NPRB GOA-IERP Summary Page

Proposal Title: Temporal and spatial axes of variability in the structure of Gulf of Alaska forage fish communities

GOA-IERP Component: Forage base (Middle Trophic Level)

Project Period: Start date: *April 2010* End date: *January 2015*

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Summary of Proposed Work:
The Gulf of Alaska (GOA) ecosystem is complex and displays substantial variability over space and time. Forage fishes provide a critical link between primary and secondary producers and upper trophic level (UTL) predators. The forage fish community includes small, fast-growing species (e.g. capelin and sand lances) as well as juvenile stages of large predatory groundfishes (e.g. walleye pollock and Pacific cod). We hypothesize that 1) forage fish populations are regulated from the bottom up, 2) the mechanisms of that regulation vary among regions of the GOA, 3) interspecies interactions are driven by variability in the habitat needs of individual species, and 4) competition among species results in reduced nutritional condition for all species. While forage fishes have received much research attention in the GOA, a comprehensive view of this community remains elusive. We propose to provide a synoptic view of forage fish distribution, abundance, habitat preferences, and trophic linkages from the shoreline out to the shelf break. In doing so, we will compare community structure at different scales. Regional and local spatial scales will be considered; temporal scales include seasonal, annual, and decadal variability. Historical

data will be synthesized and analyzed to study interannual and decadal variability in forage communities. We will conduct nearshore surveys using multiple gear types and supplement the proposed UTL offshore surveys with acoustic transects. We will assess habitat characteristics and use analyses of stable isotope ratios, fatty acids, and energy content to infer interactions among species and their effects on nutritional condition and prey quality.

Total Funding Requested From NPRB & Matching support:

	Requested	**Other Support**
Alaska Fisheries Science Center	$ 1,330,595	$ 711,198
University of Washington	$ 360,233	$ 0
Sedna Ecological, Inc.	$ 54,361	$ 0
Dalhousie University	$ 113,211	$ 76,960
Total:	**$1,858,400**	**$788,158**

Legally Binding Authorization Signature and Affiliation:

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RESEARCH PLAN

A. Project Title

Temporal and spatial axes of variability in the structure of Gulf of Alaska forage fish communities

B. Proposal Summary

The Gulf of Alaska (GOA) ecosystem is complex and displays substantial variability over space and time. Forage fishes provide a critical link between primary and secondary producers and upper trophic level (UTL) predators. The forage fish community includes small, fast-growing species (e.g. capelin and sand lances) as well as juvenile stages of large predatory groundfishes (e.g. walleye pollock and Pacific cod). We hypothesize that 1) forage fish populations are regulated from the bottom up, 2) the mechanisms of that regulation vary among regions of the GOA, 3) interspecies interactions are driven by variability in the habitat needs of individual species, and 4) competition among species results in reduced nutritional condition for all species. While forage fishes have received much research attention in the GOA, a comprehensive view of this community remains elusive. We propose to provide a synoptic view of forage fish distribution, abundance, habitat preferences, and trophic linkages from the shoreline out to the shelf break. In doing so, we will compare community structure at different scales. Regional and local spatial scales will be considered; temporal scales include seasonal, annual, and decadal variability. Historical data will be synthesized and analyzed to study interannual and decadal variability in forage communities. We will conduct nearshore surveys using multiple gear types and supplement the proposed UTL offshore surveys with acoustic transects. We will assess habitat characteristics and use analyses of stable isotope ratios, fatty acids, and energy content to infer interactions among species and their effects on nutritional condition and prey quality.

C. Soundness of Project Design and Conceptual Approach

Hypotheses and Objectives

The Gulf of Alaska (GOA) ecosystem is complex, with multiple trophic levels and linkages among its components. Environmental conditions are highly variable over seasons, years, and longer time scales (McGowan et al. 1998). Differences in topography, currents, and climate also drive great spatial variability, with lower total biomass but higher species diversity in the eastern GOA and higher biomass and fewer species in the central and western GOA (Mueter and Norcross 2002). Throughout this ecosystem, forage fishes provide the critical link between lower trophic level (LTL) species like euphasiids and copepods and upper trophic level (UTL) species including adult predatory fishes, birds, and marine mammals (Springer and Speckman 1997). The forage fish community is composed of two main groups: juvenile and adult members of small, schooling species such as capelin (*Mallotus villosus*) and Pacific sand lance (*Ammodytes hexapterus*); and juveniles of large predatory groundfish species including walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*). The population dynamics and habitat needs of these two groups vary, and the differences drive variability in the structure (relative abundance and distribution) of forage fish communities. The environment forces changes in communities by affecting the growth and survival of community members and by altering the availability of suitable habitat. Changes in the forage base affect the availability of prey to UTL predators and may impact juveniles of other UTL fish species through competition (e.g. the UTL component focal species arrowtooth flounder *Atheresthes stomias*, sablefish *Anoplopoma fimbria*, and Pacific ocean perch *Sebastes alutus*).

Although forage fishes in the GOA have been studied by many researchers, most of this work has been disjointed in space and time. As a result we lack a comprehensive understanding of how forage fish communities vary across the GOA and over time, and how such variability impacts other ecosystem members. We propose to address this problem by using a synoptic, multidisciplinary approach to understand how forage fish community structure in the GOA varies at several temporal and spatial scales. Our approach is based on the following hypotheses:

1) Variability in forage fish populations is driven by climate and the availability of plankton prey.
2) Bottom-up regulation of forage fishes exists throughout the GOA, but the mechanisms of that regulation vary by region.
3) Habitat needs of fishes vary with life stage and season, leading to variability in interspecies interactions.
4) Competition among species results in reduced nutritional condition for all species, especially in times and areas of low prey availability.

Our overall goal is to describe spatial and temporal variability in the structure of forage communities in the GOA and the effects of this variability on UTL predators. To test our hypotheses and provide a means for comparison, we will focus our efforts on the following technical objectives:

1) Provide a synoptic view of nearshore/offshore distribution and abundance (past and present) to gain a comprehensive understanding of how GOA forage communities are structured, how this structure changes in response to the environment, and the effects of this variability on prey availability for upper trophic level species.
2) Analyze habitat associations to determine how habitat needs influence the spatial overlap among species and resulting predation and competition.
3) Use analysis of stomach contents, stable isotopes, and fatty acids to infer diets and elucidate relationships among forage community members, lower trophic level prey, and upper trophic level predators.
4) Use proximate analysis to assess nutritional condition of community members and relate condition to spatial and diet overlaps among species.

Rationale and conceptual underpinning

Environmental forcing is the main determinant of early life survival for many fishes. Two processes are especially important, and are included in the UTL component hypotheses. Fish larvae depend on planktonic prey, and the availability of prey can depend on its abundance or the timing of seasonal events such as blooms. Numerous hypotheses have been forwarded to describe the critical factors, including the necessity of a temporal match between larval emergence and blooms (Cushing 1975) and a requirement for sufficient water column stability to allow plankton growth (Gargett 1997). In the GOA, prey availability in the first two weeks of feeding appears highly influential in determining larval survival (Bailey et al. 1996). Larval transport is also an important factor. Fish larvae are subject to advection by currents, and their survival depends on retention in or transport to areas that provide suitable habitat, including food. In British Columbia, along-shelf transport is thought to influence early life survival of Pacific cod and is included in the stock-recruit models used for assessment (Sinclair et al. 2001). In the central GOA capelin spawn on beaches and their larvae are apparently flushed offshore, although the fate of these larvae is unknown (Doyle et al. 2002).

Individuals select habitat by trading off requirements for food, predator avoidance, and other essential processes (e.g. spawning). For example, sediment types that allow for burial and predator avoidance are the critical habitat variables for some juvenile flatfishes in the nearshore (Norcross et al. 1995). In British Columbia lakes, the vertical distribution of sockeye salmon (*Onchorynchus nerka*) juveniles involves a trade-off between sufficient light for foraging and the increased risk of predation (Clark and Levy 1988).

These habitat preferences are driven by an individual's need to maximize its fitness, and it will choose available habitat based on how it improves fitness (Fretwell and Lucas 1970). An area with a low prey density but low predation may be preferable to habitat with more prey that is highly exposed to predators. The environment can have a strong influence on this process. Water temperature is a critical parameter for fishes because it directly affects metabolic rate (Jobling 1994). While warmer temperatures offer the potential advantages of faster growth and larger size, they also increase metabolic costs and are only beneficial when sufficient food is available to sustain increased metabolic rates. Fish will select the habitat that maximizes their growth rate, and that habitat will vary depending on tradeoffs among fish size, temperature, and food availability (Hughes and Grand 2000).

In the GOA, fish habitat choice is likely determined by an interacting combination of temperature, food availability, competition, and predator avoidance that influence species in different ways. In the laboratory juvenile pollock chose colder temperatures when their food ration was low, apparently to conserve energy by lowering their metabolic rate (Sogard and Olla 1996). When confronted with varying combinations of food types and the presence of predators, the behavior of pollock depended on the particular combination- i.e. predator avoidance was not always the dominant factor (Ryer and Olla 1998). Juvenile pollock preferred warmer inshore waters of Kodiak Island to cooler offshore waters in 2000-2001 (Logerwell et al. 2007), and juvenile pollock in the nearshore during 1993 were in better condition than those farther away from coastal bays (Wilson et al. 2005), presumably because sufficient prey were available for them to take advantage of warmer temperatures. Differences in the physiology of forage fishes also affect habitat trade-offs. In the western GOA, capelin had a daily ration that was approximately one third as large as juvenile pollock in the same area (Wilson et al. 2006). Because juvenile pollock have high growth rates, their need for food is probably greater than it is for capelin and their habitat tradeoffs (e.g. between foraging and predator avoidance) are also likely to be different.

The presence of oceanographic features is also likely to influence the distribution of forage fishes and their predators. Ocean fronts exist at different spatial and temporal scales (Mann and Lazier 1996). Tidal fronts may last a matter of hours, while fronts caused by persistent currents may be essentially permanent. Fronts often serve as an aggregator of prey items that cannot swim very far (e.g. zooplankton) and they can attract large numbers of forage fish predators. These may in turn attract UTL predators. Therefore, frontal structures are an especially important habitat feature. Similarly, the distribution of preferred habitats (e.g. temperature) can change dramatically in a short period of time. In 2000, winds resulted in an offshore expansion of warm inshore waters over 2 weeks and this event caused a shift in juvenile pollock distribution offshore (Logerwell et al. 2007).

Competition both affects habitat choice and is influenced by habitat needs and spatial overlaps. The presence of capelin in colder, offshore waters (and thus likely in less suitable habitat) was attributed to their avoidance of competition with juvenile pollock that dominated the waters closer to shore (Logerwell et al. 2007). In southeast Alaska, niche overlap among capelin, herring, and sockeye salmon smolts varied as other habitat requirements changed (Coyle and Paul 1992). Competition between herring and capelin decreased as herring moved closer to shore for spawning, but that movement also increased competition with salmon smolts. Competition may occur only between specific community members. In Prince William Sound herring and pollock had high diet overlap, as did juvenile pink and chum salmon, but there was little overlap between the pairs (Willette et al. 1997). Potential for competition also changes with ontogenetic changes in diet (Sturdevant et al. 2001).

Reduced access to prey and a resulting loss in body condition and energy reserves, whether as a result of low ecosystem productivity, competition, or other factors, has consequences for forage fishes and their predators. Forage fishes with seasonally high lipid content rely on that energy reserves for overwintering and spawning. In the Barents Sea, capelin faced with competition from polar cod had reduced fat reserves that resulted in lower survival and disrupted reproduction including delayed maturity and spawning migrations (Ushakov and Prozorkevich 2002). The energy density of herring in Prince William Sound increases until October, after which it declines despite little change in prey quality, and the accumulation of adequate fat reserves is though to be critical for overwintering survival (Foy and Paul 1999). Energy density of forage fishes is also important for predators. In southeast Alaska Steller sea lions (*Eumetopias jubatus*) are highly dependent on spring spawning runs of eulachon (Womble and Sigler 2006), which have especially high lipid content (Payne et al. 1999). Seabird productivity also declines when their access to high-quality prey is reduced (Hatch and Sanger 1992).

The dynamics of habitat choice and its structuring of fish distributions underscore the necessity for a comprehensive, simultaneous view of nearshore and offshore areas. Juvenile pollock present in inshore waters in 2000 were not there in 2001, but the survey vessel lacked the ability to access nearshore areas and so could not investigate the entire area (Logerwell et al. 2007). Similarly, while juvenile Pacific cod have been found in abundance in nearshore habitats (Abookire et al. 2007; Laurel et al. 2007), they are also regularly captured in AFSC trawl surveys farther offshore. Because a synoptic view of cod distribution is not available, it is unknown whether juveniles are broadly distributed or whether they change their distribution over time. The lack of a synoptic view also hinders estimation of abundance. Estimates of total capelin biomass vary widely (Ormseth and Vollenweider 2008), at least in part because most surveys do not cover nearshore areas. During the summer, when surveys are conducted, capelin are likely to be inshore for spawning (Doyle et al. 2002). This proposal is constructed around the view that a comprehensive understanding of GOA forage fishes relies on simultaneous sampling of nearshore and offshore areas using multiple gear types.

Basis of comparative approach

Comparative studies provide an effective means of understanding ecological processes. Our research will proceed along four potential axes of variability, two spatial and two temporal:

a) Spatial variability - regional: By sampling in the eastern and central GOA, we will be able to compare how different topographic, oceanographic, and climatological conditions influence biological communities. For example, the eastern GOA has a much narrower shelf than the central GOA and, because it is “upstream” in the Alaska Current, is more heavily influenced by conditions to the south.
b) Spatial variability - habitat types: Within each of the two main regions there is substantial variability in the types of habitat available to fishes. This variability includes upstream influences on water characteristics (e.g. glacial runoff), exposure to wave action, bottom type, vegetation, and the presence of UTL predators. While it is beyond the scope of this proposal to explore all habitat types in each area, the research is designed to focus on sites that are representative of the range of habitat types available. Comparing species abundance and interactions among these sites will allow us to determine how small-scale variation in habitat influences forage communities.
c) Temporal variability - interannual and decadal: Through a combination of retrospective analyses and new data, we plan a comprehensive examination of how community structure changes over time and the factors (environmental and otherwise) that are associated with such changes. Candidate data sets include Outer Continental Shelf Environmental Assessment Program (OCSEAP) work done around Kodiak in the 1970s, research performed by UAF and the AFSC off Kodiak in the early 2000s, and the Southeast Coastal Monitoring Program in the eastern GOA. To the extent possible, this comparison will include not only data on distribution and abundance of forage species, but also diet and food web data.
d) Temporal variability – seasonal: Seasonality is an important factor in the GOA. Availability of prey (at different trophic levels) varies seasonally, as do behaviors of individual species (e.g. spawning). Nearshore communities in particular are likely to change as different life stages of fishes develop. We will examine seasonal variability by conducting our research in three seasons: spring, summer, and fall.

Focal species

The species that will be the focus of this proposal will vary between and within the two main regions and will depend in part on which species are encountered. This is especially true for examining interactions among species; potential competitors with the UTL focal species will be identified through our surveys and diet analysis. The focal species may include some members that are not generally considered to be forage fishes: for example, species of the family Cottidae are ubiquitous in nearshore Southeast Alaska (Johnson et al. 2005). Cottidae co-occur with early life stages of some of the UTL focal species in beach seine catches and may therefore compete with them. One of the challenges for the MTL component is that we must consider forage fishes as prey, predators, and competitors. We anticipate that the list of focal species will develop as a result of our field work and our interaction with the other components, especially the UTL component.

Here, we include a preliminary list of species that we expect to play an important role in our studies. Capelin, sand lance, and eulachon (*Thaleichthys pacificus*), are key forage fish species whose members may be juveniles or adults. In addition, Pacific herring (*Clupea pallasii*) are an important member of the forage community in the eastern GOA. We will also consider juvenile pollock, Pacific cod, and Pacific salmon (*Oncorhynchus* species). In their juvenile form these species serve as an important forage base, although their habitat requirements are likely to be different from the adult forage species. While euphasiids serve as prey for some UTL predators (e.g. cetaceans), for the purposes of this proposal we consider them to be part of the LTL component. Squids and lanternfishes (Myctophidae) are an important prey item for some UTL species but are not included in this proposal, partly to make the project more manageable and also because they not as universally important as the focal species. Finally, our study will also examine the nearshore distribution, habitat use, and ecological interactions of juvenile sablefish, Pacific ocean perch, and arrowtooth flounder wherever they are encountered.

Study areas

The main study areas will coincide with those originally chosen by the UTL component: the eastern and central GOA (Fig. 1). Although the UTL component has revised their survey grid, we have maintained these core regions as a means of focusing our investigations and providing the basis for a comparative approach. The nearshore survey and sample collections will be designed to complement the UTL survey grid, and some work (e.g. hydroacoustic transects) will extend directly inshore from concurrent UTL research work. Because nearshore habitat utilization (and resulting competitive interactions) often occur at a small scale, it will be necessary for us to sample nearshore areas at a high spatial resolution. Our past experience with such surveys indicates that at this high resolution we will not have sufficient time to cover all of the nearshore areas corresponding to the UTL survey. Therefore, we will concentrate our efforts on a smaller number of sites within each general area. To focus the research and provide the best integration with the work of the other components, our proposed research also focuses solely on habitats on the outside of Southeast Alaska, and similarly does not cover areas such as Shelikof Strait and Cook Inlet. We are exploring the possibility of supplementing our research with opportunistic work inside Southeast Alaska (e.g. at the AFSC Little Port Walter field station), but these opportunities are too tentative to include in this proposal.

The following criteria govern the selection of sites:

1) The body of sites in each region must be representative of the habitats available to fishes in each region. While it is impossible to represent all habitats, sites should represent main habitat types (e.g. protected shoreline, extensive eel grass beds; see Fig. 2). In addition, habitat types so represented should be similar between the two main regions to facilitate comparisons.
2) The spatial extent of the sites should cover most of each main region.
3) At least one site in each region must be in close proximity to seabird and/or Steller sea lion predators. This is necessary to provide integration with the UTL predator portion of the UTL component.

4) The availability of historical data at or close to sampling sites will enhance our ability to investigate interannual and decadal variability. Each region has experienced past research efforts that can be related to our findings.

The planning year and pilot study will be crucial for determining the exact location of these sites, but we have provisionally identified five sites in each region that satisfy these criteria (Fig. 1). In addition, these sites represent all possible marine ecoregions within each region suggested by Piatt and Springer (2007).

tentative site	latitude	longitude	selected characteristics
central GOA			
Kiliuda Bay	57.264	-152.993	protected; eel grass; historical data
Izhut Bay	58.156	-152.280	semi-protected; canopy kelps; historical data
Barren Islands	58.891	-152.152	exposed; seabird colony site
Chugach Bay	59.168	-151.460	semi-protected; variable habitat types
Aialik Bay	59.776	-149.729	glacial-influenced fjord; sea lion rookery close
eastern GOA			
Palmas Bay	58.349	-137.029	semi-protected; adjacent historical data
Islas Bay	57.785	-136.391	protected
Shelikof Bay	57.113	-135.818	semi-protected; variable habitat types; estuary
south end Kruzof I./St. Lazaria I.	56.958	-135.718	exposed; seabird colony site
Whale Bay	56.589	-135.036	glacial-influenced fjord; historical data

Research activities

We will conduct five main research activities in satisfying the objectives: analysis of historical data, nearshore surveys, offshore acoustics survey onboard the UTL survey vessel, diet analyses, and assessment of nutritional condition and energetics. Some of the activities address more than one of the objectives.

Research activity 1: Synthesis of historical data and retrospective analysis (Objectives 1-3)

The Gulf of Alaska ecosystem has been studied intensively over the last few decades, but much of this work has focused on small areas or a limited number of species. The GOA IERP provides an opportunity to synthesize some of this information and examine the interannual and decadal variability in the structure of forage communities. This research activity will parallel the proposed field work and laboratory analysis, i.e. we will use historical data to examine changes in distribution and abundance, habitat use, diet, and interactions among species. We also anticipate that this retrospective work will be conducted in cooperation with the UTL and LTL components, both of which include retrospective analyses.

The analysis of historical data will proceed along two lines of effort:

1) Comparisons between “eras”: The focus of this effort will be to compare historical data to the data we generate in the field and laboratory components of the overall study. For example, two of our proposed study sites in the central GOA (Kiliuda Bay and Izhut Bay) were the sites of a comprehensive analysis of fish communities conducted in the late 1970s as part of the OCSEAP. Although the gear types we employ in our field work may not perfectly match those from the OCSEAP study, they are sufficiently similar to allow comparisons of the distribution and abundance of nearshore fishes in these bays. Some of these comparisons will be quantitative, e.g. we will use analysis of variance to test for changes in overall abundance and species composition. Other comparisons will necessarily be qualitative, e.g. the OCSEAP work included diet and food web analysis that will be compared to the new diet information we generate. Other datasets, such

as the food web model results produced by the AFSC, may be included in the latter comparison. We anticipate identifying similar historical datasets in other areas through an extensive literature review and consultation with faculty at the University of Alaska Fairbanks (UAF) and researchers at government institutions.

2) Analyses of physical and ecological time series: The second component of our retrospective work will be the assembling and analysis of continuous time series data. For example, the Alaska Department of Fish and Game (ADFG) and the AFSC have conducted small-mesh trawl surveys in the central and western GOA since 1972. The dataset includes information on the distribution and abundance of several focal species of the GOA IERP (e.g. capelin, arrowtooth flounder, and Pacific cod). These data, as well as others, will be compared to physical time series using generalized additive models (GAMs). The use of GAMs will allow us to determine how a variable of interest (e.g. arrowtooth abundance) responds to changes in multiple physical variables. Spatial information like latitude and longitude can also be included in GAMs. The time series analysis will be closely coordinated with the other IERP components. As a group, we will identify environmental datasets that all components will use in their retrospective analysis. We also anticipate that the results of our retrospective work will be used by the modeling component in identifying the response of ecosystem members to environmental forcing.

Research activity 2: Nearshore surveys (Objectives 1-2)
The core field work in this proposal is a series of nearshore surveys that will be conducted using a chartered fishing vessel and a skiff. These platforms will be used to deploy a variety of sampling gears to sample areas from the shoreline out to 40 m depth (the inshore limit of the upper trophic level survey). In addition, acoustics will be used to quantify midwater forage species. We will also measure multiple habitat characteristics. The nearshore work will be coordinated with the offshore surveys conducted by the UTL and LTL groups to provide a synoptic view of the two main study regions.

Survey timing: Nearshore surveys will be conducted in the spring, summer, and fall of 2011 and 2013 to fully assess seasonal changes in the forage community and its interaction with the UTL focal fish species. Although it would be ideal to conduct the offshore acoustics work in all three seasons, the lack of an appropriate survey vessel (the UTL vessel) in the spring makes spring offshore sampling unfeasible. Despite the fact that we will not achieve our synoptic view in the spring, nearshore sampling in the spring is essential to understanding nearshore dynamics. The availability of forage for UTL predators is especially important in spring (e.g. Womble and Sigler 2006). Our examination of seasonal changes in the interactions among species also requires sampling in three seasons. Understanding changes in condition that occur during the winter will be an important aspect of the energetics work and will require samples from spring (post-winter) for comparison to fall (pre-winter) samples. Finally, sampling in the spring in the nearshore will allow us to assess the fate of juvenile UTL focal fish species that settled in the nearshore the previous fall.

Pilot project: In the summer and fall of 2010 we will conduct 2 14-day pilot surveys primarily in the eastern GOA. These pilot projects will be essential for investigating study sites, developing efficient sampling methods to maximize data collection, and determining the level of effort for the acoustics work we will conduct in the nearshore in 2011 and 2013. Although most of the techniques we will employ have been used previously, the data collection demands for our nearshore surveys is very high and it is crucial that we develop an effective strategy to assess each sampling site as completely as possible within the very limited timeframe.

Survey design and fish sampling: A small vessel (approximately 50’ LOA) will be chartered for the nearshore surveys. Such small vessels can approach the shoreline much more closely than large ones and, and can be used to deploy many types of fishing gear if properly equipped. Ormseth used a 32’ vessel in 2009 to deploy a bottom beam trawl and a surface pair trawl in conjunction with a large skiff. The main limitation is the number of scientific personnel that the vessel can carry, but we have determined that three scientific crew should be sufficient for the proposed work. One of the scientists will lead the nearshore acoustics work. As described above, the research will be focused on a smaller number of sites within the larger UTL study area to provide sufficient time to survey each area in a comprehensive manner (Fig. 1). At each site a system of acoustic transects (more detail below) will be designed to cover the study site and to match up with the UTL transects exactly, so that there is a seamless transect across the shelf at our sampling site locations (Fig. 3). In addition to the acoustics, we will employ beach seines to sample the shoreline and a beam trawl to sample demersal habitats (Fig. 3). A skiff will be used to deploy the beach seine, for towing a paired trawl, and for exploring potential sampling sites. Scale is a critical factor in determining spatial overlaps among species (Levin 1992), and the spacing of transects and other gear deployments will be designed to match the goals of the research. The pilot study will be important for addressing this question.

Catches will be sorted to species, and numbers and weight determined for the major species in the haul. To assess the size structure of fish populations and provide data on growth and condition, focal forage species individual lengths and weights will be measured. These measurements will also be performed on any UTL focal species that are caught in the nearshore (juvenile pollock and cod are included in the forage fish analysis). Tissue samples will be collected and frozen for diet and energetics analysis. To compare community structure among sites, regions, and over time we will employ several metrics. The Shannon-Wiener index will be used as a measure of species diversity. We will also compare total catch biomass and species richness using ANOVA. Non-metric multidimensional scaling will be used to elucidate patterns in species composition (Mueter and Norcross 1999, Abookire and Piatt 2005).

Nearshore acoustics: We will measure midwater fish abundance and distribution using acoustic methods. Transects will be designed to cover the entire nearshore study sites. The transect design will be coordinated with transects conducted with the UTL vessel to ensure that results are directly comparable (Fig. 2). We will employ recent advances in sampling technology and analysis methods to the nearshore environment. Calibrated split beam EK60 echosounders operating at 38, 120, and 200 kHz will be used, as multiple frequencies will improve our ability to distinguish major groups of acoustic scatterers (Johnsen et al. 2009; De Robertis et al. in press). We will also employ a 38/200 kHz single-beam acoustic system in the skiff to survey in very shallow water. A species-specific target strength to length relationship is required to convert acoustic units to fish biomass, but target strength estimates are not available for many nearshore fishes. We will apply *in-situ* techniques (Traynor 1996) to estimate target strength from split-beam measurements of locally abundant taxa if suitable conditions are encountered.

Groundtruthing the acoustic backscatter (i.e. identifying species composition and size distributions) will be difficult in the nearshore due to the complexity of the backscatter and limitations on midwater sampling. Small vessels are generally not equipped with the deck gear necessary for paired-warp trawling, and net avoidance is a major problem with the small, single-warp trawls we would be able to deploy. Therefore, we will use two methods that may provide less information but which we should be able to reliably deploy. Vertical variable-mesh gillnets will be deployed in areas where large amounts of backscatter is observed. These nets will capture a wide size range of fishes and should give us information on the presence of species at different depths. A drop video camera will also be used to visually assess fishes in the water column, although discrimination of species (e.g. capelin versus eulachon) may be problematic and we will likely be unable to determine size compositions. As a result of these sampling limitations for groundtruthing, we anticipate that we may not be able to provide species-specific estimates of abundance in the nearshore. However, the acoustics work will provide us at a minimum with information on the distribution of pelagic scatterers in units comparable to those from the UTL vessel . The pilot studies will be critical to evaluate the merits and challenges of using the proposed optical and acoustical tools and methods in these GOA nearshore environments. Our budget request is designed so that the results of the pilot work can be used to determine which acoustic gears are most appropriate. For example, if the groundtruthing of the split-beam acoustic data is too problematic we may limit our work to a single, less quantitative, single-beam system on the large vessel only. In this case, the funds set aside for purchasing split-beam gear in Year 2 would not be needed.

Habitat analysis - physical variables: During the course of the nearshore surveys, we will measure multiple habitat variables. Conductivity-temperature-depth recorders (CTDs) will be deployed vertically to measure temperature and salinity and define hydrographic structures (e.g. fronts) relevant to the distribution of nearshore fishes. In addition, we will deploy datalogging CTDs (already in our possession and used successfully to analyze dramatic salinity changes in Bristol Bay) on simple, temporary moorings to quantify how temperature and salinity vary over tidal cycles. These CTDs will also be deployed on beam trawls and midwater tows. These CTDs do not provide data at a sufficiently high resolution for oceanographic work; if the LTL component requires such data we will perform selected CTD casts using a borrowed, high-resolution CTD. Bottom type will be sampled Ponar grab on soft substrates and an underwater video camera on hard substrates. The assessment of bottom type will be qualitative (e.g. gray silt, cobble); substrate characteristics such as grain size will not be analyzed. The camera will also be used to assess aquatic vegetation.

Habitat analysis - prey fields: For the purposes of this study, we consider the potential prey fields for forage fishes and UTL focal fish species to be habitat characteristics. Investigating “suitable habitat” requires the assessment of adequate prey resources in those habitats. Phytoplankton and zooplankton will be assessed using standard methods. Phytoplankton will be assessed by collecting and filtering surface water using clean plastic jars and GF/F filters. The filters will be frozen for subsequent laboratory analysis. Zooplankton will be assessed using paired 150um mini-Bongo nets (~25cm diameter each). Zooplankton samples will be preserved in formalin. Image analysis will be used to determine the relative abundance and size distribution of the major species in each sample and will be conducted in cooperation with the LTL component. We have budgeted for 10 samples each of phytoplankton and zooplankton at each sampling site.

Our habitat analyses will also be coordinated with the habitat mapping efforts of the UTL component. Although those analyses will not be completed before field surveys begin, we expect to use preliminary results in our research design. This will enhance our ability to sample in areas that will provide us the best mean of comparison. Conversely, our nearshore sampling will provide data for the UTL habitat work and provide an opportunity to groundtruth predictions of the habitat models.

Research activity 3: Offshore acoustic surveys (Objectives 1-2)
To provide a synoptic view of forage fish distribution and abundance, it is critical that we also sample in the offshore. We will supplement the existing UTL survey by adding acoustics to the sampling already planned. The design of this activity is based on previous work conducted aboard Bering-Aleutian Salmon International Survey (BASIS) vessels in the Bering Sea. The BASIS surveys are similar in design to the GOA IERP UTL surveys and we anticipate a straightforward integration of the acoustics work into the other sampling.

Survey design: The UTL survey vessel will be outfitted with a Simrad EK60 system and hull-mounted transducers (38 and 120 kHz split-beam). Acoustic transects will be conducted while the vessel transits between UTL grid stations. Midwater trawls will be performed to sample echosign, and we have requested additional funds for the UTL vessel charter to provide extra time for these tows. The abundance and biomass of major species in trawl tows will be assessed and size distributions determined. The nearshore transects will correspond as directly as is feasible to the offshore transects and, because the electronic gear is identical, will provide a seamless acoustic transect from nearshore to offshore (Fig. 2). To enhance the tight coupling between nearshore and offshore surveys, MTL scientists aboard the UTL vessel will provide measurements of abundance, biomass, and individual lengths and weights that are identical in form to those obtained in the nearshore. Because the nearshore survey will also measure UTL focal species, these two surveys combined will provide a synoptic view of both forage species and the upper level predators.

Habitat analysis: In the offshore, water column properties and prey distributions will be the determining habitat characteristics. Temperature and salinity data, as well as data on phyto- and zooplankton, will be collected in the offshore aboard the UTL and LTL vessels. We expect to use those data in studying habitat use of forage species in the offshore.

Research activity 4: Diet analyses (Objective 3)
Diets are a primary indicator of relationships among species. Predator diets yield information regarding the predator (foraging habits, prey quality) and the prey (abundance and distribution). In addition, diets can be used to determine the likelihood of competition among members of a community. A key aspect of the GOA IERP Implementation Plan is to determine the effect of environmental processes on various trophic levels and dynamical linkages among trophic levels. The research proposed here addresses this problem by using multiple techniques to trace the flow of nutrients from zooplankton to forage fishes to UTL predators.

We propose to approach our diet work using several techniques. Analysis of stomach contents is valuable for providing instantaneous assessment of diets, and we include analysis of stomachs of fishes as part of our proposed work. However, stomach content analysis may not represent the average diet and does not allow the examination of longer-term diet patterns or the source of nutrients in diet. Stable isotope (SI) and fatty acid (FA) analysis can reveal more information about diets and foraging patterns, allowing for a more comprehensive study. In SI analysis, the fraction of different isotopes of carbon and nitrogen in tissues is analyzed to produce a ratio of heavier to lighter isotopes. Because these isotopes are metabolized in animals at different rates, they can be used as a marker. Stable carbon isotopes are typically used to look at the origin of nutrients (e.g. terrestrial versus marine, benthic versus pelagic), while nitrogen stable isotopes can indicate the trophic level of the sampled individual (Hobson and Clark 1992a; Hobson and Clark 1992b). Analysis of FAs can be used in several ways to study foraging ecology and food webs in marine ecosystems. Using predator FA signatures, along with a comprehensive database of prey FA signatures, it is possible to quantitatively estimate the proportions of different prey in the predator diet (Iverson et al. 2004; Wang et al. 2009b). In addition, the presence of unique FAs found in consumers can occasionally be traced to prey species and thus used for identification of forage items (Budge et al. 2006; Budge et al. 2007). Finally in its simplest form, analysis of FAs in consumer fat stores (i.e., adipose tissue, stomach oil, blood) alone can be used to qualitatively infer spatial and temporal patterns in diets of free ranging animals. This qualitative analysis of FAs has been used in marine mammals, marine birds, fishes, and plankton (Budge et al. 2002; Beck et al. 2007; Jaschinski et al. 2008; Wang et al. 2009a). Together, analysis of stomach contents, SIs, and FAs will provide a comprehensive study on diet analysis.

Diet analysis - stomach contents: During the nearshore surveys and aboard the UTL vessel, stomachs of a selected number of individuals of the focal species will be analyzed. If possible, stomach contents will be weighed. If boat movement prevents the measurement of small samples, we will measure stomach contents volumetrically and measure average density to produce estimates of stomach contents weight. Stomach samples will be preserved in formalin for later analysis. This analysis will be similar in form to the zooplankton analysis: digital image analysis will be used to identify major species and their size distributions.

Diet analysis - stable isotopes and fatty acids: From the same individuals where we collect stomach contents we will collect tissue samples, store them in air-tight plastic bags and store them at -20 C until analysis. Zooplankton samples collected on the nearshore survey will be frozen, and we will collaborate with UTL and LTL component researchers to obtain zooplankton samples from offshore areas. We will collaborate with UTL seabird researchers to obtain adipose tissue and/or stomach oil samples from seabirds at representative breeding colonies in Eastern and Central GOA. While it would be ideal to obtain sea lion adipose tissue biopsies, it is uncertain if a permit would be granted to take biopsies. All samples will be stored in air-tight containers and stored at -20 C until analysis.

For SI analysis, samples will be dried, ground, and weighed into foil sampling cups. The samples will then be analyzed by an independent laboratory, such as the Alaska Stable Isotope Facility at UAF, using a mass spectrometer. For FA analysis, samples will be shipped to Dalhousie University. Lipids will be extracted, and fatty acids will be analyzed using gas chromatography. Stomach scans, SI analysis, and FA analysis will all occur in the same individuals. We are requesting funds to analyze a total of 480 samples in each of the full field years. Because 12 individuals of each species under study need to be analyzed to reduce variance, we will be able to analyze 40 species per field year. This will be sufficient to analyze all focal fish species (MTL and UTL), several species of zooplankton, and several UTL predators. The allocation of these samples among seasons and sampling sites will be determined during the planning year and will depend in part on the collaboration with the UTL component.

Several metrics will be used to infer relationships using diet data. Niche breadth will be estimated using the method of Petraitis (1979), which compares the proportion of prey items in the diet to their proportions in the environment. Competition among species will be inferred by calculating the Schoener index (Schoener 1968), which provides a measure of niche overlap by comparing prey composition between two species.

Research activity 5: Energetics and nutritional condition (Objective 4)

The nutritional condition of predators depends on the quality as well as quantity of prey. Therefore, we will analyze proximate composition (lipid, protein, ash, and water contents) of the focal forage species. These efforts will directly complement the energetics work in the UTL component. Collaborator Vollenweider will oversee these efforts and she is a colleague of Ron Heintz, who will be conducting the UTL analyses. As a result, the MTL and UTL energetics analyses will be essentially one project. This will provide essential data to the UTL component. It will also allow us to determine how forage species are affected by differences in their diets and ultimately, how species interactions impact individual condition and the likelihood of survival.

The bioenergetics component of the MTL component will extend the work done in the UTL component and provide modelers with estimates of biomass removals by apex predators. The bioenergetics section of the UTL component is testing the hypothesis that the growth potential of juvenile groundfish is maximized in nearshore habitats by comparing the health of fish sampled in different habitats. Samples of the target and forage species collected under the MTL will be analyzed as in the UTL. The data collected will include proximate composition and RNA/DNA. The energy content of target and forage species will be determined from the estimated lipid and protein content of each fish. Both the energy and lipid values will provide information on the health of fish sampled in different habitats, as well as the quality of forage available to UTL predators.

Estimates of the energy content will also be used to estimate biomass removals by top level predators within each sampling period. Published metabolic rates (FMR) and assimilation efficiencies (AE) will be combined with field observations of diet composition (DC), prey quality (ED), and predator abundance (N) to estimate consumption by different avian and mammalian predators in the Gulf of Alaska. Estimates of DC and N for seabirds nesting at Amatuli and St. Lazaria Islands from the UTL component. Retrospective analyses of DC and current estimates of N will be used for Steller sea lions, but the spatial component may be limited areas as large as southeast Alaska and Kodiak. Values for ED will come from forage samples collected during the research in this proposal (MTL). Additional predators can be added so long as there are concurrent observations of N and DC within some spatial context. Aside from observations of diet composition, prey quality and abundance no new parameters will be estimated for the bioenergetic models. The basic form of the models to be used is:

$$Consumption_p = \sum \frac{DC_i}{ED_i} \times \frac{FMR_i}{AE_i} \times D$$

Where the total consumption by an individual predator of the p^{th} species in a given area depends on $DC_{i,}$ proportion of the i^{th} prey in the diet, ED_i the energy density of the prey, FMR_i the field metabolic rate, AE_i the proportion of the i^{th} prey that is assimilated, D is the number of days in the sample period (i.e. summer, fall) in the geographic area examined. Multiplying the consumption by $N_{p,}$ the number of predators in the area, gives the total biomass removed.

Project Responsiveness.

UTL: The proposed work responds to the UTL component in a number of ways. The retrospective work will provide a means of comparison about how the environment has shaped conditions for the UTL focal species in the past, and will be conducted in cooperation with UTL researchers.The nearshore surveys will provide information on the distribution and abundance of juveniles of the five focal fish species, answering questions regarding survival and settlement at the end of the "gauntlet". In addition, the habitat and diet work will reveal the condition under which those juveniles live – i.e., how factors such as habitat availability and competition that might affect their survival are arranged in the nearshore. The offshore acoustics work will provide information on potential predators and competitors in offshore areas. Our contribution to the diet work of UTL predators will also enhance our knowledge of how these species interact with the focal species. Finally, the energetics work proposed here is directly connected to the similar research conducted by the UTL.

LTL: Because the techniques we are using to analyze plankton in the nearshore, these samples will be available to supplement the work of LTL researchers. While the information on water column properties we are proposing to collect may not be directly useful to the LTL oceanographers, we will modify our approach if they require such data from the nearshore. The LTL component will provide an understanding of climate/ocean links and environmental forcing that will be a crucial addition to our work. We also expect that the data from the LTL component will inform our analyses of habitat use and diet by providing information on the prey available to forage fishes and juvenile groundfish. Our retrospective work will be conducted in collaboration with the LTL component and we anticipate that the results of these analyses will complement all components. We expect that, as it is in the ecosystem, the MTL component will provide a link between the results of the LTL and UTL studies.

Modeling: The data and knowledge of relationships gained in this work will be useful for a number of types of models. Data on nearshore distribution of juvenile groundfish will be useful for informing individually-based models of larval transport and settlement. Discussions with the two potential modeling groups suggest two different ways that MTL data may be used. The analysis of niche overlaps, consumption, and condition could be used to provide rates (predation, survival) that could feed directly into models to predict survival of individuals. Alternatively, spatial data on habitat suitability (which may include presence of prey and predators, shelter from predators, or a combination of factors) could be incorporated into spatial models of optimal habitat selection. The analyses of forage fish communities could also provide important information for multispecies modeling. Also, analyses of diet will provide food web information that could generate data for models or provide something to compare them to. We expect that we will work closely with the modeling component to provide data they require.

The fundamental difference between the proposed work and previous research is that we will provide, for the first time, a synoptic view of the GOA forage community from the shoreline out to the shelf break in selected areas of the GOA. In addition, the design of our study allows us to simultaneously explore how these communities vary at different temporal and spatial scales. At the same time, our work is based on and complements earlier investigations. By choosing our study sites to correspond to similar work performed in the past several decades, we will enable a direct comparison to past conditions. This work also complements the surveys conducted by the AFSC (e.g. GOA bottom trawl survey and EIT surveys) that are conducted only in offshore areas. The proposed work also complements the ADF&G small-mesh surveys. We have also discussed this project with a group that is proposing research on humpback whales to the National Science Foundation. If that research is funded, we anticipate that our work will complement theirs.

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

Program Management

The research team will include Dr. Olav A. Ormseth (AFSC) as the lead PI and Dr. Alex De Robertis (AFSC), Dr. John Horne (University of Washington), Shiway Wang (Sedna Ecological, Inc.), and Dr. Suzanne Budge (Dalhousie University, Halifax, NS) as PIs. Dr. Robert Foy (AFSC), Dr. Franz Mueter (UAF), Dr. Chris Wilson (AFSC) and Johanna Vollenweider (AFSC) will serve as collaborators. Ormseth will carry overall management responsibility for the MTL component, lead the nearshore surveys, lead the analyses of habitat and species interactions, and assist in the retrospective analysis. He is the AFSC assessment scientist for forage fishes in Alaska and has experience in conducting nearshore surveys using small vessels. He has also performed research using stable isotopes and fatty acids. De Robertis will lead the nearshore acoustics work. As a scientist in the AFSC's Midwater Assessment group, he has extensive experience in conducting acoustic surveys, analyzing acoustic data and developing innovative sampling methods. Horne will lead the acoustics research aboard the UTL survey and his team will serve as MTL representatives on those cruises. He also has extensive acoustics experience and is currently conducting similar research in the Bering Sea (as part of BSIERP). Wang and Budge will be co-PIs for the diet work. Wang will design the sampling approach, coordinate collection, preparation, and shipment of samples, and oversee the stable isotope analysis. Budge will also assist in research design and oversee the fatty acid analysis. Wang and Budge have both participated in the development of novel uses of fatty acids and are experienced in planning and conducting laboratory analyses. Foy will assist in the analysis of retrospective data and serve as an advisor regarding the nearshore surveys. He collected some of the data we plan to use for the retrospective work and is knowledgeable regarding data sources and the central GOA region. Mueter will assist with overseeing the retrospective work. He is the PI for the UTL retrospective analysis and has an extensive background in statistical methods. Wilson will oversee the nearshore acoustics work and coordinate the work with the AFSC EIT survey. He is the head of the Midwater Assessment group and is well versed in acoustics methods. Vollenweider will coordinate activities between the MTL and the health assessment work performed by the UTL, and serve as an advisor on the nearshore work in the eastern GOA. She has experience in energetics research and in nearshore field sampling including acoustics.

To lead the retrospective work and assist Ormseth with planning and conducting the nearshore surveys, we will extend the employment of a Term Research Fisheries Biologist at the AFSC for 2.25 years. This biologist is experienced in the synthesis and analysis of historical data, including the construction of GAMs. She is also an experienced field researcher. Ormseth will oversee her work and we expect that she will work closely with Mueter and other scientists in conducting the retrospective analysis. A postdoc will be hired in the Horne lab for 3 mos. per year to conduct the offshore acoustics analysis. Horne will also employ a technician part-time to participate in field work. The requested funds will also support the first three years of a Ph.D. student in Horne's laboratory.

Ormseth will devote 3 mos. in year 1, and 4 mos. in each of years 2-5 of the GOA IERP. As a research fishery biologist in the AFSC's stock assessment group, 80% of his time is devoted to research and leadership. While his duties include several stock assessments, he is expected to conduct independent research and the GOA IERP will be his primary research activity through 2014. Similarly, De Robertis has survey and assessment responsibilities but also conducts research. Ormseth's and De Robertis' supervisors have wholeheartedly endorsed their participation in the IERP. Therefore, we do not anticipate that participation in the IERP will conflict with their duties at the AFSC.

Research Platforms

A small vessel (approximately 50' LOA) will be chartered for nearshore surveys in 2010, 2011, and 2013. Vessel charters in 2010 (2 cruises of 14 days each) will be covered using Cobb replacement funds administered by the AFSC. In 2011 and 2013, 1/3 of the charter days (3 cruises of 24 days each, 12 days in each region) will be covered using Cobb replacement funds. We are requesting NPRB GOA IERP funds for the remaining charters. We anticipate using different vessels in each region but we will attempt to charter the same vessels during each season. The vessels will be required to have sufficiently shallow draft to gain access to nearshore areas, and will accommodate at least two fishing crewmembers and three scientists. The vessel will also need to have a winch or net reel and a boom for deploying gear. In addition, we have arranged for the use of a 20' work skiff from the ABL. The skiff will be used to access the shore for beach seining and for pair trawling and reconnaissance. The UTL survey vessel (chartered vessel and NOAA replacement vessel) will serve as the platform for the offshore acoustics work, and we have requested funds for extra UTL survey time to accommodate sampling tows. We also anticipate that we will coordinate efforts during 2011 with an AFSC echo-integration trawl survey planned for 2011. However, the design of that survey is too uncertain at this point to create a detailed research plan. The stable isotope analysis will be conducted at an independent research facility, such as the Alaska Stable Isotope Facility at UAF. Preparation of the stable isotope samples will occur at the AFSC in Seattle. Analysis of plankton samples will be contracted to an appropriate facility and coordinated with the LTL component. All of the fatty acid sample preparation and analysis will be conducted at Dalhousie University. Energetics analyses will be conducted at the AFSC's laboratory in Juneau.

Timeline and Milestones

A timeline for the proposed work is included in Table 1. We are proposing 2 full years of field work (2011 and 2013), with pilot studies in the summer and fall of 2010. In each full year, nearshore surveys will occur in spring, summer, and fall. The offshore acoustics work will occur in summer and fall. Laboratory analyses will occur subsequent to the field years, e.g. the analysis of diet samples collected during 2011 will be conducted throughout 2012. Each of the entries in the table indicate measurable milestones (e.g. completion of retrospective analysis and associated report, completion of pilot field study). Dates for data availability is also indicated in Table 1. This timeline may be modified as the result of coordination of activities with the other components.

Products

This study will yield the following products:

1) For the first time, a synoptic view of the distribution and abundance of GOA forage fishes from the shoreline out to the shelf break
2) Dataset describing prey availability for UTL predators
3) Detailed GIS products showing forage fish distribution and habitat characteristics
4) Food web information, including an analysis of the transport of fatty acids through the food web from zooplankton to top predators
5) A database containing all collected data and results of the retrospective analysis

6) We anticipate producing at least the following peer-reviewed publications:
   a) Retrospective analysis of nearshore and offshore distribution of GOA forage fishes
   b) Cross-shelf distribution and abundance of forage fishes in the eastern and central GOA
   c) Habitat preferences of GOA forage fishes
   d) Trophic relationships among the GOA forage fish community
   e) Comparison of GOA food webs past and present

As detailed above, the MTL component will provide data to the UTL and modeling components and samples to the UTL and LTL components.

Research results will be disseminated through the peer-reviewed publications listed above, oral and poster presentations at conferences, websites, and AFSC publications (technical memos and quarterly reports). As detailed below, we will also seek out opportunities for outreach with the Alaska Sea Life Center and other institutions.

E. Data Management Plan

Data management will be coordinated with the plan proposed by the UTL component, including formatting appropriate for inclusion in the Alaska Marine Information System and access through web portals. Metadata will be recorded continuously throughout the project, and the AFSC has personnel to assist us in database management and metadata creation. Data management needs will include the datasets collated in the retrospective work; datasets containing forage fish distribution and abundance data as well as length compositions; acoustic datasets; habitat information; a GIS that will include subsets of these data; and datasets from the diet and condition analyses. We do not envision that computation time will be required beyond what is available on our workstations. We plan to generate a large number of images and video (for analysis purposes and to record activities), so we will require a large amount of data storage space (at least several terabytes).While obtaining data from other components is not critical to the success of our field work, access to the habitat models and LTL data would be valuable for designing and modifying our nearshore and offshore sampling plans. In addition, we plan to begin analyzing data after the first full field year is complete (2012) and it would be helpful to have access to field data from the LTL and UTL components at that time.

F. Outreach and Education Plan

We will coordinate our outreach efforts with the AFSC’s outreach coordinators, the University of Washington, and NPRB. The AFSC has recently dedicated additional personnel to focus exclusively on outreach efforts and we anticipate relying on their assistance in developing outreach plans. In addition to the website proposed in the UTL component, we suggest several other avenues for outreach. The Alaska SeaLife Center (ASLC) in Seward, Alaska is situated almost exactly in the middle of the proposed study areas and would be an ideal showcase for the GOA IERP. Research displays could even include aquariums containing the focal species of the IERP. We have worked closely with ASLC aquarium staff and have found them to be flexible and eager to make connections to the broader research community. We have also had success in the past publicizing research in Alaska communities through articles in local newspapers and interview on local radio stations. We are exploring the possibility of incorporating college-level field classes in southeast Alaska into our opportunistic sampling in inside waters. Similar opportunities may exist in the central GOA. In addition, tourists to Alaska are an underutilized audience for education and outreach regarding Alaska marine issues. Cruise passengers in southeast Alaska would benefit from receiving information on the GOA and the IERP, and would carry that message back with them to the rest of the US and to other countries. Similarly, charter boat operations could be included in the outreach effort as their clients are usually highly interested in the marine environment. Outreach efforts in Seattle may also be worthwhile, as the level of interest in Alaska and marine issues is high but the degree of knowledge about these issues often is not. The University of Washington and the Seattle Aquarium may be good contact points.

G. Coordination Strategy

Our research will be coordinated with several ongoing research activities at the AFSC. The results of the nearshore acoustics work will be used by the Midwater Assessment group to interpret the results of the GOA gulfwide surveys they conduct on an irregular basis. Data on nearshore fish distribution and abundance, as well as habitat information, will be contributed to the Nearshore Fish Atlas of Alaska, an online resource maintained by the AFSC's Auke Bay Laboratory (www.alaskafisheries.noaa.gov/ habitat/fishatlas). Diet information will be made available to the AFSC's ecosystem modeling group and we anticipate that it will inform their ongoing modeling efforts. While we have not yet established cooperation with sea lion researchers at the ASLC, we anticipate that the data we generate on forage fishes in the vicinity of the Chiswell Islands will benefit their sea lion research program.

H. Figures and Tables

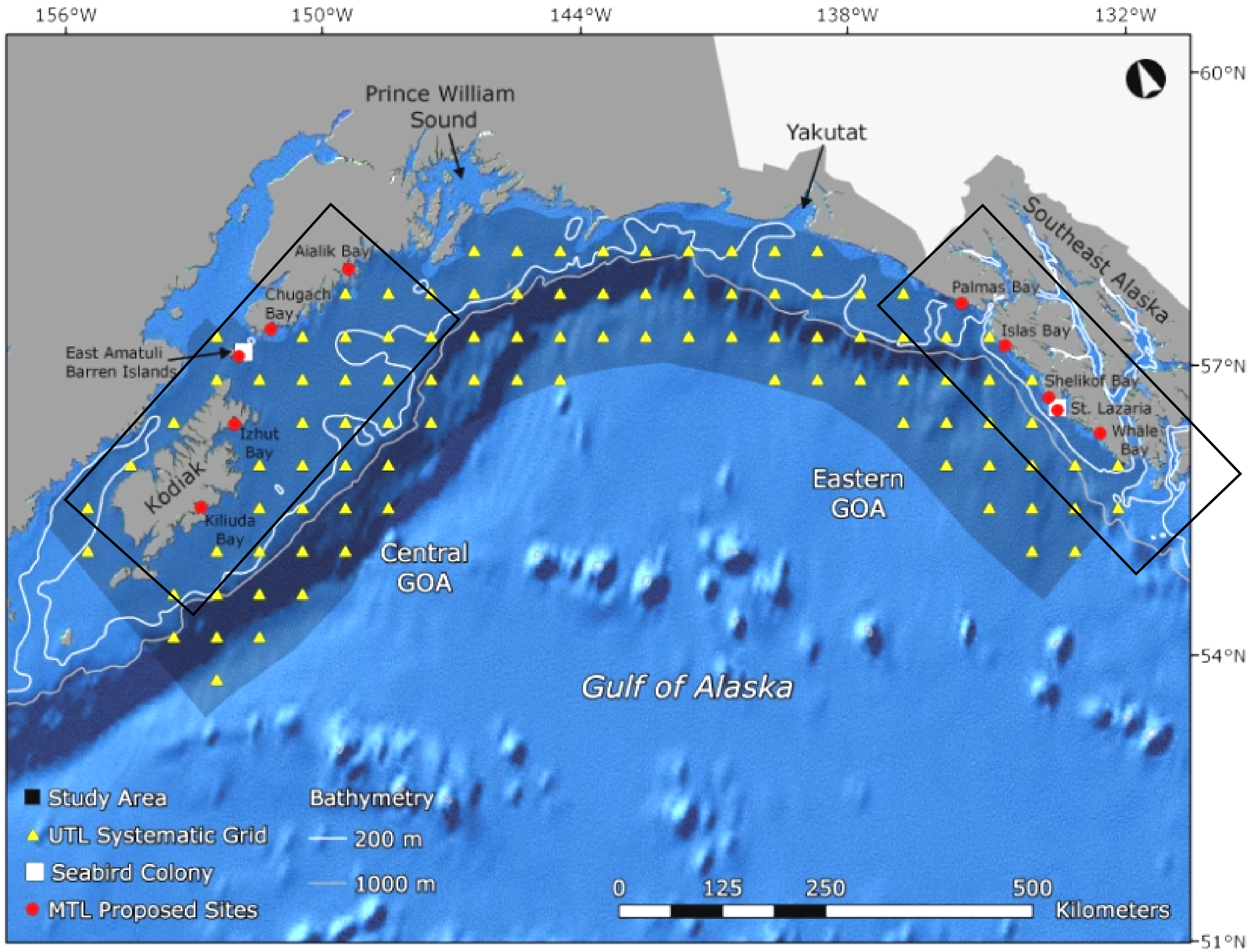

Figure 1. Map showing the location of proposed study sites for nearshore surveys. Legend is shown in figure; black rectangular outlines indicate approximate area of the original UTL sampling grid.

Figure 2. Maps downloaded from Alaska ShoreZone (http://alaskafisheries.noaa.gov/habitat/shorezone) demonstrating differences in habitat types between Kiliuda Bay on Kodiak Island (top) and the south end of Kruzof Island in Southeast Alaska (bottom).

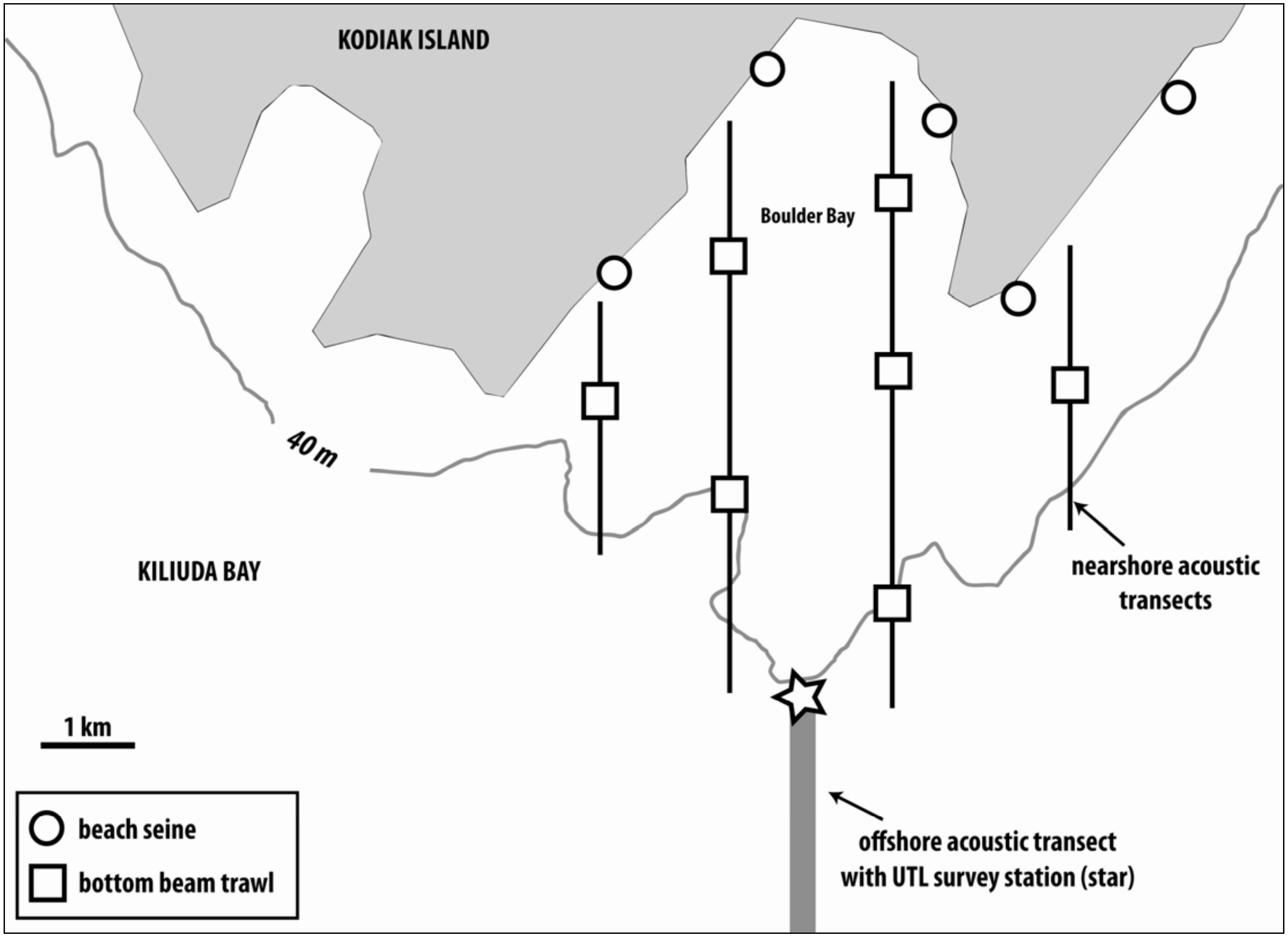

Figure 3. Schematic showing a potential design for a nearshore survey study site and how the nearshore work corresponds to the UTL component. Habitat assessment would occur at the seine and trawl sites and along the acoustic transects. While the map shows an actual location (Boulder Bay on the southeast coast of Kodiak Island), the sampling design shown is for demonstration purposes only. Actual number of seine and trawl locations, as well as transect spacing, will depend on the outcome of the planning year and survey design process.

Olav A. Ormseth, AFSC

Table 1. Timeline for proposed MTL component. SI = stable isotope, FA = fatty acid. Dates for data availability are provisional and will depend on results and coordination with other components.

	2010				2011				2012				2013				2014				2015
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
Planning																					
Retrospective																					
- Collection of historical data																					
- Data analysis																					
- Comparison historical data to new data																					
Nearshore survey (including acoustics)																					
- pilot surveys																					
- seasonal surveys																					
Offshore acoustics (aboard UTL vessel)																					
Diet analysis																					
- Sample collection for diet analyses																					
- Analysis of stomachs, SI & FA																					
Energetics analysis																					
Data analysis																					
Manuscript and report writing																					
Lead PI attends AMSS																					

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Doyle MJ, Busby MS, Duffy-Anderson JT, Picquelle SJ, Matarese AC (2002) Early life history of capelin (*Mallotus villosus*) in the northwest Gulf of Alaska: a historical perspective based on larval collections, October 1977–March 1979. ICES Journal of Marine Science 59: 997-1005

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Fretwell SD, Lucas HL (1970) On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development. Acta Biotheoretica 19: 16-36

Gargett AE (1997) The optimal stability `window': a mechanism underlying decadal fluctuations in North Pacific salmon stocks? Fisheries Oceanography 6: 109-117

Hatch SA, Sanger GA (1992) Puffins as samplers of juvenile pollock and other forage fish in the Gulf of Alaska. Marine Ecology Progress Series 80: 1-14

Hobson KA, Clark RG (1992a) Assessing avian diets using stable isotopes I: Turnover of 13C in tissues. Condor 94: 181-188

Hobson KA, Clark RG (1992b) Assessing avian diets using stable isotopes II: Factors influencing diet-tissue fractionation. Condor 94: 189-197

Hughes NF, Grand TC (2000) Physiological ecology meets the ideal-free distribution: predicting the distribution of size-structured fish populations across temperature gradients. Environmental Biology of Fishes 59: 285-298

Iverson SJ, Field C, Bowen WD, Blanchard W (2004) Quantitative fatty acid signature analysis: A new method of estimating predator diet. Ecological Monographs 74: 11-235

Jaschinski S, Brepohl DC, Sommer U (2008) Carbon sources and trophic structure in an eelgrass *Zostera marina* bed, based on stable isotope and fatty acid analyses. Marine Ecology Progress Series 358: 103-114

Jobling M (1994) Fish Bioenergetics. Chapman and Hall, London

Johnsen E, Pedersen R, Ona E (2009) Size-dependent frequency response of sandeel schools. ICES Journal of Marine Science 66: 1100-1105

Johnson SW, Neff DA, Thedinga JF (2005) An atlas on the distribution and habitat of common fishes in shallow nearshore waters of southeastern Alaska. NOAA Tech Memo NMFS-AFSC-157

Laurel J, Stoner AW, Ryer CH, Hurst TP, Abookire AA (2007) Comparative habitat associations in juvenile Pacific cod and other gadids using seines, baited cameras and laboratory techniques. Journal of Experimental Marine Biology and Ecology 351: 42-55

Levin SA (1992) The Problem of Pattern and Scale in Ecology: The Robert H. MacArthur Award Lecture. Ecology 73: 1943-1967

Logerwell EA, Stabeno PJ, Wilson CD, Hollowed AB (2007) The effect of oceanographic variability and interspecific competition on juvenile pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*) distributions on the Gulf of Alaska shelf. Deep Sea Research Part II: Topical Studies in Oceanography 54: 2849-2868

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McGowan JA, Cayan DR, Dorman LM (1998) Climate-ocean variability and ecosystem response in the northeast Pacific. Science 281: 210-217

Mueter FJ, Norcross BL (2002) Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. Fishery Bulletin 100: 559-581

Norcross BL, Holladay BA, Mueter FJ (1995) Nursery area characteristics of pleuronectids in coastal Alaska, USA. Netherlands Journal of Sea Research 34: 161-175

Ormseth OA, Vollenweider J (2008) Forage fishes in the Gulf of Alaska. IN: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, Alaska

Payne SA, Johnson AB, Otto RS (1999) Proximate composition of some north-eastern Pacific forage fish species. Fisheries Oceanography 8: 159-177

Petraitis PS (1979) Likelihood measures of niche breadth and overlap. Ecology 60: 703-710

Piatt JF, Springer AM (2007) Marine ecoregions of Alaska. IN: R Spies, ed., Long-term ecological change in the northern Gulf of Alaska. Elsevier, Amsterdam. pp. 522–526

Rogers BJ, Wangerin ME, Rogers DE (1980) Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island- including ichthyoplankton, zooplankton, and fish. A report on the fish component of the study. Environmental assessment of the Alaskan continental shelf, Final reports of Principal Investigators, Contract No. 03-5-022-67

Rooper CN, Hoff GR, De Robertis A (in review) Assessing habitat utilization and rockfish biomass in an isolated rocky ridge using acoustics and stereo image analysis. Canadian Journal of Fisheries and Aquatic Sciences

Ryer CH, Olla BL (1998) Shifting the balance between foraging and predator avoidance: the importance of food distribution for a schooling pelagic forager. Environmental Biology of Fishes 52: 467-475

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Springer AM, Speckman SG (1997) A forage fish is what? Summary of the symposium. IN: Forage fishes in marine ecosystems. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No. 97-01. University of Alaska Fairbanks, Fairbanks, Alaska

Sturdevant MV, Brase ALJ, Hulbert LB (2001) Feeding habits, prey fields, and potential competition of young-of-the-year walleye pollock (*Theragra chalcogramma*) and Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska, 1994–1995. Fishery Bulletin 99: 482-501

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Ushakov NG, Prozorkevich DV (2002) The Barents Sea capelin-a review of trophic interrelations and fisheries. ICES Journal of Marine Science 59: 1046-1052

Wang SW, Hollmen TE, Iverson SJ (2009a) Validating quantitative fatty acid signature analysis to estimate diets of spectacled and Steller's eiders (*Somateria fischeri* and *Polysticta stelleri*). Journal of Comparative Physiology B

Wang SW, Iverson SJ, Springer AM, Hatch SA (2009b) Spatial and temporal diet segregation in northern fulmars *Fulmaris glacialis* breeding in Alaska: Insights from fatty acid signatures. Marine Ecology Progress Series 377: 299-307

Willette M, Sturdevant M, Jewett S (1997) Prey resource partitioning among several species of forage fishes in Prince William Sound, Alaska. IN: Forage fishes in marine ecosystems. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No. 97-01. University of Alaska Fairbanks, Fairbanks, Alaska

Wilson MT, Brown AL, Mier KL (2005) Geographic variation among age-0 walleye pollock (T*heragra chalcogramma*): evidence of mesoscale variation in nursery quality? Fishery Bulletin 103: 207-218

Womble JN, Sigler MF (2006) Seasonal availability of abundant, energy-rich prey influences the abundance and diet of a marine predator, the Steller sea lion *Eumetopias jubatus*. Marine Ecology Progress Series 325: 281-293

NAME AND ADDRESS:

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Dalhousie University
Halifax, NS, B3L 2X4

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PROFESSIONAL PREPARATION & EDUCATION

Memorial University of Newfoundland, St. John's, NF. PhD Chemistry (1994-1999)

Acadia University, Wolfville, NS. BSc Chemistry (1989-1993)

APPOINTMENTS

Associate Professor, Department of Process Engineering and Applied Science, Dalhousie University, Halifax, NS. (2009-present)

Assistant Professor, Department of Process Engineering and Applied Science, Dalhousie University, Halifax, NS. (2004-2009)

Adjunct Professor with Department of Biology and Marine Biology, University of North Carolina Wilmington, Wilmington, North Carolina. (2005-present)

Visiting Fellow, Sea Mammal Research Unit University of St. Andrews, St. Andrews, Scotland. (2004)

Post-Doctoral Fellow, Department of Biology, Dalhousie University, Halifax, Nova Scotia (1999-2003)

FIVE MOST RELEVANT PUBLICATIONS

Budge, S. M., Wooller, M.J., Springer, A. M., Iverson, S. J., McRoy, C.P. and Divoky, G.J. 2008. Tracing carbon flow in an arctic marine food web using fatty acid-stable isotope analysis. Oecologia 157: 117-129.

Cooper, M.H., Budge, S.M., Springer, A.M. and Sheffield, G. 2008. Resource partitioning by sympatric pagophilic seals in Alaska: Monitoring effects of climate variation with fatty acids. Polar Biology. In press.

Budge, S. M., Springer, A. M., Iverson, S. J., Sheffield, G. and Rosa, C. 2008. Blubber fatty acid composition of bowhead whales, *Balaena mysticetus*: implications for diet assessment and ecosystem monitoring. Journal of Experimental Marine Biology and Ecology 359: 40-46.

Budge, S. M., Springer, A. M., Iverson, S. J. and Sheffield, G. 2007. Fatty acid biomarkers reveal niche separation in an arctic benthic food web. Marine Ecology Progress Series 336: 305-309.

Budge, S. M., Iverson, S. J. and Koopman, H. N. 2006. Studying trophic ecology in marine cosystems using fatty acids: A primer on analysis and interpretation. Marine Mammal Science 22: 759-801.

FIVE OTHER RELEVANT PUBLICATIONS

Thiemann, G. W., Budge, S. M., Iverson, S. J. and Stirling, I. 2007. Unusual fatty acid biomarkers reveal age- and sex-specific foraging in polar bears (*Ursus maritimus*). Canadian Journal of Zoology 85: 505-517.

Koopman, H. N., Budge, S. M., Ketten, D. R. and Iverson, S. J. 2006. The topographical distribution of lipids inside the mandibular fat bodies of odontocetes: Remarkable complexity and consistency. IEEE Journal of Oceanic Engineering 31:95-106.

Budge, S. M., Cooper, M. H. and Iverson, S. J. 2004. Demonstration of the deposition and

CV – Suzanne Budge

modification of dietary fatty acids in pinniped blubber using radiolabelled precursors. Physiological and Biochemical Zoology 77: 682-687.

Thiemann, G. W., Budge, S. M. and Iverson, S. J. 2004. Determining blubber fatty acid composition: a comparison of *in situ* direct and traditional methods. Marine Mammal Science 20:284-295.

Budge, S. M., Iverson, S. J., Bowen, W. D. and Ackman, R. G. 2002. Among- and within- species variability in the fatty acid signatures of marine fish and invertebrates on the Scotian Shelf, Georges Bank, and southern Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Sciences 59: 886-889.

COLLABORATORS in the last 48 months

Robert Ackman (Dalhousie)
Deborah Austin (Parks Canada)
Don Bowen (DFO Canada)
Arjun Chhetri (Dalhousie)
Margaret Cooper (Dalhousie)
George Divoky (UAF)
Hector Douglas (UAF)
Bill Henry (UCSC),
Raffic Islam (Dalhousie)
Sara Iverson (Dalhousie)
Darlene Ketten (WHOI)
Heather Koopman (UNC at Wilmington)
Santosh Lall (National Research Council Halifax)
Peter McRoy (UAF)
Cheryl Rosa (NSBDWM)
Scott Shaffer (UCSC)
Gay Sheffield (ADFG)
Alan Springer (UAF)
Ian Stirling (Canadian Wildlife Service)
Martin Tango (Dalhousie)
Gregory Thiemann (University of Alberta)
Chris Watts (Dalhousie)
Matthew Wooller (UAF)

Alex De Robertis
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Seattle WA 98115
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PROFESSIONAL INTERESTS:

Fisheries acoustics, behavioral ecology of fish and zooplankton, optical ecology, predator-prey interactions, biological oceanography, research vessels.

EDUCATION AND EMPLOYMENT:

2003-Present Research Fishery Biologist, Alaska Fisheries Science Center. Research related to acoustic surveys in the North Pacific.

2001-2003 National Research Council Postdoctoral Fellow, Northwest Fisheries Science Center. Project title: Feeding ecology of juvenile salmonids in turbid environments. Adviser: Richard D. Brodeur

1995-2001 Ph.D. Biological Oceanography, Scripps Institution of Oceanography. Dissertation: Small-scale spatial distribution and swimming behavior of euphausiids in relation to visual predation risk. Adviser: Mark D. Ohman.

1995 BS Biology University of California Los Angeles. College Honors.

TEN RELEVANT PUBLICATIONS:

De Robertis, A., McKelvey, D., and Ressler, P.H. (in review) Development and application of empirical multi-frequency methods for backscatter classification. Canadian Journal of Fisheries and Aquatic Sciences.

Rooper, C. N., Hoff, G. R., and De Robertis, A. (in review) Assessing habitat utilization and rockfish biomass in an isolated rocky ridge using acoustics and stereo image analysis. Canadian Journal of Fisheries and Aquatic Sciences

Kotwicki, S., De Robertis, A., von Szalay, P., Towler, R. (2009) The effect of light intensity on the availability of walleye pollock (*Theragra chalcogramma*) to bottom trawl and echo-integration trawl surveys in the Eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences, 6:983-994

De Robertis A, Hjellvik V, Williamson NJ, Wilson CD (2008) Silent ships do not always encounter more fish: comparison of acoustic backscatter recorded by a noise-reduced and a conventional research vessel. ICES J. of Mar. Sci. 65: 623-635

De Robertis, A, Morgan, C. A., Schabetsberger, R. A, Zabel, R. A., Brodeur, R. D., Emmett, R. L., Knight, C. M., Krutzikowsky, G. K., and Casillas, E. (2005) Columbia River plume fronts: II Distribution, abundance and feeding ecology of juvenile salmon. Mar. Ecol. Prog. Ser. 299:33-44.

Morgan C. A., De Robertis A., and Zabel R.W. (2005) Columbia River plume fronts: I Hydrography, zooplankton distribution, and community composition. Mar. Ecol. Prog. Ser. 299:19-31

De Robertis, A., Ryer, C. H., Veloza, A., and Brodeur, R. D. (2003). Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Can. J. Fish. Aquat. Sci. 60:1517-1526.

Gómez-Gutiérrez, J., Peterson, W. T., De Robertis, A., and Brodeur, R. D. (2003). Massive mortality of euphausiids caused by apostome ciliates. Science. 301: 339.

De Robertis, A. 2002. Small-scale spatial distribution of the euphausiid *Euphausia pacifica* and overlap with planktivorous fish. J. of Plank. Res. 24: 1207-1220.

De Robertis, A. 2002. Size-dependent visual predation risk and the timing of vertical migration: An optimization model. Limnol. Oceanogr. 47: 925-933.

De Robertis, A., Eaine, K., and Rau, G. H., 2001. Eat and run: anoxic feeding and subsequent aerobic recovery by *Orchomene obtusus* in Saanich Inlet, British Columbia, Canada. Mar. Ecol. Prog. Ser. 219: 221-227.

COLLABORATORS WITHIN LAST 4 YEARS:

Chris Wilson, NOAA/AFSC
Paul Wade NOAA/AFSC
Neal Williamson, NOAA/AFSC
Stan Kotwicki, NOAA/AFSC
Patrick Ressler NOAA/AFSC
Ian Higginbottom, Sonardata
Vidar Hjellvik, Institute of Marine Research
Nils Olav Handegard, Institute of marine Research

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Professional Preparation

Dalhousie University	Marine Biology	B.Sc. (Honours), 1985
Dalhousie University	Fisheries Ecology	M.Sc., 1988
Memorial University of Newfoundland	Fisheries Ecology	Ph.D, 1995
SUNY Buffalo State College	Fisheries Acoustics	Post Doc, 1995-1997

Appointments

2008- Associate Professor -- University of Washington, School of Aquatic and Fishery Sciences. Affiliated with the Quantitative Ecology and Resource Management Program.

2004-2008 Research Associate Professor -- University of Washington, School of Aquatic and Fishery Sciences. Affiliated with the Quantitative Ecology and Resource Management Program.

2001-2004 Research Assistant Professor – University of Washington, School of Aquatic and Fishery Sciences. Affiliated with the Quantitative Ecology and Resource Management Program.

1999-2000 Research Scientist – NOAA Alaska Fisheries Science Center and University of Washington, Joint Institute for the Study of the Atmosphere and Ocean.

1997-1999 Research Scientist - NOAA Great Lakes Environmental Research Laboratory. Adjunct Assistant Professor - School of Natural Resources and Environment and College of Engineering, University of Michigan.

1996-1997 Adjunct Assistant Professor - Geography and National Center for Geographic Information and Analysis. State University of New York, University at Buffalo.

Relevant Publications

Gregg, M.C. and J.K. Horne. 2009. Turbulence, acoustic backscatter, and pelagic nekton in Monterey Bay. Journal of Physical Oceanography 39: 1097-1114.

Horne, J.K. 2008. Acoustic ontogeny of teleost fish. Journal of Fish Biology 73: 1444-1463.

Burgos, J.M. and J.K. Horne. 2008. Acoustic characterization and classification of pelagic organisms distributions. ICES Journal of Marine Science 65: 1235-1247.

Horne, J.K. and P.D. Walline. 2005. Spatial and temporal variance of walleye pollock in the Eastern Bering Sea. Canadian Journal of Aquatic and Fishery Science 62: 2822-2831.

Horne, J.K. 2000. Acoustic approaches to remote species identification: a review. Fisheries Oceanography 9: 356-371.

Other Publications

Horne, J.K., Sawada, K., Abe, K., Kreisberg, R., Barbee, D., and Sadayasu, K Swimbladders under pressure: anatomical and acoustic responses by walleye pollock. ICES Journal of Marine Science 66: 1162-1168.

Henderson, M.J., Horne, J.K. and R.H. Towler. 2008. The influence of beam position and swimming direction on fish target strength. ICES Journal of Marine Science 65: 226-237.

Burgos, J.M. and J.K. Horne. 2007. Sensitivity analysis and parameter selection for detecting aggregations in acoustic data. ICES Journal of Marine Science 64: 160-168.

Horne, J.K. and J.M. Jech. 2005. Models, measures, and visualizations of fish backscatter. *In* H. Medwin [ed.]. Sounds in the Seas: Introduction to Acoustical Oceanography. pp. 374-397. Academic, New York.

Gauthier, S. and J.K. Horne. 2004. Acoustic characteristics of forage fish species in the Gulf of Alaska and Bering Sea. Canadian Journal of Aquatic and Fishery Science 61: 1839-1850.

Synergistic Activities

Member of Acoustical Oceanography Technical Committee, Acoustical Society of America.

Member of Scientific Organization Committee, ICES Symposium on the Ecosystem Approach with Fisheries Acoustics and Complementary Technologies (SEAFACTS, ICES).

Organizer of Acostic Backscatter Modeling Workshop, National Ocean Partnership Program.

Member of Science and Technology Advisory Committee (STAC), Ocean Observatories, National Science Foundation (ORION, NSF).

Founder and coordinator of the NOAA Alaska Fisheries Science Center and University of Washington, School of Aquatic and Fishery Sciences Undergraduate Summer Intern Program.

Collaborators & Other Affiliations

Whitlow L. Au	University of Hawaii
John K.B. