# NPRB GOA-IERP Summary Page

**Proposal Title:** Surviving the Gauntlet: A comparative study of the pelagic, demersal, and spatial linkages that determine groundfish recruitment and diversity in the Gulf of Alaska ecosystem

**GOA-IERP Component:** UTL

**Project Period:** Start date: October 2010 End date: September 2014

**Subaward Recipient(s):**

Jamal H. Moss: Alaska Fisheries Science Center, 17109 Point Lena Loop Road, Juneau, AK 99801, (907)-789-6609, jamal.moss@noaa.gov

Franz Mueter, UAF School of Fisheries and Ocean Sciences, 17101 Point Lena Loop Road, Juneau, AK 99801, (907)-796-5448, fmueter@alaska.edu

Leslie Slater: Alaska Maritime National Wildlife Refuge, 95 Sterling Highway, Suite 1 MS 505, Homer, AK 99603, Leslie_Slater@fws.gov

**Principal Investigators & Co-investigators:**

Lead PI: Jamal H. Moss, Alaska Fisheries Science Center, jamal.moss@noaa.gov
PI #1 Kalei Shotwell, Alaska Fisheries Science Center, kalei.shotwell@noaa.gov
PI#2: Franz Mueter, UAF School of Fisheries and Ocean Sciences, franz.mueter@uaf.edu
PI#3: Shannon Atkinson, UAF School of Fisheries and Ocean Sciences, atkinson@sofs.uaf.edu

**Summary of Proposed Work:**

The overall goal of our proposed research focuses on identifying and quantifying the major ecosystem processes that regulate recruitment strength of key groundfish species in the Gulf of Alaska (GOA). We concentrate on a functional group of five predatory fish species that are commercially important and account for most of the predatory fish biomass in the GOA. Taken together they encompass a range of life history strategies and geographic distributions that provide contrast to explore regional ecosystem processes. We focus on recruitment success because large swings in the abundance of these species have occurred despite precautionary fishing levels. Their early life begins with an offshore pelagic phase followed by a nearshore settlement phase. Spatial distribution, food preference, and habitat suitability of these two life history phases are poorly known. Fieldwork will define a critical environmental window for these five focal species by examining the gauntlet they endure while crossing from offshore spawning to nearshore settlement areas. We will contrast two regions: the central GOA with a broad shelf dominated by high oceanographic variability and large demersal fish biomass and the eastern GOA with a narrower shelf, lower demersal biomass, and higher species diversity. Retrospective data analysis combined with environmental covariates and multispecies stock assessment models will determine the relative influence of environmental parameters and identify processes influencing recruitment. Regional differences will be linked to dietary preference of top level predators to infer causal mechanisms for population trends and influence of climate change on ecosystem structure and diversity.

**Total Funding Requested From NPRB & Matching support:**

| | Requested | Other Support |
|---|---|---|
| Alaska Fisheries Science Center | $1,325,913 | $3, 575,675 |
| **Total:** | **$1,325,913** | **$3,575,675** |

**Legally Binding Authorization Signature and Affiliation:**

Signature: William Karp  Date: 6/30/10

*William A. Karp, Ph.D.*
*Deputy Dircetor for Science and Research*
*Alaska Fisheries Science Center*

# NPRB GOA-IERP Summary Page

**Proposal Title:** Surviving the Gauntlet: A comparative study of the pelagic, demersal, and spatial linkages that determine groundfish recruitment and diversity in the Gulf of Alaska ecosystem

**GOA-IERP Component:** UTL

**Project Period:** Start date: October 2010 End date: September 2014

**Subaward Recipient(s):**

Jamal H. Moss: Alaska Fisheries Science Center, 17109 Point Lena Loop Road, Juneau, AK 99801, (907)-789-6609, jamal.moss@noaa.gov

Franz Mueter, UAF School of Fisheries and Ocean Sciences, 17101 Point Lena Loop Road, Juneau, AK 99801, (907)-796-5448, fmueter@alaska.edu

Leslie Slater: Alaska Maritime National Wildlife Refuge, 95 Sterling Highway, Suite 1 MS 505, Homer, AK 99603, Leslie_Slater@fws.gov

**Principal Investigators & Co-investigators:**
Lead PI: Jamal H. Moss, Alaska Fisheries Science Center, jamal.moss@noaa.gov
PI #1 Kalei Shotwell, Alaska Fisheries Science Center, kalei.shotwell@noaa.gov
PI#2: Franz Mueter, UAF School of Fisheries and Ocean Sciences, franz.mueter@uaf.edu
PI#3: Shannon Atkinson, UAF School of Fisheries and Ocean Sciences, atkinson@sofs.uaf.edu

**Summary of Proposed Work:**
The overall goal of our proposed research focuses on identifying and quantifying the major ecosystem processes that regulate recruitment strength of key groundfish species in the Gulf of Alaska (GOA). We concentrate on a functional group of five predatory fish species that are commercially important and account for most of the predatory fish biomass in the GOA. Taken together they encompass a range of life history strategies and geographic distributions that provide contrast to explore regional ecosystem processes. We focus on recruitment success because large swings in the abundance of these species have occurred despite precautionary fishing levels. Their early life begins with an offshore pelagic phase followed by a nearshore settlement phase. Spatial distribution, food preference, and habitat suitability of these two life history phases are poorly known. Fieldwork will define a critical environmental window for these five focal species by examining the gauntlet they endure while crossing from offshore spawning to nearshore settlement areas. We will contrast two regions: the central GOA with a broad shelf dominated by high oceanographic variability and large demersal fish biomass and the eastern GOA with a narrower shelf, lower demersal biomass, and higher species diversity. Retrospective data analysis combined with environmental covariates and multispecies stock assessment models will determine the relative influence of environmental parameters and identify processes influencing recruitment. Regional differences will be linked to dietary preference of top level predators to infer causal mechanisms for population trends and influence of climate change on ecosystem structure and diversity.

**Total Funding Requested From NPRB & Matching support:**

| | Requested | Other Support |
|---|---|---|
| University of Alaska | $743,379 | $0 |
| **Total:** | **$743,379** | **$0** |

**Legally Binding Authorization Signature and Affiliation:**

Signature:________________ Date: 06/30/10

*Andrew Parkerson-Gray*
*Director, Office of Sponsored Programs*
*University of Alaska Fairbanks*

# NPRB GOA-IERP Summary Page

**Proposal Title:** Surviving the Gauntlet: A comparative study of the pelagic, demersal, and spatial linkages that determine groundfish recruitment and diversity in the Gulf of Alaska ecosystem

**GOA-IERP Component:** UTL

**Project Period:** Start date: October 2010 End date: September 2014

**Subaward Recipient(s):**

Jamal H. Moss: Alaska Fisheries Science Center, 17109 Point Lena Loop Road, Juneau, AK 99801, (907)-789-6609, jamal.moss@noaa.gov

Franz Mueter, UAF School of Fisheries and Ocean Sciences, 17101 Point Lena Loop Road, Juneau, AK 99801, (907)-796-5448, fmueter@alaska.edu

Leslie Slater: Alaska Maritime National Wildlife Refuge, 95 Sterling Highway, Suite 1 MS 505, Homer, AK 99603, Leslie_Slater@fws.gov

**Principal Investigators & Co-investigators:**

Lead PI: Jamal H. Moss, Alaska Fisheries Science Center, jamal.moss@noaa.gov
PI #1 Kalei Shotwell, Alaska Fisheries Science Center, kalei.shotwell@noaa.gov
PI#2: Franz Mueter, UAF School of Fisheries and Ocean Sciences, franz.mueter@uaf.edu
PI#3: Shannon Atkinson, UAF School of Fisheries and Ocean Sciences, atkinson@sofs.uaf.edu

**Summary of Proposed Work:**

The overall goal of our proposed research focuses on identifying and quantifying the major ecosystem processes that regulate recruitment strength of key groundfish species in the Gulf of Alaska (GOA). We concentrate on a functional group of five predatory fish species that are commercially important and account for most of the predatory fish biomass in the GOA. Taken together they encompass a range of life history strategies and geographic distributions that provide contrast to explore regional ecosystem processes. We focus on recruitment success because large swings in the abundance of these species have occurred despite precautionary fishing levels. Their early life begins with an offshore pelagic phase followed by a nearshore settlement phase. Spatial distribution, food preference, and habitat suitability of these two life history phases are poorly known. Fieldwork will define a critical environmental window for these five focal species by examining the gauntlet they endure while crossing from offshore spawning to nearshore settlement areas. We will contrast two regions: the central GOA with a broad shelf dominated by high oceanographic variability and large demersal fish biomass and the eastern GOA with a narrower shelf, lower demersal biomass, and higher species diversity. Retrospective data analysis combined with environmental covariates and multispecies stock assessment models will determine the relative influence of environmental parameters and identify processes influencing recruitment. Regional differences will be linked to dietary preference of top level predators to infer causal mechanisms for population trends and influence of climate change on ecosystem structure and diversity.

**Total Funding Requested from NPRB & Matching Support:**

| | Requested | Other Support |
|---|---|---|
| Alaska Maritime National Wildlife Refuge | $ 55,415 | $ 151,415 |
| **Total:** | **$ 55,415** | **$ 151,415** |

**Legally Binding Authorization Signature and Affiliation:**

Signature: [signature] Date: 8 July 2010

*Steven J. Delehanty*
*Refuge Manager*
*Alaska Maritime National Wildlife Refuge*

# RESEARCH PLAN

A. Project Title

Surviving the Gauntlet: A comparative study of the pelagic, demersal, and spatial linkages that determine groundfish recruitment and diversity in the Gulf of Alaska ecosystem

B. Proposal Summary

The overall goal of our proposed research focuses on identifying and quantifying the major ecosystem processes that regulate recruitment strength of key groundfish species in the Gulf of Alaska (GOA). We concentrate on a functional group of five predatory fish species that are commercially important and account for most of the predatory fish biomass in the GOA. Taken together they encompass a range of life history strategies and geographic distributions that provide contrast to explore regional ecosystem processes. We focus on recruitment success because large swings in the abundance of these species have occurred despite precautionary fishing levels. Their early life begins with an offshore pelagic phase followed by a nearshore settlement phase. Spatial distribution, food preference, and habitat suitability of these two life history phases are poorly known. Fieldwork will define a critical environmental window for these five focal species by examining the gauntlet they endure while crossing from offshore spawning to nearshore settlement areas. We will contrast two regions: the central GOA with a broad shelf dominated by high oceanographic variability and large demersal fish biomass and the eastern GOA with a narrower shelf, lower demersal biomass, and higher species diversity. Retrospective data analysis combined with environmental covariates and multispecies stock assessment models will determine the relative influence of environmental parameters and identify processes influencing recruitment. Regional differences will be linked to dietary preference of top level predators to infer causal mechanisms for population trends and influence of climate change on ecosystem structure and diversity.

C. Soundness of Project Design and Conceptual Approach.

**Hypotheses and Objectives**

The highly complex and dynamic marine environment in the Gulf of Alaska (GOA) supports a rich and diverse ecosystem, which exhibits strong gradients in population stability and species composition over space and time (Mueter and Norcross 2002). The mechanisms underlying these fluctuations are poorly understood but likely involve both top-down and bottom-up controls (Mundy 2005). We propose to improve our understanding of the variability in this ecosystem through regional comparison of recruitment variability in five predatory fish species and examine the effects of this variability on top level predators. We hypothesize that:

1) Early life survival of marine fish is influenced by climate driven variability in a biophysical gauntlet described by offshore and nearshore productivity, larval and juvenile transport, and settlement into suitable demersal habitat. The probability of survival is linked to health and condition as reflected in instantaneous growth and consumption rates of fish travelling the gauntlet.
2) Environmental and biological variability are less pronounced in the eastern GOA than the central GOA and the greater stability and higher species diversity in the eastern GOA make the region more ecologically resilient to climate change and human forcing (Miller et al. 2005, Hughes et al. 2005).
3) Differences in survival of fish among years and areas results in fluctuations in available prey, which directly affects the dietary preference and foraging strategy of top level predators such as seabirds (Thayer et al. 2008).

To address these hypotheses, we propose to quantify variability in climate drivers, in distribution, abundance, and condition of key fish species at several stages during their early life, and in the diet of top level predators in two regions of the GOA. By comparing the responses of upper trophic level variability to climate forcing between these two contrasting systems, we will gain a better understanding of how these systems may respond to future climate variability and how inherent differences in the structure of these systems affect their resilience to such variability.

The overall goal of our proposed research focuses on understanding the major ecosystem processes that regulate recruitment strength of key groundfish species in the GOA. Our first specific objective is to quantify, by region, the temporal variability in potential climatic, oceanographic, or biological drivers influencing the early life survival of key groundfish species. Differences between the eastern and central GOA will be examined through retrospective analyses of available spatial datasets. Second, we will determine by region the abundance, distribution, and condition of key groundfish species during their offshore to nearshore pelagic phase through at-sea sampling with concurrent observations of the biophysical environment (i.e. oceanography, prey, competitor, and predator fields). The lower trophic level (LTL) and the middle trophic level (MTL) components will be responsible for generating the concurrent observations of oceanography, prey, and competitor fields. The MTL will be responsible for diet analysis of marine fish predators captured during the offshore to nearshore pelagic phase. Third, we will create benthic habitat suitability maps by region through analysis of available substrate data (e.g. depth, slope, grain-size) to characterize the nearshore demersal habitat. Fourth, we will develop growth curves and consumption rates through laboratory work, which will parameterize simple bioenergetics models that will estimate potential fish growth throughout their pelagic phase. Fifth, we will analyze dietary preference and foraging behavior of seabirds and relate diet to prey availability. We will coordinate with the bioenergetics component of the MTL to estimating total biomass removals by seabirds. The modeling component will develop a biophysical model (e.g. Regional Ocean Model System (ROMS) linked to a nutrient-phytoplankton-zooplankton (NPZ) model) that will generate hindcasts and forecasts of LTL variability. Measurements from the laboratory and fieldwork, along with available historical time series collected during the retrospective analysis, will be used to calibrate the biophysical model. Predictions from this model will be used as covariates in multi-species models of fish population dynamics to examine the effects of environmental and LTL variability on competition and predator-prey interactions among key groundfish species. Covariates will be identified that best capture recruitment variability based on retrospective analysis of environmental/LTL variability with single-species recruitment, and then used in multi-species models to improve estimates of recruitment. Finally, we will evaluate the consequences of potential management strategies by simulating multi-species dynamics under different climate and fishing scenarios.

## Background and Justification

Population dynamics of fish stocks are primarily governed by ecosystem processes such as competition, predation, and environmental variability, by anthropogenic processes such as fishing (Hollowed et al. 2000) and, increasingly, by climate change. Variability in stock assessment parameter estimates of recruitment, natural mortality, growth, and catchability result from interactions among these processes (Maunder and Watters 2003). Processes influencing recruitment are the dominant drivers of stock size fluctuations because eggs, larvae, and young juveniles are subject to both bottom-up and top-down controls (Mundy 2005, Yatsu et al. 2008). Recruitment is generally defined as the abundance of the youngest fish entering a population that can be estimated successfully (Myers 1998). In this study, we focus on recruitment from the egg stage to young-of-the-year (YOY) fish, which is widely believed to be a critical period for determining future stock size (Hjort 1914), especially in groundfish (Myers and Cadigan 1993). We concentrate on identifying the processes influencing recruitment for key groundfish species to (1) better understand the relative influences of climate change and fishing on future stock sizes and to (2) more accurately predict future catch rates and population sizes by improving model parameter estimates (Maunder and Watters 2003).

We focus on a functional grouping of the five top predatory groundfish species that are commercially or ecologically valuable and represent different life history strategies in the GOA: arrowtooth flounder (*Atheresthes stomias*), Pacific cod (*Gadus macrocephalus*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), and walleye pollock (*Theragra chalcogramma*). Taken together, these species account for the vast majority of the predator biomass in the GOA and include species of high commercial value (e.g. sablefish) and high trophic connectivity (e.g. arrowtooth flounder). Because of these qualities, even small perturbations to these species could trigger system level thresholds resulting in severe economic loss and structural changes to the ecosystem such as community reorganization (Gaichas and Francis 2008). Additionally, the life history strategies of these species span a wide range of opportunistic to selective foragers, mesopelagic to benthic adult habitat along the continental shelf to slope, fast to slow growth rates, and a short to long lifespan. A variety of life history strategies have evolved to tolerate various environmental conditions, and specific population response to the same climate event may be different depending on the strategy (Yatsu et al. 2008). Understanding the fluctuations of these five species in concert will allow identification of successful strategies given a particular set of ecological conditions.

We will examine how ecosystem processes of competition, predation, and environmental variability influence recruitment dynamics of the five selected groundfish species during their early life history. Variability in recruitment results from fluctuations in spawning stock size (i.e. egg production) and variability in egg-to-recruit survival. Recruitment estimates based on the most recent stock assessments for these species are highly variable and appear unrelated to spawning biomass (Hanselman et al. 2007, Turnock and Wilderbuer 2007, Dorn et al. 2008, Hanselman et al. 2008, and Thompson et al. 2008). The trajectory of recruitment also differs among species ranging from extremely episodic such as with sablefish to oscillatory for pollock (Yatsu et al. 2008). Given the apparent lack of a spawner-recruit relationship, and the variety of responses among species, it appears unlikely that the level of spawning has a strong influence on recruitment variability over the range of observed abundances. While fishing on pre-recruit stages may also affect pre-recruit survival, and hence recruitment, large fluctuations in recruitment and stock sizes in spite of precautionary fishing levels suggest that recruitment is driven primarily by ecosystem processes. Therefore, we focus on environmental influences on recruitment levels during the early life of these fish, rather than direct effects of fishing or the level of adult spawning biomass.

A recent analysis of the recruitment and survival indices of commercial fish stocks in the GOA determined that environmental processes at regional scales (100s to 1000 km) are most important in driving recruitment variability (Mueter et al. 2007). Therefore, we focus our study on comparing ecosystem processes and their effects on recruitment in two regions of the GOA: the eastern and central areas (Figure 1). We choose the eastern and central GOA as our two study regions because they represent the upstream and downstream conditions of the dominant current systems in the GOA and high and low demersal biomass and species diversity. Two major current systems dominate the GOA: the subarctic gyre and the Alaska Coastal Current (Ladd et al. 2005). The eastward flowing North Pacific Current of the subarctic gyre bifurcates into two broad eastern boundary currents offshore of British Columbia. The north branch is the Alaska Current which narrows and intensifies near Prince William Sound to become the western boundary current known as the Alaskan Stream (Weingartner et al. 2002, 2009). The Alaska Coastal Current (ACC) is a narrow, wind- and buoyancy-driven current that flows in a counter-clockwise direction along the continental shelf (Weingartner et al. 2002). It is mediated by downwelling-favorable winds and freshwater runoff, which give the current a very strong seasonal signal (Ladd et al. 2005, Weingartner et al. 2005). The eastern GOA therefore serves as a link between the ecosystems of British Columbia and the northern GOA and may be critical in governing the future states of the GOA ecosystem (Weingartner et al. 2009). The wider and more productive continental shelf in the central GOA leads to a higher biomass of demersal fishes but relatively lower species diversity, whereas the narrow shelf of the eastern GOA has a much higher species diversity and lower biomass (Mueter and Norcross 2002). High species richness provides a buffer against the effects of climate variability and populations will be smaller but more stable over time (Hughes et al. 2005).

**Proposed Research Activities**

We define the critical window for survival of our key groundfish species to be bounded by larval development in the offshore pelagic zone to early juvenile settlement in the nearshore zone. Survival during this period is dependent on a myriad of factors in the offshore pelagic environment related to cross-shelf transport, nutrients, productivity, and energy, which control the quantity, condition, and location of these fish delivered to the nearshore. We hypothesize that successful recruitment for these species depends primarily on three linked processes: offshore and nearshore productivity, larval and YOY transport, and settlement into suitable demersal habitat. Our proposed research activities are designed to collect data and perform surveys that will sample the continuum of the eastern through central GOA in order to discover the causal mechanism for generating the two contrasting systems and determine the location of the physical and biological shift. This information will aid in developing models to explain recruitment variability of our five focal species and how these fluctuations affect top level predators. The health of the GOA ecosystem may depend on the inherent structure and subsequent resiliency of each region. In the next several sections (subheadings in italics) we describe the conceptual framework (concept) and proposed activities (approach) for each of our major objectives. Requirements from each of the integrated research components will be stated within each section. A responsibilities and linkages section will follow to summarize the responsibilities of each component and demonstrate how each objective informs the final products and deliverables of this proposal.

*Retrospective Analysis*

Concept: A thorough literature review and subsequent collection of available datasets provides baseline information of the ecosystem processes throughout the GOA. By evaluating previous methodologies, we can determine the best sampling approach and identify significant gaps in current knowledge. If the review and datasets are organized by trophic level, this will add another level of utility for establishing trophic links to our five focal species. Collating relevant information such as time of spawning, development, growth, recruitment histories, and habitat preferences for our five focal species and other linked species will refine later model development and simulation testing. Additionally, categorizing datasets by direct and indirect pressures on our five focal species will help identify large versus small scale mechanisms that influence recruitment strength. For example, physical variables such as sea surface temperature will directly impact the suitability of the pelagic environment for our focal species on the scale of large water masses. A warm or cool regime may favor different life history strategies. On the other hand, fluctuations in the abundance of top level predators will indirectly influence our focal species in complicated trophic interactions. Steller sea lion (*Eumetopias jubatus*) abundance has declined dramatically in the central and western GOA since the 1960s (Trites and Larkin 1996), while abundance has increased about 3% per year in the eastern GOA (Pitcher et al. 2007). One theory for the decline is nutritional stress where an inadequate quantity or quality of prey will lead to lower juvenile survival, episodic adult mortality, and reduced fecundity (Calkins et al. 1999, Atkinson et al. 2008). Many studies have found that groundfish serve as the staple of the Steller sea lion diet, with pollock often appearing most frequently (Trites et al. 2007, Womble et al. 2009). Strong seasonal and spatial variability of their energy-rich prey such as herring, *Clupea pallasii*, will lead to changes in the sea lion diet and foraging strategy (Womble et al. 2009) and, therefore, fluctuations in competitor biomass for several of our focal species. These indirect effects likely occur in localized areas and are difficult to quantify but may lead to the development of new hypotheses and sampling procedures for testing these complex trophic relationships.

Often the exploratory phase of variable selection includes a myriad of potential environmental predictors that increases the chance for development of spurious relationships. Developing hypotheses suited to the ecological plausibility for a given species will aid in reducing this possibility (Shotwell et al. 2005). Incorporating the spatial component into the retrospective analysis allows for identification of long-term regional trends and analysis of the spatial overlap between different datasets. This will help refine causal relationships between the various trophic levels and the recruitment strength of our focal species. Once mean conditions are established, representative datasets for each trophic level should be selected that influence each of the focal species based on direct and indirect effects. Temporal analysis of these datasets will explore the influence of regimes shifts on recruitment strength of the focal species and prepare the data for potential future use within single or multi-species assessment models.

Approach: We will perform a literature review of relevant life history information for the five focal groundfish species. Available datasets will be collected that relate to this review and represent potential drivers influencing the early life survival of the five focal species. We will consider all resolution levels of biological and physical indices from the high resolution satellite measurements to large scale surveys of fish, seabirds, and marine mammals. Examples of datasets are listed in Table 1 and organized by trophic level category. An initial examination of the dataset will determine whether the data represent direct or indirect pressures on recruitment. Following the literature review and data categorization, we will compile available data and coordinate with the data manager to organize this information within a relational database. Scientists in the LTL, MTL, and modeling component will have access to this database for developing sampling methodologies and testing hypotheses. A few of these datasets may require more development of historical information, such as recalculating biomass estimates at finer scales of resolution.

Following data collection and any subsequent re-estimation or laboratory analysis, we will develop spatial maps of mean conditions for several representative datasets by trophic category to identify long-term patterns and delineate a faunal or physical break between the eastern and central GOA. Once regions are identified, we will perform a time series analysis to determine the datasets most related to the recruitment estimates of our five focal groundfish species. These datasets will serve as potential predictor variables in a generalized additive model framework to develop an index of recruitment for each of the five focal species. Temporal trends will be compared by region and species to identify successful life history strategies for alternating climate regimes. These retrospective tasks are listed in Table 1 following the example datasets. This spatial and temporal analysis will serve to prepare datasets for later use by the modeling component for testing effects of climate variability on groundfish recruitment and trophic interactions up through top level marine predators.

*Offshore to Nearshore Pelagic Stage*

Concepts: We define two stages of early life history for the five selected groundfish species that are critical for determining recruitment strength: the offshore to nearshore pelagic stage and the nearshore settlement stage. From late winter through early spring, spawning and egg incubation take place at depth and larvae swim to the surface. The offshore to nearshore pelagic stage is the time from spawning in late winter, early spring through arrival at the nearshore of YOY in mid-summer to late fall. Location of spawning and egg incubation occurs as far offshore as 160 km along the upper slope in 400+ meters water depth for sablefish (Wing 1997) to as far inshore as the inner shelf in 50 meters water depth for some Pacific cod (Klovach et al. 1995). We use the 160 km distance from shore as a guideline for the extent of the offshore pelagic stage. Spawning for these five species may occur from early winter through summer; however, peak spawning is likely within the late winter to early spring (Sigler et al. 2001, Blood et al. 2007). Several of these species are observed in shallow coastal bays just before and after settlement (e.g. Abookire et al. 2007). We use the entrance of these coastal bays as our guideline for the nearshore extent of the pelagic stage. Timing and location of settlement is largely unknown for these species and likely includes a range of depths given the different habitat requirements. Generally, settlement should be before the first overwinter period, although some species may perform vertical migrations throughout their nearshore existence (Sogard and Olla 2001). Juveniles of these species may overwinter in the nearshore for one to several years before they begin offshore movement into adult habitat (Carlson and Straty 1981, Rutecki and Varosi 1997). Upon arrival, both the pelagic and demersal nearshore habitats influence the ability to feed, avoid predators, and compete with other species.

The physical structure, transport processes, and biology of the Northeast Pacific Ocean respond strongly to forcing at several time and space scales that can result in large interannual changes for both coastal and offshore regions of North America (Batcheldor 2002). These fluctuations affect the abundance, distribution, and condition of our five focal groundfish species. Cross-shelf transport is influenced by several physical mechanisms including mesoscale eddies, episodic upwelling, freshwater runoff, tidal mixing, and complex bottom topography (Weingartner et al. 2002, Ladd et al. 2005, Bailey et al. 2008), many of which have seasonal signatures. These factors also impact the stability of the water column influencing the timing and size of spring blooms and therefore the prey field. Late winter to early spring oceanographic conditions influence the temporal and spatial scale of these features that manifest in the summer and fall (Weingartner et al. 2009). Zooplankton and forage fish respond to these seasonal and interannual fluctuations in prevailing oceanographic conditions (Coyle and Pinchuk 2005, Conners and Guttormsen 2005). Various species of seabirds and marine mammals rely upon the persistence of forage aggregations or “hotspots” (Gende and Sigler 2006) which have been associated with seasonally fluctuating oceanographic features (e.g. fronts, upwelling zones) that also respond to climate change (Anderson and Piatt 1999, Miller et al. 2005).

In order to understand the influences on recruitment during the offshore to nearshore pelagic stage we must sample this environment during the critical window of survival for the five groundfish species and include a sampled area large enough to test regional differences. Previous surveys have been successful in capturing egg, larvae, and YOY of the five groundfish species on which our proposal is focused; however, sampling has been periodic with little concurrent information on the biophysical environment in which these fish were captured. The Fisheries-Oceanography Coordinated Investigations (FOCI) program has successfully sampled larvae from the central and western GOA since the early 1970s using bongo nets and Tucker trawls that are towed vertically through the water column. Sampling primarily occurred during April and May and surveys commonly captured larvae of all key species, although rockfish (*Sebastes* spp.) were not identified to species (Matarese et al. 2003). The U.S. Global Ocean Ecosystem Dynamics (GLOBEC) program sampled the GOA from Yakutat to southwest Kodiak Island during summer using a surface trawl identical to our proposed surface trawl. YOY of the five target species were captured with the exception of arrowtooth flounder. The Southeast Alaska Coastal Monitoring (SECM) program has conducted surface trawling at four coastal stations off Icy Point in southeast Alaska (7 to 65 km offshore) from spring to fall during 1997-2001. The Marine Ecology and Stock Assessment (MESA) program conducted surveys in May 1990 (Wing 1995) and August 2005 (warm) and 2006 (cold) to investigate ichthyoplankton distribution in the eastern GOA. As part of a voluntary logbook program in southeastern Alaska, commercial salmon trollers identified prey in stomachs of chinook and coho salmon from 1977-1991 along the outer coast of Alaska from Dixon Entrance to Yakutat. Pollock YOY were common prey items during July, August, and September and sablefish YOY were common prey during September (Wing 1985). Small mesh trawl surveys for shrimp and forage fish around Kodiak Island have been conducted by the Alaska Fisheries Science Center (AFSC) and the Alaska Department of Fish and Game (ADFG) since 1953. Catch is dominated by shrimp, Pacific cod, pollock, and flatfish, including arrowtooth flounder, and shorter time series of rockfishes and sablefish are available (Anderson and Piatt 1999).

Approach: We propose a comprehensive pelagic sampling plan to survey Cape Ommaney to the far western edge of Kodiak Island during three seasons: spring, summer, and fall during 2011 and 2013 to adequately characterize the abundance, distribution, and condition of the five groundfish species in the eastern to central GOA. Timeline for sampling procedures is depicted in Table 2. A dedicated spring survey is required from the lower trophic level (LTL) component to obtain concurrent measurements of temperature and salinity profiles, nutrient levels, primary productivity, and zooplankton taxonomic composition. Additionally, sampling for larvae during this survey following the methods described in Matarese et al. (2003) would identify the initial spatial distribution (time zero) of this stage for each groundfish species. Ichthyoplankton samples of the five focal species should be identified and preserved in 95% non-denatured ETOH for later analyses. For the summer and fall surveys, the lower, middle, and upper trophic level (LTL, MTL, and UTL, respectively) components will collect concurrent observations of the biophysical environment (i.e. oceanography, prey, competitor, and fish predator fields). Cooperation between field components will be essential for meeting survey objectives.

We propose a systematic sampling design (Figure 1) to generate station locations for the summer and fall surveys. With very little information on the offshore to nearshore pelagic distribution of the five focal species, a systematic grid allows for the fewest assumptions on population structure. The evenly spread stations create the continuum from the eastern to central GOA allowing for sampling in both the cross-shelf and along-shelf direction and to aid in identifying the biophysical break between regions. Disadvantages of this systematic design include the inability to calculate an unbiased estimate of variance and the potential bias in density estimates due to clustered populations (Cochran 1977). In general, surveys are often restricted to one systematic sample due to time and vessel limitations. However, the objective of the integrated approach is to compare between regions, seasons, and two years across multiple trophic levels. The systematic fixed station design will allow for direct comparison of relative densities between years and while unbiased estimates of variance are unavailable, relative variance between areas and years can be compared with post-stratified estimates, simple random sampling estimates, and bootstrapping (Efron and Tibshirani 1993). Additionally, since the survey is targeting multiple species and environmental covariates, a design that provides the maximum spatial coverage is preferred to a design that makes assumptions about components with which we have relatively little prior knowledge. Using traditional sampling methods for estimating biomass such as stratified-random sampling would involve tradeoffs between objectives, and make modeling of spatial dynamics difficult.

