Hourly to daily.

Types of analysis:

- Covariability of transports in the Subarctic and Subtropical Gyres their connection to the interior N. Pacific and wind forcing.
- Seasonal and mesoscale circulation variability in selected areas of the two gyres.
- Relationship between surface pigments, SST, wind and circulation (Thomas)
- Small-scale circulation in regions next to the coast (Svejkovsky) using SAR data.

Progress anticipated at the end of year 1:

- The 1-km AVHRR data will be processed and made available through ftp and a web site in an ongoing fashion. Data from 1981-1997 will be processed similarly as quickly as possible (several past years should be available by the end of 1998).
- A subset of the 9-km Pathfinder AVHRR data will be made for the Northeast Pacific from the available data set near the end of year 1 (approximately 1985-1996).

- SeaWiFS ocean color (and OCTS, when available) data will be collected over the NE Pacific and made available to those who are officially registered users with NASA.
- The covariability of transports will be analyzed for the period October 1992 to November 1997 (or later, if available) to show the normal seasonal cycle of basin-scale tranports and the interannual variability during the onset of the 1997-1998 El Nino.

Appendix 2. Main conclusions from GEM and SEA/APEX (Mundy 2006, GOAIERP Plan Team)

GEM and SEA/APEX: Control of production of birds, fish and mammals in the Gulf of Alaska

Determinants of birth, growth and death

Classical dichotomy

1. Fishing, predation, disease and associated interactions with physical controls

2. Physical control of rates of production, distribution of production and pathways of energy flow (species composition)

SEA specifics

- Year class strength in pink salmon is primarily determined in the first 180 days after marine entry by mortalities that are dependent on prey density, species composition of prey, and the joint spatial distributions of juvenile pink salmon, predators and prey, and the interactions among these factors.
    - Prey density: Prey density determines growth rate which in turn determines rate of predation on salmon
    - Prey density: Prey density is determined by atmospheric and oceanic forcing through physical transport of prey and delivery of nutrients to the first trophic level.
    - Species composition: The presence and availability of large copepods determines distribution of pink salmon and their predators more so than the presence and availability of other species of zooplankton.
    - Species composition: The presence and availability of large copepods determines the rate of predation on juvenile pink salmon
    - Spatial distribution: Rates of salmon mortality are lower when salmon are near shore and conversely
    - Species composition: Rates of salmon mortality are modulated by species composition of prey independent of joint distributions of pink salmon and prey; more large copepods mean lower predation rates on salmon
    - Interactions between spatial distribution and species composition are important determinants of year class strength in pink salmon
    - Interactions between prey density and species composition are important determinants of year class strength in pink salmon
    - Interactions between temperature and growth are important determinants of year class strength in pink salmon

- Year class strength in herring is primarily determined in the first 180 days after hatching by mortalities that are dependent on prey density, species composition of prey, the spatial distribution juvenile herring in the fall of the first year of life.
    - Prey density: Prey density in summer determines the allocation of energy between storage and bodily structure.
    - Prey density: Prey density in summer controls winter survival by determining energy reserves of age-0 herring in the fall.
    - Prey density: Prey density is determined by atmospheric and oceanic forcing through physical transport of prey and delivery of nutrients to the first trophic level.
    - Spatial distribution: Mortality is controlled by transport of larvae to suitable rearing habitat (embayments)

- Species composition: Species composition of prey determines energy density which determines size at age and energy content of herring in the fall
- Interactions between spatial distribution and species composition are important determinants of year class strength in herring
- Interactions between prey density and species composition are important determinants of year class strength in herring
- Interactions between temperature and growth are important determinants of year class strength in herring