The study area extends from the previously defined range of offshore to nearshore based on the biology of the focal species and Cape Ommaney to western Kodiak. Station spacing is initially determined by the minimum distance required to sample the area while maintaining transit and field work efficiency. The current grid spacing is 28 nautical miles resulting in a total of 100 stations within the study area. This distance is below the minimum required for identifying both major current systems and mesoscale features (e.g. shelf break fronts, eddies, freshwater plumes) based on results from previous oceanographic surveys in the GOA (L. Eisner AFSC pers. comm.). Offshore extent, minimum grid spacing, and total number of stations will be refined with data from a southeast Alaska pilot summer survey in 2010. For each station, the LTL will be responsible for the physical and biological oceanographic measurements. Products will include vertical and horizontal measurements of temperature, salinity, depth (CTD profiles, surface thermosalinograph), phytoplankton biomass and size structure (fluorescence, discrete water samples), and zooplankton abundance, biomass, and community structure (Multi-Net). This data will be used to determine location of oceanic fronts, mixed layer depths, and primary and secondary production at each grid station. The UTL will conduct surface trawling at each station using methods similar to those of the GLOBEC (GOA) and to the Bering-Aleutians Salmon International Survey (BASIS) programs, which are also used in the Bering Sea Integrated Ecosystem Research Program (BSIERP). A subsample of YOY of the five focal species captured in the surface trawls will be frozen at -20 C for transport to the laboratory for later analyses. Additional surface trawls will be made with a live-box to capture live fish for laboratory health assessments. The UTL will be responsible for estimating abundance, distribution, and condition of YOY groundfish. The MTL will be responsible for estimating abundance, distribution, and condition of the forage base that is also captured in the surface trawls. The MTL will also be responsible for diet analysis of relevant trawl caught species, including YOY groundfish, forage fish, and large predatory fish. Sampling during summer and fall will reveal the dynamic conditions (stratified vs. mixed) of the offshore and nearshore pelagic zone. Using previously tested methodologies will allow for easy comparison between other large marine ecosystems such as the Bering Sea, and be compatible with past sampling efforts in the GOA.

*Nearshore Settlement*

Concept: Upon arrival in the nearshore YOY fish must acquire prey, avoid predation, and settle to suitable benthic habitat in order to recruit successfully. Habitat selection by YOY fish is species specific and is related to dietary requirements and predator avoidance (Sogard and Olla 1993, Stoner and Titgen 2003). For example, biogenic structure such as corals provides shelter from predators and attraction of prey; however, this structure may provide an advantage or disadvantage to competing species depending on their cryptic coloration. The availability of suitable habitat, as determined by substrate type, infauna, and epifauna along with oceanographic conditions, play a strong role in determining the success of YOY fish settlement (Carlson and Straty 1981, Abookire et. al. 2007).

Approach: Available information on habitat preferences will be combined with available substrate data (e.g. bathymetry, substrate samples, as described below) to create benthic habitat suitability maps by region and fish species. We will model habitat suitability as a function of known species preferences and habitat distribution and will incorporate information on the nearshore prey, competitor, and predator fields to the extent we can quantify these distributions for different regions. This will ultimately determine probability of successful recruitment in the nearshore settlement stage.

Benthic habitat data exists at varying resolutions from detailed bottom mapping and actual bottom observations (e.g. Shotwell et al. 2008) to general low resolution bathymetry and regional sediment distribution paper maps (e.g. Carlson et al. 1977). Three main types of bathymetric data exist in the GOA: low resolution remotely sensed data of broad regional extent, high-resolution multibeam bathymetry of limited areal extent, and National Ocean Service (NOS) point data of variable resolution. Scientists at the AFSC are currently constructing a highly detailed bathymetric map of the GOA seafloor so that seafloor measures (e.g. topographic roughness) can be analyzed (M. Zimmermann AFSC pers. comm.). Since 2000, the US Geological Survey (USGS) and its collaborators have compiled seabed data from existing reports and datasets into usSEABED, which is a nation-wide integrated seafloor characterization database (Reid et al. 2006). Preliminary analysis of these data in central GOA shows muddy sediment in bathymetric lows such as Shelikof Strait with coarser sediment (to gravel) on bathymetric highs such as Albatross Banks. These data will be used to create continuous gridded surfaces of sediment and rock distributions. In combination, the highly detailed bathymetry with sediment distribution grids should provide the first regional contextual three-dimensional observations of sediment distributions in the GOA (e.g. Figure 2). This information will provide a knowledgeable, scalable, basis for YOY habitat suitability analysis.

We will utilize these newly created bathymetry and sediment distribution grids and associated seafloor measures to predict the distribution of suitable benthic habitat for the five groundfish species. Habitat suitability will depend on the groundfish species and will be obtained from the literature (e.g. Freese and Wing 2003, Abookire et al. 2007). Available information will be used to quantify habitat preferences for each species and habitat type on an ordinal scale (e.g. good, adequate, poor) or on a continuous scale (habitat suitability index), depending on data availability. We will refine our estimates of suitability as further literature, field observations, and laboratory based studies become available.

The distribution of potential prey, predators, and competitors will be an additional factor that should be considered in determining habitat suitability and will be evaluated by the upper trophic level. Some measure of the nearshore prey, competitor, and predator distributions will be available from the nearshore grid stations of the pelagic stage sampling grid described above. However, this is unlikely to provide sufficient coverage of these distributions. The middle trophic level (MTL) component is requested to select representative habitats of the nearshore to augment the information from the pelagic grid stations. Information from existing small mesh surveys in both the eastern and central GOA (e.g. AFSC/ADFG small mesh survey, Southeast Alaska humpback whale survey) and the afore-mentioned sediment distribution maps may be useful for choosing these sampling areas. Data collected from these representative habitats will be used to generate presence/absence information on the distribution of marine fish species and top level predators by habitat in these nearshore bays. This information along with estimates of total available habitat from the bathymetry and sediment distribution maps described above will inform the habitat suitablity model. Estimates of the prey and competitor fields are also available from the diet of planktivorous and piscivorous seabirds (respectively) with short foraging distance (as described below in the Top Predator stage). Predation estimates will be derived from biomass estimates of predatory fish from nearshore stations of existing surveys (e.g. NMFS trawl survey, IPHC survey) and seabird/marine mammal bioenergetics models of biomass removals (as described below in the Top Predator stage and detailed in the MTL proposal). The end product will be the predicted ability of YOY to feed, compete, and avoid predation based on the estimated availability of suitable demersal habitat.

*Health Assessment*

Concept*:* Instantaneous growth, condition and consumption rates of fish passing through the gauntlet will served as an indirect measure of health that may be linked to probability of early life survival. Survival of YOY marine fish over the first year of life is related to growth (Mazur et al. 2007) and energetic condition (Moss et al. 2009). We will examine seasonal, spatial, and interannual conditions for supporting the growth of Pacific cod, Pacific ocean perch, sablefish, and pollock YOY in three different habitats (slope, shelf, and nearshore). The amount of energy available in each habitat will be quantified along with growth (based on fieldwork and laboratory experiments). The conditions will be simulated in bioenergetic models to assess performance in different habitats. Arrowtooth flounder will not be included because previous surveys indicate they rely on different marine habitats, since they are not caught in pelagic habitat by surface trawls.

We will use simple bioenergetic models to estimate potential fish growth in different habitats and model outputs will be compared with field observations of fish abundance and distribution. The effect of temperature and body size on consumption and metabolism are the most sensitive parameters in bioenergetics models (Beauchamp et al. 1989). These parameters will be estimated from a series of laboratory experiments involving Pacific ocean perch. Models for sablefish already exist (Sullivan and Smith 1982; Furnell 1987; Ryer and Olla 1997; Sogard and Olla 2001). A similar analysis is currently being performed for pollock and Pacific cod as part of the BSIERP. These parameters will be combined with data on food habits and temperatures collected at sea in order to predict growth trajectories in different habitats. Bioenergetics model simulations will be realized for each species, region, and habitat. Comparisons of model output with observed abundances and distribution will be used to explore observed recruitment variability.

Approach*:* Bioenergetic parameters requiring measurement include resting and active (various swimming speeds) metabolic rates and consumption rates. Metabolic rates will be determined by measuring oxygen consumption using a respirometer. Consumption rates will be determined by feeding fish commercial fish food pellets to satiation. The difference between the mass offered and mass not eaten will be the mass consumed. Feeding will occur over a 24 h period, permitting expression of consumption as g per day. These model parameters will be developed over a range of thermal conditions and body sizes. Estimation of growth potential also requires evaluation of prey quality and consumption. Prey energy content will be estimated from either bomb calorimetric methods or proximate analysis of prey items. Habitat-specific food habits of juvenile groundfish will be evaluated by stomach content analysis. This analysis will be performed for each habitat in both sampling locations (eastern and central GOA).

An independent assessment of growth potential will be conducted by relating field observations of RNA/DNA ratios to laboratory derived relationships between growth, temperature and RNA/DNA ratio. Models for Pacific ocean perch and sablefish will be constructed from the same series of laboratory experiments used to develop bioenergetic parameters. These models will be used to translate RNA/DNA ratios of fish captured at sea to instaneous growth (Lankin et al. 2008). Research efforts to develop similar models for Pacific cod and walleye pollock are currently underway at the AFSC. Growth estimates acquired over multiple habitats in the eastern and central GOA will be used to test the hypothesis that nearshore habitat is most beneficial for juvenile groundfish relative to other offshore habitats. Comparison of these results with the outputs from bioenergetic models will provide a method for gauging the uncertainty of our conclusions.

*Top Predator Stage*

Concept: Various species of seabirds and marine mammals have been associated with particular oceanographic features (e.g. fronts, eddies, upwelling zones) and prey aggregations (Piatt et al. 2007, Witteveen et al. 2008). These hotspots are considered sites of critical ecosystem linkages between trophic levels and are often affiliated with bathymetric structures such as canyons, banks, and coastal topography (Sydeman et al. 2006). There exists considerable temporal variability of these hotspots (Yen et al. 2005), which will have a large effect on the energy requirements for central place foragers (use of marine environment for forage and terrestrial sites for rest and care of young) such as seabirds (Piatt et al. 2006). Seabirds expend considerable energy in flight and diving under water for food (Bryant and Furness 1995). Rhinoceros auklets typically dive to about 30 m where conditions force sandlance and other small schooling fishes to the surface (Gaston and Dechesne 1996). Surface-feeding storm-petrels can spend relatively more time searching for patchily distributed food, and compared to auklets, travel farther from the colony. Both species provide a comparison for conditions in shelf break regions. Steller sea lions will change foraging behavior in response to seasonal distributions of high-energy prey (Womble and Sigler 2006) and alter dive activity in response to oceanographic features such as chlorophyll *a* concentrations (Fadely et al. 2005).

A growing body of evidence supports the use of seabirds as indicators of ecosystem health (NPRB 2006), and several recent studies have used different seabird species to determine relative abundance, composition, and condition of fish in the GOA (Piatt et al. 2007, Thayer et al. 2008). Prey reductions near breeding colonies may influence seabirds' foraging distance (Ainley et al. 2003) and seabirds may vary their foraging behavior according to oceanographic productivity patterns across their breeding ranges (Boersma et al. 2009). Oceanographic conditions can affect chick growth and reproductive success via frequency, size, and composition of prey fed to chicks. Success is variable among years because of climate perturbations, changes in prey availability, and other factors (Boersma 2008). It may be that trends in foraging distribution and effort are linked to fluctuations in groundfish recruitment and the forage base; and detailed information on where these seabirds feed will help better understand linkages between physical oceanic conditions, and predator-prey responses. Diet of top level predators such as seabirds is affected by variability in their prey abundance (Thayer et al. 2008), and we hypothesize that dietary preference and foraging strategy of these top level predators is directly related to relative abundance of suitable prey, including groundfish, in the nearshore. Factors influencing recruitment of our focal groundfish species will affect composition of available prey for these predators and will be reflected in seabird population differences between the eastern and central GOA. We propose to compare dietary preference and foraging strategy of seabirds in the eastern and central GOA study regions to assess dependence of these top level predators on recruitment strength of our key groundfish species.

Seabirds are thought to consume the juveniles of most commercial species (Boldt 2004). Thayer et al. (2008) discusses the diets of piscivorous seabirds at two major colonies in the GOA. Sablefish and rockfish are included in the top species of prey for juvenile predatory fishes in the GOA, and it is estimated that between fifteen to eighty percent of the biomass of juvenile forage fish may be removed by birds each year near breeding colonies (Wiens and Scott 1975, Furness 1978, Springer et al. 1986, Logerwell and Hargreaves 1997). There are an estimated 7.2 million breeding pairs of seabirds in the GOA (Stephensen and Irons 2003), and an additional 30 million birds from five main species arrive in the summer for all of Alaska (Boldt 2004). Considering the lower estimate of 7.2 million pairs (14.4 million adult birds), and applying it to a worldwide ratio of seabird consumption (Brooke 2004), the result is an estimate of 914,000 metric tons of fish taken by seabirds in the GOA each year.

Approach: Datasets collected during the retrospective analysis (describe above) will serve to generate an estimate of total predation pressure during the offshore to nearshore stages. Predation estimates of adult predatory fish for the nearshore during late summer will be derived from biomass estimates from all nearshore stations of existing surveys (e.g. 2011 and 2013 NMFS trawl survey). Biomass removals from seabirds and other marine mammals will be estimated by bioenergetics models as detailed in the MTL proposal. We will collect information on seabirds and marine mammals during the summer and fall offshore to nearshore pelagic surveys as an estimate of the predator field on early pelagic stages of the five groundfish species. A trained seabird and marine mammal scientist will conduct standard visual line-transect surveys for marine mammals (Moore et al. 2002) and standard visual strip-transect surveys for seabirds to estimate top predator density at each grid station (Gould and Forsell 1989).

Data on seabird productivity, diet composition, and chick growth have been collected at St. Lazaria Island annually since 1994 and at East Amatuli Island intermittently since 1993 (Figure 1). Recent seabird studies focused on St. Lazaria Island populations suggest that interannual changes in ocean temperature and food web restructuring have altered the timing of nesting and reproductive success (Slater and Byrd 2009). Seabirds breeding at St. Lazaria for which long-term data sets exist are rhinoceros auklets (*Cerorhinca monocerata*, piscivores which feed in coastal waters) and fork-tailed and Leach's storm-petrels (*Oceanodroma furcata* and *O. leucorhoa*, primarily planktivores which feed offshore and along the shelf break). Long-term data collected at East Amatuli Island exist at various temporal resolutions for black-legged kittiwakes (*Rissa tridactyla*), common murre (*Uria aalge*), and tufted puffins (*Fratercula cirrhata*).

We will continue the diet collections on St. Lazaria and East Amatuli Islands during summer of 2011 and 2013 which will correspond to the summer pelagic grid survey. Additionally, we will equip rhinoceros auklets with platform terminal transmitter (PTT) tags to evaluate feeding patterns during the chick-rearing period. Lightweight, miniaturized, improved electronic devices will allow us a greater ability to quantify time-budgets of burrow-nesting seabirds, investigate relationships between foraging habitats and environmental features, and quantify overlap with commercial fisheries (e.g. Weimerskirch et al. 1997, Catard et al. 2000). Receivers within the colony will record the birds' presence on land which, throughout the study, will allow us to evaluate foraging effort across years based on frequency and duration of chick-feeding bouts. Tags will also record feeding locations which may allow an assessment of interactions with prey when compared to the summer grid surveys. Concurrently, auklet chicks will be measured to determine annual growth rates, and as in past years, diet samples will be collected to evaluate the relative abundance and importance of individual prey species in auklet diets.

*Ecosystem Modeling*

Concept: We propose that the modeling component of this Integrated Ecosystem Research Program (IERP) further develop existing biophysical models of the region (e.g. Coyle et al. *in press*) to develop indices of lower trophic level (LTL) variability, which can be used as explanatory variables to inform multi-species models of upper trophic level (UTL) variability. The biophysical model should consist of a hydrodynamic model (e.g. Regional Ocean Model System or ROMS) linked to a nutrient-phytoplankton-zooplankton (NPZ) model, which can generate hindcasts and forecasts of LTL variability. In addition, we ask that transport models (for example individual based models (IBM) linked to a biophysical model) be developed to construct indices of recruitment based on transport to suitable nursery areas for two representative species included in the UTL model. We suggest Pacific ocean perch and sablefish as the best candidates for the two representative species and provide justification below. Field-based estimates of spring to fall spatial distributions of Pacific ocean perch and sablefish can be used to tune the model, and to predict the spatial locations where each species will eventually settle onto demersal habitat in the two regions. Recruitment success depends on encountering the right habitat at the right time (or within a critical time period) and requires successful transport of pre-settlement stages to suitable demersal habitat.

The biophysical model will provide indices of LTL variability that can be used in retrospective studies to better understand recruitment variability. Critical indices identified in the biophysical model may also be used as covariates in single-species or multi-species stock assessment models to provide improved estimates of recruitment variability and as indicators of potential future climate variability in simulation studies. Results from retrospective analyses, from previous studies such as NEP GLOBEC, and from the proposed fieldwork of this IERP can be used to help parameterize the biophysical model. The development of such a model for the GOA can also be informed by the development of a similar model for the eastern Bering Sea shelf under the BSIERP. We do not propose the development of a full, vertically integrated modeling approach because we believe that the spatial dynamics in the GOA are too complex and because available and newly collected data will be insufficient to support such a modeling effort under this IERP.

Approach: The transport models (IBM or similar) will provide indices of recruitment success related to the transport of eggs and larvae from offshore spawning locations to inshore settlement areas. Due to the potential high model complexity, we suggest two candidate species for constructing such models, sablefish and Pacific ocean perch, who, among our five focal species, exhibit extreme life history strategies with respect to dispersal. Pacific ocean perch are viviparous, providing more maternal care and releasing more active larvae into the pelagic environment. Several genetic studies have demonstrated low dispersal rates for this species, despite the potential for high dispersal due to the exposure to strong oceanographic currents (Johansson et al. 2008, Palof 2008). This suggests local stock structure which may result from a life history strategy that utilizes distinct transport pathways. An example of this type of strategy has been suggested for arrowtooth flounder that may utilize tidal transport to nearshore nursery areas through deep water canyons and sea valleys (Bailey et al. 2008). Pacific ocean perch may be actively navigating in the surface currents with vertical migration in response to tidal flow. Thus, the UTL will perform genetic identification analysis of YOY Pacific ocean perch collected during our field work to be used by the modeling component. This is required because transport models should be integrated with the underlying genetic signal. The model should combine, genetic, oceanographic, and behavioral aspects of the species to realistically characterize larval and YOY dispersal (e.g. Selkoe et al. 2008). In contrast, sablefish are oviparous (as are pollock, Pacific cod, and arrowtooth) with a prolonged egg stage and pelagic YOY with long and wide pectoral fins. These adaptations suggest that sablefish exhibit passive, long-distance dispersal during their pelagic stage. Sablefish also migrate extensively during later life stages and are considered a single population for all of Alaska (Heifetz and Fujioka 1991, Kimura et al. 1997). The presumed reliance on local retention mechanisms in Pacific ocean perch and long-distance dispersal in sablefish suggest that these two species may be more sensitive to climate-driven variability in transport. Being at the opposite ends of the retention/dispersal spectrum makes these species good candidates for identifying key ecosystem variables related to transport that affect survival and recruitment for our five species and would provide useful environmental covariates for single-species and multi-species stock assessment models.

Following development of the transport models, the modeling component should integrate data and results from the proposed fieldwork and retrospective studies for at least three species of primary interest that have strong trophic linkages (e.g. arrowtooth flounder) and serve as important prey for seabirds and Steller sea lions (pollock and Pacific cod). The other focal fish species (e.g. Pacific ocean perch, sablefish) may be included in the multi-species model if feasible. To compare multi-species dynamics between the eastern and central areas we propose that separate models be developed for each region. These models will synthesize the LTL information, including relevant recruitment indices developed from retrospective analyses and from the transport models into a predictive model for different climate regimes and different groundfish harvest strategies. The models would contribute both a retrospective component for evaluating multi-species dynamics over the past several decades, as well as a tool to conduct management strategy evaluations. For example, an existing multispecies age-structured assessment (MSASA) model of the population dynamics of pollock, Pacific cod, and arrowtooth flounder in the GOA (Van Kirk et al. *in review*) provides a possible template. This model accounts for species interactions by estimating predation mortality as a flexible function of predator and prey abundances as fitted to long time series of stomach-content data collected by AFSC. Due to data limitations a simpler model such as a biomass dynamics model (e.g. BSIERP F2875) could be developed for the eastern region. For prediction purposes, estimates of predation of juvenile fishes by seabirds and Steller sea lions from existing data and from the proposed field work can be used to help quantify predation losses. To account for variability at the lower trophic levels these models should use indices of climate, environment and prey abundance, or YOY recruitment indices from the IERP field studies and retrospective analyses, as covariates in the model to improve estimates of recruitment of the principal groundfish species that serve as the focus of the model.

In retrospective mode, the models can be used to test specific hypotheses about the effects of climate variability on recruitment of and trophic interactions among the focal species. A better understanding of the critical mechanisms linking climate variability in the GOA ecosystem to UTL variability will improve predictive models of future ecosystem changes, help identify management strategies that are robust to such changes, and enhance stock assessment performance and ultimately ecosystem health.

*Application to Fisheries Management*

Concept: Forecasting recruitment is an important aspect of determining sustainable future catch levels based on current stock status of these five species of groundfish. Since different recruitment levels can sustain different catches, the ability to forecast recruitment strengths will enable fisheries managers to provide sound advice on catch levels. Additionally, stock assessments are strengthened if the mechanistic links between the environment and recruitment are well understood and can be conveyed effectively to stakeholders. The improved recruitment predictions, and a better understanding of recruitment dynamics, developed from this study can be used to guide further stock assessment research including management strategy evaluations, testing assumed variances, and sensitivity analyses. Products from this study will solidify ongoing trophic level ecosystem models (Boldt 2008) by establishing predator, competitor, and prey linkages. Additional applications to fishery management include the development of a framework to evaluate benefits of marine protected areas, spatial fisheries management, and identification of essential fish habitat. By increasing the mechanistic understanding of groundfish recruitment and improving the data inputs for ecosystem models, this study will build the foundation to fulfill the mandate of ecosystem based assessments.

Approach: To evaluate the consequences of potential management strategies, we request that the modeling component construct fishing scenarios and use simulation exercises. By shifting human-controlled impacts (fishing pressure) on target populations, complex system responses can be observed and assessed against management goals with regards to fisheries and stock conservation. A series of simulations should be constructed in which fishing pressure is selectively increased, decreased, or left unchanged, for each species and across all species combinations. The multi-species model will be able to display the complex population dynamics necessary to develop management strategies that include predation considerations. This can be done using a variety of environmental and climate scenarios that produce alternative indices of prey abundance, recruitment, and influential environmental variables.

**Responsibilities Summary and Components Linkages**

The initial spring grid survey that provides an estimate of initial spring conditions (oceanographic conditions, phytoplankton and zooplankton community) for the egg/larvae pelagic stage is required of the lower trophic level component. Concurrent measurements of oceanographic conditions, phytoplankton and zooplankton community and sampling of forage species must occur during the summer and fall grid surveys. The lower and middle trophic level proposals must include these products. Abundance, distribution, and condition estimates of competitors to YOY (e.g. capelin, herring) in the nearshore settlement stage must be included in the middle trophic level proposal. The ecosystem modeling component must build the biophysical, transport, and multi-species models for each region that incorporates results from the retrospective analysis and proposed fieldwork from the upper, middle, and lower trophic levels.

Retrospective analysis and proposed fieldwork will inform all developed models which will in turn predict responses to climate change and anthropogenic forcing for all trophic levels. Products from proposed field work will build upon and calibrate existing data sets (Table 1) as well provide the necessary data to understand trophic linkages and ecosystem structure. Comparisons between eastern and central GOA model results will identify successful recruitment strategies of our five focal fish species and capture fundamental differences that make the eastern GOA more resilient to climate change.

D. <u>Project Responsiveness to NPRB Research Priorities or Identified Project Needs</u>

Three Overarching Premises of the NPRB Science Plan (NPRB 2005):

1) Natural variability in the physical environment influences trophic structure and overall productivity.
2) Human impacts superimpose additional changes, including increased levels of contaminants, habitat alterations, and increased mortality of certain species that may initiate ecosystem change.
3) Natural and/or human-induced changes affect people who live and work in the region, forcing adaptation to the changing environment, ecosystem, and management scheme.

Our investigation contributes to evaluating the three overarching premises of the NPRB Science Plan (NPRB 2005) and the overarching question of the GOAIERP Invitation which is based on these premises. Addressing Premise 1, the project accomplishes an identification and initial quantification of the major ecosystem processes that regulate the abundance, distribution, and condition of five predominant upper trophic level fish species. Further to Premise 1, the project will sample young-of-the-year (YOY) in summer and fall, and concurrent surface measurements of TSNPZ (temperature, salinity, nutrients, phytoplankton, zooplankton) to explore the temporal limits and geographic stability of the critical time-space window for survival. This window is bounded by egg and larval development in the offshore pelagic zone to YOY settlement in the nearshore zone. In addressing Premises 1 and 2, the project explores trophic linkages from primary productivity upward and impacts of environmental processes and fishing on productivities through modeling. Finally, as explained below, one of the major accomplishments of this project addresses Premise 3 by better informing fishery managers and resource-dependent coastal communities of the consequences of climate change.

The collection of fish by surface trawl and synoptic subsurface TSNPZ in summer and fall builds upon the experience of, and is comparable to, that of NEP GLOBEC (Gulf of Alaska) and BASIS (Bering Sea); however the transect-based sampling approach of NEP GLOBEC will be replaced by a survey grid similar to the approach used in BASIS. The use of these standardized sampling methods has the added benefit of supporting future comparisons between these two large marine ecosystems, Gulf of Alaska and Bering Sea. The proposed field sampling is complementary to, but substantially different from the normal National Marine Fisheries Service (NMFS) management functions that support commercially important marine fish stock assessments in the same area. These include observation on fishing vessels, catch-accounting, and fishery-independent surveys using trawl and longline gear. The use of environmental variables to help estimate parameters for single species stock assessment models is not a normal NMFS function at present, however advising NMFS of how to do this would be one of the major accomplishments of this project, and a major contribution to fishery management.

Retrospective screening of the many metrics related to cross-shelf transport, nutrients, productivity, energy, predation and food production will establish baseline information on the ecosystem processes governing the eastern and central GOA. This newly acquired information will aid the evaluation of conditions required for successful recruitment for these fish species over three linked processes within the critical window: offshore and nearshore productivity, larval and juvenile transport, and settlement into suitable demersal habitat. Multi-species models using information derived from these three linked processes establishes linkages between underlying environmental variability, recruitment and top predator behavior. Comparison between the eastern and central GOA will identify successful mechanisms for ecosystem resilience and ultimately health.

The products of this research program are directly relevant to federal and state management of commercial and subsistence harvests of the five focal fish species, as well as to federal regulation of seabirds and Steller sea lions that may limit harvests of these fish species. Access of commercial and subsistence harvesters to fish is ultimately based on sustainable levels of harvest established by fish stock assessments. Current fish stock assessments can be improved with more reliable estimates of recruitment particularly in the most recent year classes when very little information exists in the assessment model. Successful integration of relevant environmental time series into stock assessment models may potentially increase efficiency in harvest decisions, improve geographic catch apportionment, and allow for more reliable future harvest projections.

E. <u>Program Management, Timeline and Milestones</u>.

**Program Management:**

The research team will consist of Jamal Moss (AFSC) as the lead PI, Kalei Shotwell (AFSC), Shannon Atkinson (UAF) and Franz Mueter (UAF) as PIs. Collaborators include Tom Gelatt (NMML), Nadine Golden (USGS), Jon Heifetz (AFSC), Ron Heintz (AFSC), Jane Reid (USGS), Leslie Slater (USFWS), and Mark Zimmermann (AFSC). Dr. Moss will be responsible for overall project management and leading fisheries oceanographic surveys. Dr. Shotwell and Dr. Heifetz will lead the development of habitat suitability maps and coordinate with the modeling component on recruitment and management related issues. Dr. Mueter will lead retrospective spatial analysis on fish and seabird populations. Dr. Atkinson will oversee project administration for UAF and participate in retrospective analyses. Ms. Reid will provide expertise on usSEABED and Gulf of Alaska sediment distributions and Ms. Golden will grid and integrate sediment and bathymetric data. Mr. Zimmermann will provide bathymetric expertise and a large quality-tested dataset to the study. Dr. Heintz will lead bio-physical experiments on YOY Pacific ocean perch in the wet laboratory. Ms. Slater will lead the seabird component, provide seabird food habits and fledging rates from St. Lazaria Is. (rhinoceros auklet) and Barren Is. (tufted puffin) monitoring sites, organize data on historic seabird sightings from the North Pacific Pelagic Seabird Database, and oversee at-sea seabird and marine mammal observers.

A staff biologist will be hired at AFSC for 2.9 years to plan, coordinate, and lead fisheries oceanographic field surveys; and assist with laboratory experiments and project logistics. Two post doctoral students will be hired at AFSC. The first post doc will be hired for 2.75 years under the direction of Dr. Heintz to develop RNA/DNA growth models and conduct laboratory experiments that will ultimately generate bioenergetics model parameters for Pacific ocean perch. The second post doc will be employed for 2 years under the direction of Drs. Heifetz and Shotwell to develop the habitat suitability maps. A post doctoral student and a master's candidate will work under the direction of Dr. Mueter to retrospectively model potential drivers influencing the early life survival of the five target marine species. Dr. Atkinson will oversee project administration for UA and assist Dr. Mueter with the retrospective analysis.

**Research Platforms:**

A Stern-ramp trawler 100-160 feet in length will be chartered using NOAA Ship John N. Cobb replacement funds (dedicated) for July/August fisheries oceanographic surveys 2011 and 2013. Federal funding has been requested for these charters, and the AFSC will work with NPRB to develop acceptable alternatives if the FY11 and 13 appropriations are different than expected, and 45 days at sea aboard the Miller Freeman (dedicated) will be provided in kind by AFSC in 2013 for the fall survey. Bio-physical research on YOY Pacific ocean perch will be conducted at the AFSC's wet laboratory in Juneau, AK which has approximately 2,000 square feet of enclosed space, overhead electrical power and 1,200gpm of seawater flow.

**Timeline and Milestones:**

A timeline detailing project milestones and accomplishments for the upper trophic level is provided (Table 2). Deliverables for the entire project include a database of collected field data and historical time series, retrospective analysis, habitat suitability models for all five focal species, transport model for Pacific ocean perch and sablefish, multi-species model with environmental covariates, and the publication of numerous manuscripts. Peer-reviewed manuscripts will include at least: 1) a retrospective analysis of datasets pertaining to the potential drivers influencing the recruitment dynamics of five predatory groundfish species; 2) summary of the seasonal abundance, distribution, and condition of five predatory groundfish species 3) habitat suitability models for five predatory groundfish species; 4) the utility of seabirds as indicators of YOY marine fish abundance and the implication of interannual differences in prey field on chick condition; 5) a newly parameterized bioenergetics model for YOY Pacific ocean perch with interannual differences in growth trajectory and implications for recruitment; 6) the relationship of RNA/DNA rations with observed growth in the laboratory and field estimates of instantaneous growth.

F. <u>Data Management Plan</u>

NPRB will be responsible for data management, and $352,940 dollars are being held back from the UTL component to support the hiring of a database manager. The integrated data management component will be compatible with the NPRB requirements concerning data management and metadata submittal, so that results from the GOA IERP studies are integrated into the Alaska Marine Information System (AMIS) system (Johnson/NPRB 704). Data management will be a cooperative effort with UTL investigators to insure that the data is available on-line and will be compatible and comparable.

G. Outreach and Education Plan

Ms. Bonita Nelson (AFSC) will serve as education and outreach coordinator (in kind) for the project and coordinate activities with NPRB staff. Coordination will include developing strategies through which investigators and collaborators can provide education and outreach activities through NPRB's existing infrastructure. This will be accomplished with the assistance of the lead PI. A website will be developed for the project by the database coordinator with the assistance of NPRB. This website will include a description of the GOA IERP project and hyperlinks to web pages with supporting information, data, and resources.

H. Coordination Strategy

Monthly meetings will be held either at UAF or AFSC to coordinate, plan future activities, and disseminate information amongst the PIs and collaborators. A teleconference line will be available to allow collaborators who are not located in Juneau, AK a chance to participate. Funding has been allocated for each PI and collaborator to participate in an annual GOA IERP planning and coordination meeting in Anchorage, AK. Graduate and post doctoral students will participate in fisheries oceanographic surveys coordinated through the lead PI.

I. Figures and Tables

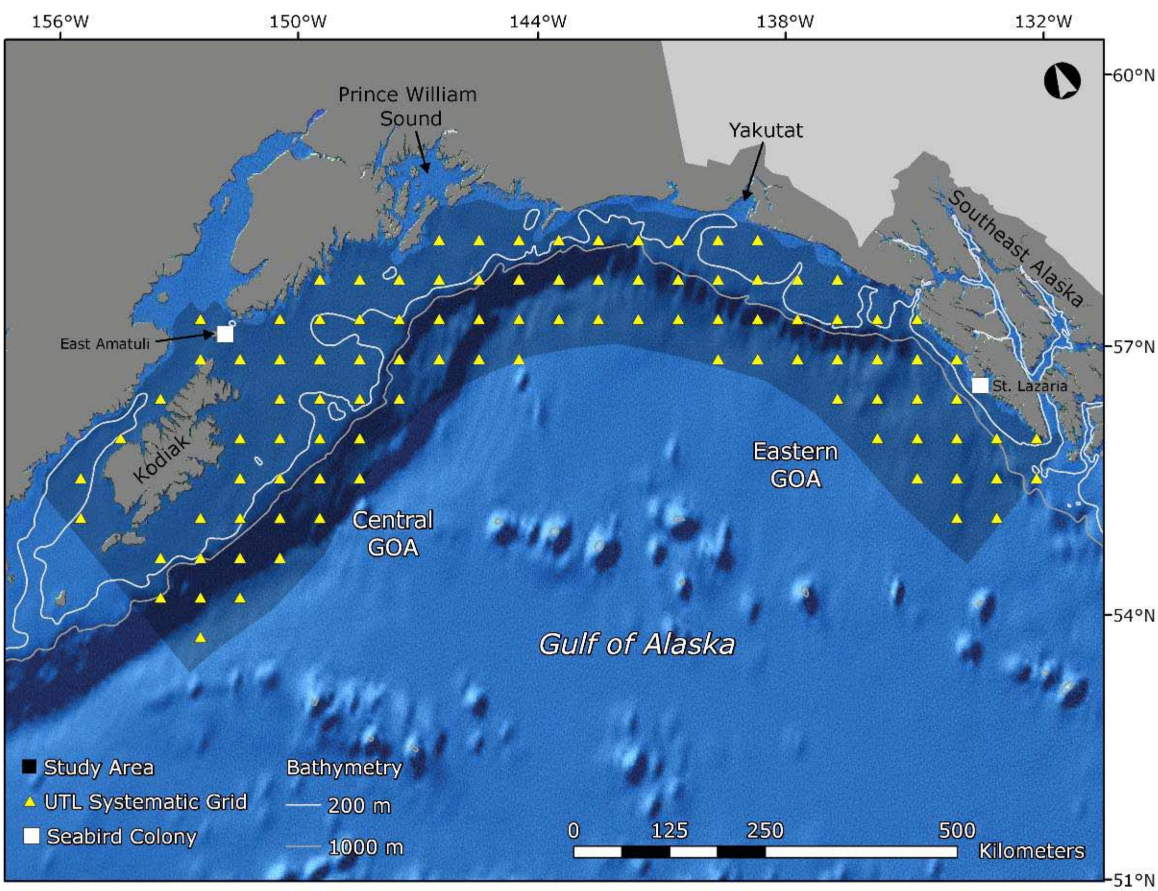

Figure 1: Proposed systematic stations (yellow triangles) for UTL summer and fall sampling from Cape Ommaney to western edge of Kodiak Island. Also shown are the study area extent (dark shaded area) and seabird colony locations.

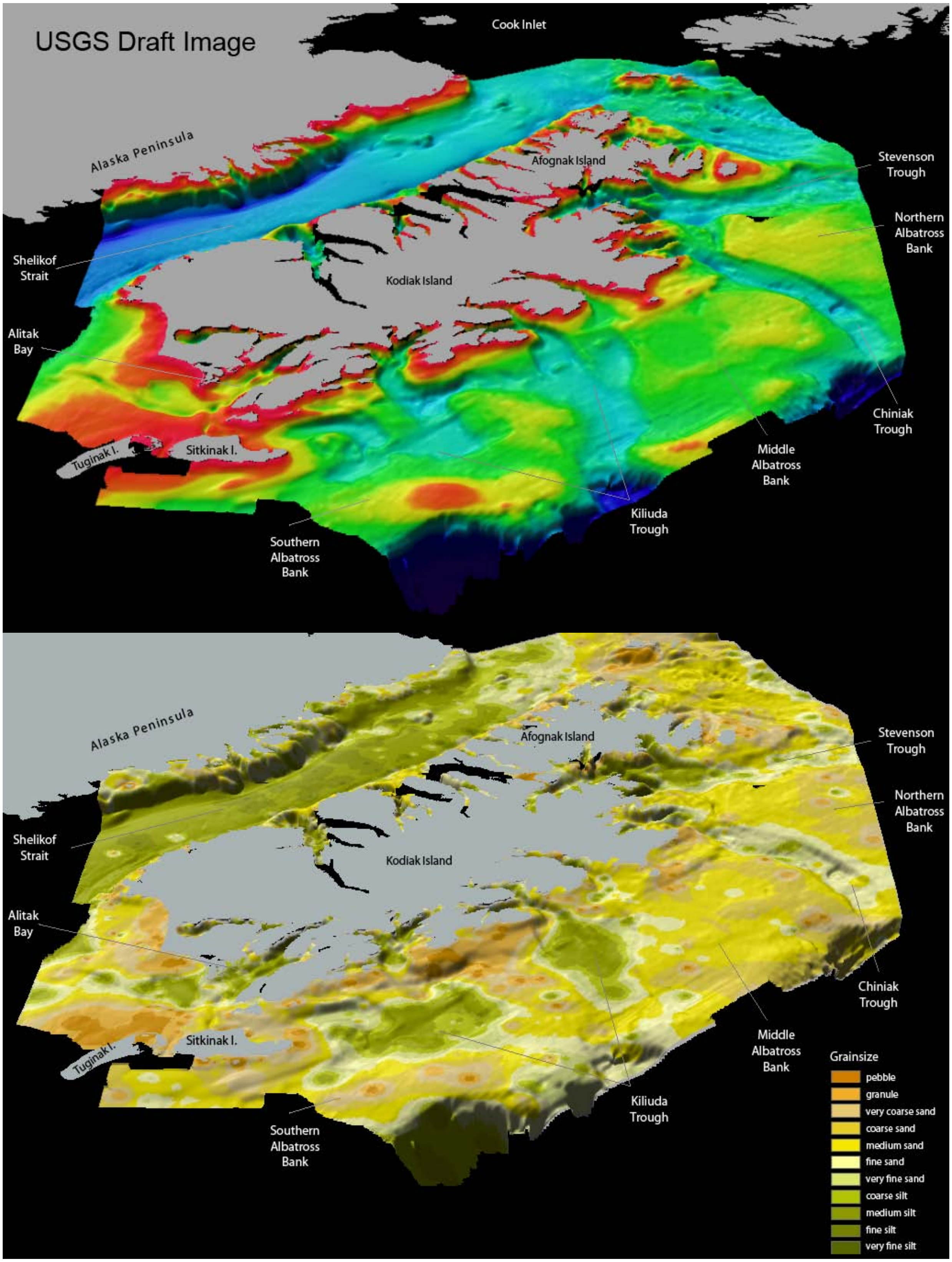


Figure 2: Gridded National Ocean Service bathymetry (top) and interpolated unpublished usSEABED surficial sediment (bottom) from USGS analysis in the central GOA region.

Table 1: List of example databases to be considered for retrospective analysis tasks

**Retrospective Tasks**

Compile data by trophic level, develop indices

| Trophic Level | Dataset description |
|---|---|
| Physical Environment | Sea surface temperature (AVHRR, ERSST), sea surface height (Aviso derived products), surface vector winds (NCAR/NCEP, QuikScat) |
| Phytoplankton | Ocean color (SeaWiFS/MODIS), primary productivity |
| Zooplankton | Seward line, SECM line zooplankton data (only previously cleaned electronically available data) |
| Ichthyoplankton | FOCI egg and larvae counts (only previously cleaned electronically available data) |
| Adult Fish Predators | ABL Sablefish survey for relative indices of abundance by area, NMFS Trawl survey (RACEBASE) biomass estimates by area |
| Seabirds | North Pacific Pelagic seabird data on pelagic distribution and abundance |

Analysis of spatial patterns (no temporal component)

- Spatial analysis of representative datasets by trophic level for determining mean conditions and long-term patterns to include ocean color, fish predators, and seabirds

Analysis of temporal trends by area following spatial analysis

- Time series analysis of representative datasets by trophic level for identifying datasets most related to the recruitment of the five focal groundfish species
- Development of generalized additive model framework to include relevant predictor variables by focal species identified in time series analysis

Table 2: GOA IERP Timeline of upper trophic level component (UTL) activities

| | **2009** | | **2010** | | | | **2011** | | | | **2012** | | | | **2013** | | | | **2014** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| Planning and preparation | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | |
| Retrospective analysis | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Fisheries survey EGOA – Pilot year | | | | ■ | ■ | | | | | | | | | | | | | | | | |
| Fisheries survey EGOA and WGOA & concurrent seabird and marine mammal surveys | | | | | | | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | |
| Fish sample processing | | | | ■ | ■ | | | | | | | | ■ | ■ | ■ | | ■ | ■ | ■ | | |
| Acquire Pacific ocean perch and run RNA/DNA collaboration studies | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Habitat suitability analysis | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| Seabird data collection at colonies | | | | | ■ | | | | ■ | | | | ■ | | | | ■ | | | | |
| Data analysis | | | | | | | ■ | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Manuscript writing | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ |

## J. References

Abookire, A.A., J.T. Duffy-Anderson, and C.M. Jump. 2007. Habitat associations and diet of young-of-the-year Pacific cod (*Gadus macrocephalus*) near Kodiak, Alaska. Mar. Biol. 150: 713-726.

Ainley, D.G., R.G. Ford, E.D. Brown, R.M. Suryan, D.B. Irons. 2003. Prey resources, competition, and geographic structure of kittiwake colonies in Prince William Sound. Ecology. 84(3): 709-723.

Anderson, P.J., and J.F. Piatt. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Mar. Ecol. Prog. Ser. 89:117-123.

Atkinson, S., DeMaster, D.P., and Calkins, D.G. 2008. Anthropogenic causes of the western Steller sea lion *Eumetopias jubatus* population decline and their threat to recovery. Mammal Rev. 38(1): 1-18.

Bailey, K.M., A.A. Abookire, and J.T. Duffy-Anderson. 2008. Ocean transport paths for the early life history stages of offshore-spawning flatfishes: A case study in the Gulf of Alaska. Fish and Fisheries. 9: 44-66.

Batcheldor, H. P. 2002. Physical and biological conditions and processes in the northeast Pacific Ocean. Progress in Oceanography 53: 105-114.

Beauchamp, D. A., D. J. Stewart, and G. L. Thomas. 1989. Corroboration of a bioenergetics model for sockeye salmon. Transactions of the American Fisheries Society. 118: 597-607.

Blood, Deborah M., Ann C. Matarese, and Morgan S. Busby. 2007. Spawning, egg development, and early life history dynamics of arrowtooth flounder (*Atheresthes stomias*) in the Gulf of Alaska. NOAA Professional Paper NMFS 7, 28 p.

Boersma, P.D. 2008. Penguins as marine sentinels. Bioscience. 58(7): 597-607.

Boersma, P.D., G.A. Rebstock, F. Esteban, and S.E. Moore. 2009. Following the fish: Penguins and productivity in the South Atlantic. Ecol. Monog. 79:  59-76.

Boldt, J. 2008. Ecosystem Considerations for 2009. Appendix C. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Bering Sea, Aleutian Islands, and Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Boldt, J.  2004.  Appendix C:  Ecosystem considerations for 2005: Reviewed by The Plan Teams for the Groundfish Fisheries of the Bering Sea, Aleutian Islands, and Gulf of Alaska.  North Pacific Fishery Management Council.

Brooke, M. 2004.The food consumption of the world's seabirds. Proceedings: Biological Sciences, Vol. 271 Suppl. 4 pp. 246-248.

Bryant, D.M., and R.W. Furness. 1995. Basal metabolic rates of North Atlantic seabirds. International Journal of Avian Science. 137(2): 219-226.

Calkins, D.G., and E.A. Goodwin. 1988. Investigation of the declining sea lion population in the Gulf of Alaska. Unpublished Report, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518.

Calkins, D.G., D.C. Mallister, K.W. Pitcher, G.W. Pendleton. 1999. Steller sea lion status and trend in southeast Alaska: 1979-1997. Marine Mammal Science. 15(2): 462-447.

Carlson, P.R., Molnia, B.F., Kittelson, S.C., and J.C. Hampson, Jr., 1977, Map of distribution of bottom sediments on the continental shelf, northern Gulf of Alaska: U.S. Geological Survey Miscellaneous Field Studies 876, 2 plates.

Carlson, H. R., and R. R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.

Catard, A., H. Weimerskirch, and Y. Cherel. 2000. Exploitation of distant Antarctic waters and close shelf-break waters by White-chinned Petrels rearing chicks. Mar. Ecol. Prog. Ser. 194: 249–261.

Cockran, W.G. 1977. Sampling Techniques. 3rd Ed. John Wiley & Sons, Inc. New York. 428 p.

Conners, M.E. and M.A. Guttormsen 2005. Appendix: Forage Fish Species in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska as projected for 2006. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Coyle, K.O., and A.I. Pinchuk. 2005. Seasonal cross-shelf distribution of major zooplankton taxa on the northern Gulf of Alaska shelf relative to water mass properties, species depth preferences and vertical migration behavior. Deep Sea Res. II. 52: 217-245.

Dorn, M.W., K. Aydin, S. Barbeaux, M. Guttormsen, B. Megrey, K. Spalinger, and M. Wilkins. 2008. Assessment of the walleye pollock stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska as projected for 2009. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Dragoo, D. E., G. V. Byrd, and D. B. Irons. 2003. Breeding status, population trends and diets of seabirds in Alaska, 2001. U.S. Fish and Wildl. Serv. Report AMNWR 03/05.

Effron, B. and R. Tibshirani. 1993. An Introduction to the Bootstrap. New York, Chapman and Hall.

Evans, K.R., P.R. Carlson, M.A. Hampton, M.S. Marlow, and P.W. Barnes, 2000, Map of distribution of bottom sediments on the continental shelf, Gulf of Alaska: U.S. Geological Survey Miscellaneous Field Studies MF-2335, 1 plate.

Fadely, B.S., B.W. Robson, J.T. Sterling, A. Greig, and K.A. Call. 2005. Immature Steller sea lion (*Eumetopias jubatus*) dive activity in relation to habitat features of the eastern Aleutian Islands. Fish. Oceanogr. (Suppl. 1):243-258.

Freese, J.L., and B.L. Wing. 2003. Juvenile red rockfish, *Sebastes* sp., associations with sponges in the Gulf of Alaska. Mar. Fish. Rev. 65(3):38-42.

Fritz, L.W. and Hinckley, S. 2005. A critical review of the regime shift - "junk food" - nutritional stress hypothesis for the decline of the western stock of Steller sea lion. Mar. Mammal Sci. 21:476-518.

Furness, R. 1978. Energy requirements of seabird communities: a bioenergetic model. Journal of Animal Ecology 47:39-53

Furnell, D. J. (1987). Partitioning of locomotor and feeding metabolism in sablefish (*Anoplopoma fimbria*). Can. J. Zool./J. Can. Zool 65(3): 486-489.

Gaichas S.K. and R.C. Francis. 2008. Network models for ecosystem-based fishery analysis: A review of concepts and application to the Gulf of Alaska marine food web. Can. J. Fish. Aquat. Sci. 65: 1965-1982.

Gaston, A.J., and S.B. Dechesne. 1996. Rhinoceros Auklet (*Cerorhinca monocerata*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/212 doi:10.2173/bna.212

Gende, S. M., and M. F. Sigler. 2006. Persistence of forage fish 'hot spots' and its association with foraging Steller sea lions (*Eumetopias jubatus*) in southeast Alaska. Deep Sea Res. II 53:432-441.

Gould, P.J., and D.J. Forsell. 1989. Techniques for shipboard surveys of marine birds. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, DC. Fish Wildl. Tech. Rep. 25. 22p.

Groome, M.G., C.E. Gutmacher, and A.J. Stevenson. 1997. Atlas of GLORIA sidescan-sonar imagery of the Exclusive Economic Zone of the United States: EEZ-View. U.S. Geological Survey Open-file Report 97-540, 1 compact disc.

Hanselman, D. H., J. Heifetz, J.T. Fujioka, S.K. Shotwell, and J. N. Ianelli. 2007. Gulf of Alaska Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2008. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D.H., C.R. Lunsford, J.T. Fujioka, and C.J. Rodgveller. 2008. Assessment of sablefish stock in Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska as projected for 2009. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Harney, J.N., Cochrane, G.R., Etherington, L.L., Dartnell, P., Golden, N.E., and Chezar, H., 2005, Geologic characteristics of benthic habitats in Glacier Bay, southeast Alaska. U.S. Geological Survey Open-File Report 2006-1081. Online (http://pubs.usgs.gov/of/2006/1081/).

Heifetz, J. and J. T. Fujioka. 1991. Movement dynamics of tagged sablefish in the northeastern Pacific Ocean. Fish. Res. 11:355-374.

Hinckley, S., Hermann, A.J., Meir, K.L., and Megrey, B.A. 2001. The importance of spawning location and timing to successful transport to nursery areas: a simulation modeling study of Gulf of Alaska walleye pollock. ICES J. Mar. Sci. 58: 1042-1052.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapp. P.-V. Reun. Cons.Int. Explor. Mer, 20: 1–228.

Hollowed, A.B., N. Bax, R. Beamish, J. Collie, M. Fogarty, P. Livingston, J. Pope, and J.C Rice. 2000. Are multispecies models an improvement on single-species models for measuring fishing impacts on marine ecosystems? ICES Journal of Marine Science. 57: 707–719.

Hughes, T.P., D.R. Bellwood, C. Folke, R.S. Steneck, and J. Wilson. 2005. New paradigms for supporting the resilience of marine ecosystems. Trends in Ecology and Evolution. 20:7: 380-386.

Johansson. M.L., M.A. Banks, K.D. Glunt, H.M. Hassel-Finnegan, and V.P. Buonaccorsi. 2008. Influence of habitat discontinuity, geographical distance, and oceanography on fine-scale population genetic structure of copper rockfish (*Sebastes caurinus*). Molecular Ecology. 17: 3051-3061.

Kimura, D.K., A.M. Shimada, F.R. Shaw. 1997. Stock structure and movement of tagged sablefish, *Anoplopoma fimbria*, in offshore northeast Pacific waters and the effects of El Nino-Southern Oscillation on migration and growth. Fish. Bull. 96:462-481.

Klovach, N.V., O.A. Rovnina, and D.V. Kol'stov. 1995. Biology and exploitation of Pacific cod, *Gadus macrocephalus*, in the Anadyr_Navarin region of the Bering Sea. J. Ichthyol. 35:9-17.

Ladd C., P. Stabeno, E.D. Cokelet. 2005. A note on cross-shelf exchange in the northern Gulf of Alaska. Deep-Sea Research II 52: 667-679.

Logerwell. E. and B.Hargreaves. 1997. Seabird impacts on frrage fish: population and behavioral interactions. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Pp 191-195.

Lankin, K.F., M.A. Peck, L.J. Buckley, and D.A. Bengtson. 2008. The effects of temperature, body size and growth rate on energy losses due to metabolism in early life stages of haddock (*Melanogrammus aeglefinus*). Marine Biology 155(5): 461-472.

Loughlin, T.R., A.S. Perlov, V.A. Vladimirov. 1992. Range-wide survey and estimation of total number of Steller sea lions in 1989. Mar. Mamm. Sci. 8:220-239.

Mashburn, K., and S. Atkinson. 2005. Evaluation of adrenal function in serum and feces of Steller sea lions (Eumetopias jubatus): influences of molt, gender, sample storage, and age on glucocorticoid metabolism. Journal of Endocrinology, 40:97-102.

Matarese, A.C., D.M. Blood, S.J. Picquelle, and J.L. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). NOAA Prof. Paper NMFS 1, 281 p.

Maunder M.N., and G.M. Watters. 2003. A general framework for integrating environmental time series into stock assessment models: Model description, simulation testing, and example. Fish. Bull. 101: 89-99.

Mazur, M.M., M.T. Wilson, A.B. Dougherty, A. Buchheister, and D.A. Beauchamp. 2007. Temperature and prey quality effects on growth of juvenile walleye pollock *Theragra chalcogramma* (Pallas): A spatially explicit bioenergetics approach. Journal of Fish Biology 70:816-836.

McKenzie, J. and Wynne, K.M. 2008. Spatial and temporal variation in the diet of Steller sea lions in the Kodiak Archipelago, 1999 to 2005. Mar. Ecol. Prog. Ser. 360: 265-283.

Merrick, R.L. 1995. The relationship of the foraging ecology of Steller sea lions (*Eumetopias jubatus*) to their population decline in Alaska. Ph.D. Dissertation, University of Washington, Seattle, 171 p.

Merrick, R.L., M.K. Chumbley, and G.V. Byrd. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: A potential relationship. Can. J. Fish. Aquat. Sci. 54: 1342-1348.

Miller, A.J., Lorenzo, E.D., Neilson, D.J., Kim, H.-J., Capotondi, A., Alexander, M.A., Bograd, S.J., Schwing, F.B., Mendelssohn, R., Hedstrom, K., and Musgrave, D.L. 2005. Interdecadal changes in mesoscale eddy variance in the Gulf of Alaska circulation: Possible implications for the Steller sea lion decline. Atmosphere-Ocean 43: 231-240.

Moore, S.E., Waite, J.M., Friday, N.A., and T. Honkalehto. 2002. Cetacean distribution and relative abundance on the central-eastern and southeastern Bering Sea shelf with reference to oceanographic domains. Prog. Oceanogr. 55:249-261.

Moss, J.H., E.V. Farley, A.M. Feldmann, and J.N. Ianelli. In press. Spatial distribution, energetic status, and food habits of eastern Bering Sea age-0 walleye pollock. Transactions of the American Fisheries Society.

Mueter, F.J., J.L. Boldt, B.A. Megrey, and R.M. Peterman. 2007. Recruitment and survival of Northeast Pacific Ocean fish stocks: Temporal trends, covariation, and regime shifts. Can. J. Fish. Aquat. Sci. 64: 911-927.

Mueter, F.J., and Norcross, B.L. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. Fish. Bull. 100(3): 559-581.

Mundy, P.R. 2005. The Gulf of Alaska, Biology and Oceanography. Alaska Sea Grant, University of Alaska, Fairbanks, pp.214

Myers, R.A. 1998. When do environment-recruitment correlations work? Review in Fish Biology and Fisheries. 8: 285-305.

Myers, R.A. and N.G. Cadigan. 1993. Density-dependent juvenile mortality in marine demersal fish. Can. J. Fish. Aquat. Sci. 50(8): 1576-1590.

Norcross, B.L., Holladay, B.A., and Mueter, F.J. 1995. Nursery area characteristics of pleuronectids in coastal Alaska, USA. Neth. J. Sea Res. 34(1-3): 161-175.

Norcross, B.L., Mueter, F.J., and Holladay, B.A. 1997. Habitat models for juvenile pleuronectids around Kodiak Island, Alaska. Fish. Bull. 95: 504-520.

Norcross, B.L., Holladay, B.A., Abookire, A.A. and Dressel, S.C. (1998) Defining habitats for juvenile groundfishes in southcentral Alaska, with emphasis on flatfishes. Final Report. OCS Study MMS 97-0046. University of Alaska Coastal Marine Institute, Fairbanks, AK.

NPRB (North Pacific Research Board). 2005. North Pacific Research Board Science Plan.
North Pacific Research Board. Anchorage, AK. 198 p.

NPRB (North Pacific Research Board). 2006. Seabirds as indicators of marine ecosystems: an integrated NPRB science plan for Alaska. Final Report. NRPB Project 516.

Orsi, J. A., E. A. Fergusson, M. V. Sturdevant, B. L. Wing, A. C. Wertheimer, and W. R. Heard. 2006. Annual Survey of Juvenile Salmon and Ecologically Related Species and Environmental Factors in the Marine Waters of Southeastern Alaska, May–August 2005 (NPAFC Doc. 955) Auke Bay Lab., Alaska Fish. Sci. Cen., Nat. Mar. Fish. Serv., NOAA, 11305 Glacier Highway, Juneau, AK 99801-8626, USA, 108 p.

Palof, K. 2008. Population genetic structure of Alaskan Pacific ocean perch (*Sebastes alutus*). M.S. thesis, University of Alaska Fairbanks 65p.

Piatt, J.F., G.S. Drew, and D.B. Irons. 2006. Atlas of seabird distribution at sea in Alaska. U.S. Geological Survey and U.S. Fish and Wildlife Service, Anchorage, Alaska. DRAFT Report, http://www.absc.usgs.gov/research/NPPSD/products.htm.

Piatt, J.F., Sydeman, W.J., Wiese, F., 2007. Introduction: A modern role for seabirds as indicators. Mar. Ecol. Prog. Ser. 352: 199-204.

Pitcher, K.W., P.F. Olesiuk, R.F. Brown, M.S. Lowry, S.J. Jeffries, J.L. Sease, W.L. Perryman, C.E. Stinchcomb, L.F. Lowry. 2007. Abundance and distribution of the eastern North Pacific Steller sea lion (*Eumetopias jubatus*) population. Fish Bull 105:102-115.

Reid, J.A., J.M. Reid, C.J. Jenkins, M. Zimmermann, S.J. Williams, and M.E. Field. 2006. usSEABED: Pacific Coast (California, Oregon, Washington) offshore surficial-sediment data release. U.S. Geological Survey Data Series 182, version 1.0. Online (http://pubs.usgs.gov/ds/2006/182/).

Rutecki, T.L. and E.R. Varosi. 1997. Distribution, age, and growth of juvenile sablefish, *Anoplopoma fimbria*, in Southeast Alaska. In M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 45-54. NOAA Tech. Rep. 130.

Ryer, C. H. and B. L. Olla (1997). Altered search speed and growth: Social versus independent foraging in two pelagic juvenile fishes. Marine Ecology Progress Series 153: 273-281.

Selkoe, K.A., C.M. Henzler, and S.D. Gaines. 2008. Seascape genetics and the spatial ecology of marine populations. Fish and Fisheries. 9: 363-377.

Shotwell, S.K., M.D. Adkison, and D.H. Hanselman. 2005. Accounting for climate variability in forecasting Pacific salmon in data-limited situations. *In* Fisheries Assessment and Management in Data-Limited Situations. Alaska Sea Grant College Program. AK-SG-05-02. 871-900.

Shotwell, S.K., J. Heifetz, D.L. Courtney, and H.G. Greene. 2008. Mapping marine benthic habitat in the Gulf of Alaska: Geological habitat, fish assemblages, and fishing intensity. *In* B.J. Todd and H.G. Greene (Editors) Marine the Seafloor for Habitat Characterization. Geological Association of Canada Special Paper 47: 349-368.

Sigler, M. F. and C. R. Lunsford. 2001. Effects of individual quotas on catching efficiency and spawning potential in the Alaska sablefish fishery. Can. J. Fish. Aquat. Sci. 58: 1300-1312.

Sinclair, E.H., and T.K. Zeppelin. 2002. Seasonal and Spatial Differences in Diet in the Western Stock of Steller Sea Lions (*Eumetopias jubatus*). Journal of Mammalogy. 83(4): 973-990.

Slater, L., and G.V. Byrd. 2009. Status, trends, and patterns of covariation of breeding seabirds at St Lazaria Island, Sou. theast Alaska, 1994–2006. J. Biogeogr. 36: 465-475.

Sogard, S.M., and B.L. Olla. 1993. The influence of predator presence on utilization of artificial seagrass habitats by juvenile walleye pollock, *Theragra chalcogramma*. Journal Environmental Biology of Fishes. 37(1): 57-65.

Sogard, S.M. and B.L. Olla. 2001. Growth and behavioral responses to elevated temperatures by juvenile sablefish *Anoplopoma fimbria* and the interactive role of food availability. Marine Ecology Progress Series 217: 121-134.

Springer, A. D. Roseneau, D. Lloyd, C. McRoy, and E. Murphy. 1986. Seabird responses to fluctuating prey availability in the eastern Bering Sea. Marine Ecology Progress Series 32:1-12

Stephensen, S. and D. Irons. 2003. Comparison of colonial breeding seabirds in the eastern Bering Sea and Gulf of Alaska. Marine Ornithology 31:167-173.

Stoner, A.W., and R.H. Titgen. 2003.Biological structures and bottom type influence habitat choices made by Alaska flatfishes. Journal of Experimental Marine Biology and Ecology. 292(1): 43-59.

Sullivan, K.M. and K.L. Smith, Jr. 1982. Energetics of Sablefish, *Anoplopoma fimbria*, Under Laboratory Conditions. Canadian Journal of FIsheries and Aquatic Sciences 39(7): 1012-1020.

Sydeman, W.J., R.D. Brodeur, C.B Grimes, A.S. Bychkov, and S. McKinnell. 2006. Marine habitat ‘‘hotspots’’ and their use by migratory species and top predators in the North Pacific Ocean: Introduction. Deep-Sea Research II 53: 247–249.

Thayer, J.A., D.F. Bertram, S.A. Hatch, M.J. Hipfner, L. Slater, W.J. Sydeman, and Y. Watanuki. 2008. Forage fish of the Pacific Rim as revealed by diet of a piscivorous seabird: Synchrony and relationships with sea surface temperature. Can. J. Fish. Aquat. Sci. 65: 1610–1622.

Thompson, G., J. Ianelli, and M. Wilkins. 2008. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska as projected for 2009. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Trites, AW and R Joy 2005. Dietary analysis from fecal samples: How many scats are enough? J.Mammal. 86:704-712.

Trites, A.W., P.A. Larkin. 1996. Changes in the abundance of Steller sea lions (Eumetopias jubatus) in Alaska from 1956 to 1992: how many were there? Aquat. Mamm. 22:153−166.

Trites, A.W., A.J. Miller, H.D.G. Maschner, and 27 others. 2007. Bottom-up forcing and the decline of Steller sea lions (*Eumetopias jubatas*) in Alaska: assessing the ocean climate hypothesis. Fish. Oceanogr. 16: 46-67.

Turnock, B.J. and T.K. Wilderbuer. 2007. Gulf of Alaska arrowtooth flounder stock assessment. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska as projected for 2008. North Pacific Fishery Management Council, 605 W 4th Avenue, Suite 306, Anchorage, AK 99510.

Van Kirk, K.F., Quinn, T.J., II, and Collie, J.S. *in review*. A multispecies model for the Gulf of Alaska. Can. J. Fish. Aquat. Sci.

Waite J.N., and V.N. Burkanov. 2006. Steller sea lions (*Eumetopias jubatus*) diet in the Russian Far-East. *In* A. W. Trites, S. K. Atkinson, D. P. DeMaster, L. W. Fritz, T. S. Gelatt, L. D. Rea, and K. M. Wynne (editors), Sea lions of the world. Alaska Sea Grant Program Report AK-SG-06-01, University of Alaska, Fairbanks.

Waite J.N., and K.L. Mashburn. 2005. Dietary differences between sex and age classes of Steller's sea lions (*Eumetopias jubatus*). Poster at the 16th Biennial Conference on the Biology of Marine Mammals. San Diego, CA.

Wakabayashi, K., R.G. Bakkala, and M.S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys. *In* R.G. Bakkala and K. Wakabayashi (editors), Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Int. North Pac. Fish. Comm. Bull. 44. p. 7-29.

Weimerskirch, H., Y. Cherely, F. Cuénot-chaillet, and V. Ridoux . 1997. Alternative foraging strategies and resource allocation by male and female wandering albatrosses. Ecology. 78: 2051-2063.

Weingartner, T.J., Coyle, K., Finney, B., Hopcroft, R., Whitledge, T., Brodeur, R., Dagg, M., Farley, E., Haidvogel, D., Haldorson, L., Hermann, A., Hinckley, S., Napp, J., Stabeno, P., Kline, T., Lee, C., Lessard, E., Royer, T., and Strom, S. 2002. The Northeast Pacific GLOBEC Program: Coastal Gulf of Alaska. Oceanography 15(2): 48-63.

Weingartner, T.J., Danielson, S.L., and Royer, T.C. 2005. Freshwater variability and predictability in the Alaska Coastal Current. Deep Sea Research II 52: 169–191.

Weingartner, T., L. Eisner, G.L. Eckert, and S. Danielson. 2009. Southeast Alaska: oceanographic habitats and linkages. Journal of Biogeography 36: 387-400.

Wiens, J. and J. Scott. 1975. Model estimation of energy flow in Oregon coastal seabird populations. The Condor 77:439-452.

Wing, B.L. 1985. Salmon stomach contents from the Alaska troll logbook program 1977–1984. NOAA Technical Memorandum NMFS F/NWC-91.

Wing, B.L. and D.J. Kamikawa. 1995. Distribution of neustonic sablefish larvae and associated ichthyoplankton in the eastern Gulf of Alaska, May 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-53, 48 p.

Wing, B.L. 1997. Distribution of sablefish, *Anoplopoma fimbria*, larvae in the Eastern Gulf of Alaska. *In* M. Saunders and M. Wilkins (eds.). Proceedings of the International Symposium on the Biology and Management of Sablefish. pp 13-26. NOAA Tech. Rep. 130.

Witteveen, B.H., R.J. Foy, K.M. Wynne, Y. Tremblay. 2008. Investigation of foraging habits and prey selection by humpback whales (*Megaptera novaeangliae*) using acoustic tags and concurrent fish surveys. Marine Mammal Science 24 (3): 516-534.

Womble, J.N., and M.F. Sigler. 2006. Seasonal availability of abundant, energy-rich prey influences the abundance and diet of a marine predator, the Steller sea lion Eumetopias jubatus. Mar. Ecol. Prog. Ser. 325: 281-293.

Womble, J.N., M.F. Sigler, and M.F. Willson. 2009. Linking seasonal distribution patterns with prey availability in a central-place forager, the Steller sea lion. Journal of Biogeography. 36 (3): 439-451.

Yatsu, A., K.Y. Aydin, J.R. King, G.A. McFarlane, S. Chiba, K. Tadokoro, M. Kaeriyama, and Y. Watanabe. 2008. Elucidating dynamic responses of North Pacific fish populations to climatic forcing: Influence of life-history strategy. Prog. In Ocean. 77: 252-268.

Yen, P.W., W.J. Sydeman, K.H. Morgan, and F.A. Whitney. 2005. Top predator distribution and abundance across the eastern Gulf of Alaska: Temporal variability and ocean habitat associations. Deep-Sea Research II. 52: 799-822.

York, A. 1994. The population dynamics of northern sea lions, 1975- 1985. Marine Mammal Science 10:38:51.

**Jamal H. Moss**

Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration
17109 Point Lena Loop Road, Juneau, AK 99801
(907) 789-6609
jamal.moss@noaa.gov

**Education:**
Ph.D. 2006, College of Ocean and Fisheries Sciences, University of Washington
M.S. 2001, College of Ocean and Fisheries Sciences, University of Washington
B.A. 1997, Connecticut College

**Professional Experience:**
AFSC Ocean Carrying Capacity Program: Research Fisheries Biologist, 2003-present
North Pacific Fish Commission: U.S. Delegate and Rappeteur, 2007-present
Fisheries and the Environment: Steering Committee Member, 2007-present
Alaska Chapter of the American Fisheries Society: President, 2006-2007
American Fisheries Society: Strategic Planning Committee Member, 2008-present

**Awards:**
Gates Millennium Scholar: Bill and Melinda Gates Foundation, 2001
Kasahara Award: American Institute of Fishery Research Biologists, 2007

**Current Research:**
1. North Pacific Research Board: Principal Investigator 1) Estimation of source contribution and dispersal histories of Pacific cod recruits using otolith elemental composition
2. Artic-Yukon Kuskokwim Sustainable Salmon Initiative: Principal Investigator 1) Parameterization of temperature and weight dependence of maximum consumption rate of juvenile chum salmon and development of a biogenetics model. 2) Assessment of regional and interannual juvenile chum salmon growth potential across the eastern Bering Sea shelf
3. Global Ocean Ecosystem Dynamics: Principal Investigator 1) quantification of spatial variability in juvenile pink salmon growth potential across the Gulf of Alaska and implications for production and survival
4. Bering-Aleutian Salmon International Survey: Principal Investigator 1) Quantification of interannual variability in trophic structuring of the epipelagic fish community in the Chukchi Sea and eastern Bering Sea. 2) Affects of climate on the ecology, production, and status of age-0 walleye pollock inhabiting the eastern Bering Sea

**Field and Laboratory Experience:**
Field Party Chief: BASIS program FV *Northwest Explorer* (2006), FV *Sea Storm* (2003-2007), GLOBEC program FV *Great Pacific* 2004.
Research scientist: RV *John N. Cobb* (2003, 2006), RV Miller Freeman (2003) FV *Sea Storm* (2002-2007), FV *Great Pacific* (2001-2003)
Supervisor: Effect of temperature and weight dependence on sculpin consumption and metabolic rates (2000-2001), Foraging behavior and zooplankton consumption rates for juvenile pink and chum salmon (2005-2006), Temperature and weight dependence on consumption on maximum consumption rate of juvenile chum salmon (2006-2007)

**Peer Reviewed Publications:**
Cross, A.D., D.A. Beauchamp, **J.H. Moss**, and K.W. Myers. *In press*. Interannual variability in

early marine growth, size-selective mortality, and marine survival for Prince William Sound pink salmon. Marine and Coastal Fisheries.

**Moss, J.H.**, E.V. Farley, A.M. Feldmann, and J.N. Ianelli. *In press*. Spatial distribution, energetic status, and food habits of eastern Bering Sea age-0 walleye pollock. Transactions of the American Fisheries Society.

**Moss, J.H.**, D.A. Beauchamp, A.D. Cross, E.V. Farley, J.H. Helle, and K.W. Myers. *In press*. Bioenergetic model estimates of interannual and spatial patterns in consumption demand and growth potential of juvenile pink salmon (*Oncorhynchus gorbuscha*) in the Gulf of Alaska. Deep Sea Research II.

**Moss, J.H**., N. Hillgruber, C. Lean, J Mackenzie-Grieve, K. Mull. *In press*. Linking marine and freshwater domains to improve our understanding of variation in salmon abundance, AYK SSI Symposium Proceedings.

**Moss, J.H.** and D.A. Beauchamp. 2007. Functional response of juvenile pink and chum salmon: effects of consumer size and two types of prey. Journal of Fish Biology 70:1-13.

**Moss, J.H**., D.A. Beauchamp, A.D. Cross, K.W. Myers, E.V. Farley, Jr., J.M. Murphy, and J.H. Helle. 2005. Higher marine survival associated with faster growth for pink salmon (*Oncorhynchus gorbuscha*). Transactions of the American Fisheries Society 134:1313-1322 .

E.V. Farley, Jr., J.M. Murphy, **J.H. Moss**, A.M. Feldmann, and L.B. Eisner. *In press*. Marine ecology of western Alaska juvenile salmon. AYK SSI Symposium Proceedings.

Cross, A.D., D.A. Beauchamp, K.W. Myers, and **J.H. Moss**. 2008. Early marine growth of pink salmon in Prince William Sound and the coastal Gulf of Alaska during years of low and high survival. Transactions of the American Fisheries Society 137:927-939.

Armstrong, J.L., K.W. Myers, D.A. Beauchamp, N.D. Davis, R.V. Walker, J.L. Boldt, J.J. Piccolo, L.J. Haldorson, and **J.H. Moss**. 2008. Interannual and Spatial Feeding Patterns of Hatchery and Wild Juvenile Pink Salmon in the Gulf of Alaska in Years of Low and High Survival. Transactions of the American Fisheries Society 137:1299-1316.

Farley, E.V. Jr., **Moss, J.H**., and R.J. Beamish. 2007. A review of the critical size, critical period hypothesis for juvenile Pacific salmon. North Pacific Anadromous Fish Commission Bulletin 4:311-317.

Farley, E.V., Jr., J.M. Murphy, B.L. Wing, **J.H. Moss**, and A. Middleton. 2005. Distribution, migration pathways, and size of western Alaska juvenile salmon along the eastern Bering Sea shelf Alaska Fishery Research Bulletin 11(1):15-26.

Farley, E.V., Jr., J.M. Murphy, B.L. M.L. Adkison, L.B. Eisner, J.H. Helle, **J.H. Moss**, and J.L. Nielsen. 2007. Early marine growth in relation to marine-stage survival rates for Alaska sockeye salmon (*Oncorhynchus nerka*). Fish Bulletin 105:121-130.

Armstrong, J.L. J.L. Boldt, A.D. Cross, **J.H. Moss**, N.D. Davis, K.W. Myers, R.V. Walker, D.A. Beauchamp and L.J. Haldorson. 2005. Distribution, size and interannual, seasonal and diel food habits of the northern Gulf of Alaska juvenile pink salmon, *Oncorhynchus gorbuscha*. Deep-Sea Research II 52:247-265.

Cross, A.D., D.A. Beauchamp, J.L. Armstrong, M. Blikshteyn, J.L. Boldt, N.D. Davis, L.J. Haldorson, **J.H. Moss**, K.W. Myers and R.V. Walker. 2005. Consumption demand of juvenile pink salmon in Prince William Sound and the coastal Gulf of Alaska in relation to prey biomass. Deep Sea Research II 52:347-370.

**S. KALEI SHOTWELL**
Auke Bay Laboratories TSMRI/AFSC/NMFS/NOAA
17109 Pt. Lena Loop Rd., Juneau, AK 99801
(907) 789-6056, Kalei.Shotwell@noaa.gov

## EDUCATION

| | | | |
|---|---|---|---|
| University of Oregon, Eugene, OR | BS | Biology, departmental honors | 1998 |
| University of Alaska Fairbanks, AK | PhD | Fisheries | 2004 |

## PROFESSIONAL EXPERIENCE

**2004-present:** **Fishery Research Biologist, Auke Bay Laboratories, TSMRI-AFSC-NMFS-NOAA**
Responsibilities: Stock assessment, spatial analysis, and recruitment studies on Gulf of Alaska groundfish, benthic habitat assessment, chief scientist and participant on surveys

**1999-2004:** **Graduate Research Assistant, University of Alaska Fairbanks**
Research responsibilities: abundance estimation, forecasting with environmental information, simulation modeling, lecturing.

**2003-2004:** **GIS Contractor, Auke Bay Laboratory AFSC-NMFS-NOAA**
Responsibilities: Produce habitat GIS of multibeam mapped areas in Gulf of Alaska and analyze existing and new biological data sources by habitat type.

## SELECTED PUBLICATIONS

Shotwell, S.K., and M.D. Adkison. 2004. Estimating Indices of Abundance and Escapement of Pacific Salmon for Data-Limited Situations. Tran. Amer. Fish. Soc. 133: 538-558.

Shotwell, S.K. 2005. Utilizing Multi-Source Abundance Estimation and Climate Variability to Forecast Pacific Salmon Populations. Doctoral thesis. UAF – SFOS. pp. 156.

Shotwell, S.K., M.D. Adkison, and D.H. Hanselman. 2005. Accounting for Climate Variability in Forecasting Pacific Salmon in Data-Limited Situations. Alaska Sea Grant College Program. AK-SG-05-02. 871-900.

Shotwell, S.K., D.H. Hanselman, and D.M. Clausen. 2005 – 2008. Gulf of Alaska Rougheye Rockfish. *In* Stock assessment and fishery evaluation report for the groundfish resources of the GOA. NPFMC.

Hanselman, D.H., J. Heifetz, J.T. Fujioka, S.K. Shotwell, and J. N. Ianelli. 2007-2008. Gulf of Alaska Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish fisheries of the GOA. NPFMC.

Stone, R.P. and S.K. Shotwell. 2007. State of the Deep Coral Ecosystems in the Alaska Region: Gulf of Alaska, Bering Sea, and the Aleutian Islands. Pp. 65-108. *In*: S. Lumsden, T. Hourigan, A. Bruckner, and G. Door (eds.), The state of deep coral ecosystems of the United States. NOAA Tech. Memo. CRCP-3, 365 pp.

Shotwell, S.K, J. Heifetz, D.L. Courtney, and H.G. Greene. 2008. Mapping marine benthic habitat in the GOA: geological habitat, fish distributions, and fishing intensity. In Marine Benthic Habitat Mapping. GeoHab Chapter 5.

## TRAINING AND FIELD EXPERIENCE

- NOAA Satellite Workshop for GIS, NESDIS-NOAA, 2006; Satellite Remote Sensing in Biological Oceanography, Cornell University, 2007; NMFS National Stock Assessment Workshops 2004, 2006; Advanced GIS Techniques for Fish Biologists, AFS, 2003; Population Dynamics with AD Model Builder, UAF, 2003.
- Certified NOAA Working Diver, PADI Divemaster, small boat operations, CPR/1st Aid, proficient in ArcGIS, R, AD Model Builder, MS office products
- 25+ surveys conducting research with hook-and-line, pots, trawls, gillnets, longlines, plankton nets, CTD’s, tagging, hydroacoustics, submersibles, and scuba.

**Abbreviated Curriculum Vitae**

**Name**: Shannon Atkinson, Ph.D., Professor

**Address**: University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, 17101 Point Lena Loop Road. Juneau, AK 99801

**Telephone**: (907) 796-5453 **Fax**: (907) 796-5446 **E-Mail**: atkinson@sfos.uaf.edu

**Professional Experience**
Professor, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences 2000-present
Professor of Marine Science, University of Alaska Fairbanks, and Senior Scientist Alaska SeaLife Center 2000-2007
Associate Researcher, Hawaii Institute of Marine Biology, University of Hawaii 1991- 2000
Affiliate Researcher, Hawaii Institute of Marine Biology, University of Hawaii 1989-1991,
Experimental Scientist, Commonwealth Scientific and Industrial Research Organization (CSIRO), Division of Animal Production, Western Australia 1986-1988

**Administrative Experience**
- ❖ Principal Investigator, approximately $41.3 million of Fish and Wildlife Service and National Marine Fisheries Service grants to Alaska SeaLife Center 2000-2008.
- ❖ Principal Investigator, Alliance for Coastal Technologies, NOAA funded national partnership to promote technology development. May 2005 $75,000; May 2006 $300,000, May 2007 $122,000; 2008 $110,000.
- ❖ Acting Project Manager, National Fish and Wildlife Foundation grant to conduct research on Steller sea lions. Feb-Dec 2000 $650,000

**Teaching Experience**
24 MSc and PhD students whose committees I have or am currently chairing,
26 MSc and PhD students whose committees I am a member,
11 undergraduate students who have done directed research,
5 students to whom I have served as a mentor (3 veterinary students, 1 foreign veterinarian, and 1 liberal arts student)

**Awards**
1. U.S. Dept of Commerce, NOAA. Marine Environmental Stewardship Award for Marine Debris Removal Project, Northwestern Hawaiian Archipelago. 1998.
2. Vice President Al Gore's National Performance Review- Silver Hammer Award for Marine Debris Removal Project, Northwestern Hawaiian Archipelago. 1999.
3. Sigma Xi the Scientific Research Society devoted to the promotion of Research Science, duly elected a member by the Alaska Chapter of the Society. 2003.

**Publications**
80 Peer-reviewed publications in international journals, 12 Book Chapters and Editorships, 130 Conference abstracts

**Sample recent publications**
1. **Atkinson, S.,** Calkins, D., Burkanov, V., Castellini, M., Hennen, D., and Inglis S. (2008a) Impact of changing diet regimes on Steller sea lion body condition. Mar. Mamm. Sci. 24(2): 276-289

2. **Atkinson, S.**, DeMaster, D.P., and Calkins, D.G. (2008b) Anthropogenic causes of the Steller sea lion decline and their threat to recovery. Mammal. Rev. 39(1): 1-18
3. Maniscalco, JM., Matkin, CO., Maldini, D., Calkins, DG., **Atkinson, S**. (2007) Assessing killer whale predation on Steller sea lions from field observations in Kenai Fjords, Alaska. Mar. Mamm. Scie. 23 (2): 306-321
4. Parker, P., Harvey, J.T., Maniscalco, J.M., and **Atkinson, S.** (2008) Pupping and site fidelity among individual Steller sea lions (*Eumetopias jubatus*) at Chiswell Island, Alaska. C. J. Zoolog. 86(8): 862-833
5. Maniscalco, J.M., Calkins, D.G., Parker, P. and **Atkinson, S.** (2008) Causes and extent of natural mortality among Steller sea lion (*Eumetopias jubatus*) pups. Aquat. Mammal. 34(3): 277-287

**Franz-Josef Mueter, Ph.D.**

Fisheries Division
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

17101 Point Lena Loop Road, Juneau, AK 99801
Phone: (907) 796-5448, FAX: (907) 796-5447
E-mail: franz.mueter@uaf.edu

## Education

Ph.D. University of Alaska Fairbanks (1999). Major: Fisheries Oceanography
M.S. University of Alaska Fairbanks (1998). Major: Statistics
M.S. University of Alaska Fairbanks (1992). Major: Biological Oceanography
Vordiplom (B.S.) Rhino-Westphalian Technical University, Aachen, Germany. Major: Biology

## Employment

2008-present Assistant Professor, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Alaska, USA
1999-present Statistical consultant and owner, Sigma Plus, Statistical Consulting Services
2006-2007 Adjunct faculty, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Alaska, USA
2002-2005 Research Associate / Research Scientist, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, Washington, USA
1999-2001 Post-doctoral fellow, School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, Canada
1995-99 Research Assistant, Institute of Marine Science, University of Alaska, Fairbanks, AK
1993-94 Research Technician, Juneau Center, School of Fisheries and Ocean Science, University of Alaska, Fairbanks, Juneau, Alaska, USA

## Professional Services

2008-present Co-chair, ESSAS Working Group 4: Climate Effects on Upper Trophic Levels
2007-present Guest Editor, Special Issue of ICES Journal of Marine Science
2005-2007 Scientific Steering Committee, PICES/ICES Early Career Scientist Conference
2003-present Scientific and Statistical Committee. North Pacific Fisheries Management Council
2003-2004 SCOR/IOC Working Group 119: Quantitative Ecosystem Indicators for Fish Mgmt
2003 North Pacific Ecosystem Status Working Group

## Current activities

Retrospective Analysis of pattern in productivity of fish, seabirds and marine mammals in the Eastern Bering Sea Ecosystem - NPRB BSIERP Project F3868
Correlative multi-species biomass dynamics model, Eastern Bering Sea – NPRB BSIERP Project F2875

## Most relevant publications (Gulf of Alaska)

Mueter, F.J., Broms, C., Drinkwater, K.F., Friedland, K.D., Hare, J.A., Hunt Jr., G.L., Melle, W., and Taylor, M. 2009. Ecosystem responses to recent oceanographic variability in high-latitude Northern Hemisphere ecosystems. *Prog. Oceanogr.* **accepted**.
Mueter, F.J., Boldt, J., Megrey, B.A., and Peterman, R.M. (2007). Patterns of covariation in productivity among Northeast Pacific fish stocks. *Can. J. Fish. Aquat. Sci.*64: 911-927.
Mueter, F.J., and Megrey, B.A. (2006). Maximum productivity estimates for the groundfish complexes of the Gulf of Alaska and Eastern Bering Sea / Aleutian Islands. *Fish. Res.* 81:189-201.
Mueter, F.J. (2004) Gulf of Alaska. *In: Marine Ecosystems of the North Pacific*. PICES Special Publication 1, pp.153-175.

Mueter, F.J., and Norcross, B.L. (2002). Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. *Fish. Bull.* 100:559-581

**Other publications**

Mueter, F.J., and M.A. Litzow. (2008). Warming climate alters the demersal biogeography of a marginal ice sea. *Ecol. Appl*. 18: 309-320.

Aydin, K., and Mueter, F.J. 2007. The Bering Sea - A dynamic food web perspective. *Deep Sea Research II* 54: 2501-2525.

Mueter, F.J., Ladd, C., Palmer, M.C., and Norcross, B.L. (2006). Bottom-up and top-down controls of walleye pollock (*Theragra chalcogramma*) on the eastern Bering Sea shelf. *Prog. Oceanogr.* 68:152-183.

Mueter, F.J., Pyper, B.J. and Peterman, R.M. (2005) Relationships between coastal ocean conditions and survival rates of Northeast Pacific salmon at multiple lags. *Trans. Am. Fish. Soc.* 134:105-119.

Mueter, F.J. and Megrey, B.A. (2005). Distribution of population-based indicators across multiple taxa to assess the status of Gulf of Alaska and Bering Sea groundfish communities. *ICES J. Mar. Sci.* 62: 344-352

**Professional memberships**

American Fisheries Society; American Statistical Association, American Association for the Advancement of Science

**List of collaborators in the last 48 months**

Kerim Aydin (NOAA-AFSC), Jennifer L. Boldt (AFSC), Stephen R. Braund, Cecilie Broms (IMR, U Bergen), Are Dommasnes (IMR), Sherri Dressel (ADF&G), Ken F. Drinkwater (IMR), Jannike Falk-Petersen (IMR), Kevin D. Friedland (NOAA-NEFSC), Sarah Gaichas (AFSC), Harald Gjøsæter (IMR), Jonathan A. Hare (NEFSC), George L. Hunt Jr. (UW), Gordon H. Kruse (UAF), Jason S. Link (NOAA-NEFSC), Mike Litzow (AFSC), Bernard Megrey (AFSC), Webjørn Melle (IMR, U Bergen), Larry L. Moulton (MJM), Stephen M. Murphy (ABR, Inc.), William Overholtz (NEFSC), Randall M. Peterman (SFU), Georg Skaret (IMR), William Stockhausen (AFSC), Maureen Taylor (NEFSC).

# BIOGRAPHICAL SKETCH

KENNETH 0. COYLE

Institute of Marine Science
University of Alaska
PO Box 757220
Fairbanks, AK 99775-7220

Telephone: 907-474-7705
Fax: 907-474-7204
e-mail: coyle@ims.uaf.edu

PROFESSIONAL PREPARATION:
Ph.D., 1997 (Oceanography), University of Alaska
M.Sc., 1974 (Oceanography), University of Alaska
B.Sc., 1971 (Oceanography), University of Washington

APPOINTMENTS:
2008 – Present Research Faculty
1989 - 2008 Research Associate
1974 - 1989 Research Technician

PUBLICATIONS (five most relevant + five related):

Coyle, K. O., Pinchuk, A. I., Eisner, L. B., Napp, J. M. 2008. Zooplankton species composition, abundance and biomass on the eastern Bering Sea shelf during summer: the potential role of water column stability and nutrients in structuring the zooplankton community. Deep Sea Res. II. 55: 1775-1791.

Coyle, K. O., Konar, B., Blanchard, A., Highsmith, R. C., Carroll, J., Carroll, M., Denisenko, S. G., Sirenko, B. I. 2007. Potential effects of temperature on the benthic infuanal community on the southeastern Bering Sea shelf: Possible impacts of climate change. Deep-Sea Research II, 54: 2885–2905

Coyle, K. O., Bluhm, B., Konar, B., Blanchard, A., Highsmith, R. C. 2007. Amphipod prey of gray whales in the northern Bering Sea: comparison of biomass and distribution between the 1980s and 2002 - 2003. Deep Sea Res. II 54: 2906 – 2918

Coyle, K. O. 2005. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. Fish. Oceanogr. 14 (Suppl. 1): 77 – 92.

Coyle, K. O. and A. I. Pinchuk. 2005. Seasonal cross-shelf distribution of major zooplankton taxa on the northern Gulf of Alaska shelf relative to water mass properties, species depth preferences and vertical migration behavior. Deep Sea Res. II. 52: 193 – 216.

Coyle, K. O. and A. I. Pinchuk. 2003. Annual cycle of zooplankton abundance, biomass and production on the northern Gulf of Alaska shelf, October 1997 through October 2000. Fish. Oceanogr. 12: 327-338

Coyle, K. O. and A. I. Pinchuk. 2002. The abundance and distribution of euphausiids and zero-age pollock on the inner shelf of the southeast Bering Sea near the Inner Front in 1997-1999. Deep Sea Res. II, 49: 6009-6030.

Coyle, K. O. and A. I. Pinchuk. 2002. Climate-related differences in zooplankton density and growth on the inner shelf of the southeastern Bering Sea. Prog. Oceanogr. 55: 177-194.

Coyle, K. O. and G. L. Hunt. 2000. Seasonal differences in the distribution, density and scale of zooplankton patches in the upper mixed layer near the western Aleutian Islands. *Plankton. Biol. Ecol.*, 47: 31-42.

Coyle, K. O. 1998. *Neocalanus* scattering layers near the western Aleutian Islands. *J. Plank. Res.* 20(6): 1189-1202.

COLLABORATORS AND OTHER AFFILIATIONS**:**

Collaborators (last 48 months):

George Hunt, Dept. of Ecology and Evolutionary Biology, University of California Irvine, Irvine
Gordie Swartzman, Applied Physics Laboratory, University of Washington.
Jeff Napp, National Marine Fisheries Service, NOAA, Seattle
Phyllis Stabeno, Pacific Marine Environmental Lab, NOAA, Seattle
Steve Zeeman, University of New England, Biddeform, Maine
Sue Moore, National Marine Mammal Laboratory, NOAA, Seattle
Alexei Pinchuk, Institute of Marine Science, University of Alaska
Tom Weingartner, Institute of Marine Science, University of Alaska
Terry Whitledge, Institute of Marine Science, University of Alaska
Russell Hopcroft, Institute of Marine Science, University of Alaska
Ray Highsmith, National Institute for Undersea Science and Technology, University of Mississippi
Bodil Bluhm, Institute of Marine Science, University of Alaska
Brenda Konar, Institute of Marine Science, University of Alaska
Al Herman, PMEL, NOAA, Seattle Washington
Michael J. Dagg (LUMCON)
Sarah Hinckley, National Marine Fisheries Service, NOAA, Seattle
Mike Carroll, Akvaplan Niva, Tromso, Norway
Jolynn Carroll, Akvaplan Niva, Tromso, Norway
Stanoslav Denisenko, Zoological Institute, Russian Academy of Sciences, St. Petersberg
Boris Sirenko, Zoological Institute, Russian Academy of Sciences, St. Petersberg

Graduate Advisors:

M.Sc. Advisor: Rita Horner (University of Washington); Committee Members: Vera Alexander (University of Alaska Fairbanks), Mirabelle Allen (Deceased).

PhD Advisor: Ted Cooney (University of Alaska retired); Committee Members: Ray Highsmith (University of Mississippi), Tom Royer (Old Dominion University), Ed Murphy (University of Alaska), John Goering (University of Alaska, retired).

Post-Doctoral Advisors: NONE

Served on the following student' s committees: Stacy Smith, Alexei Pinchuk, William Williams, Georgina Blamey, Hui Liu, Leandra deSousa, Charles Adams, Lei Guo, Marcus Janout, Jennifer Bolt, Xian Wang, Laura Slater, Amanda Byrd, Tracy Merrill, Jennifer Bell, Andreas Winter, Seth Danielson, Jennifer Questel, Martin Schuster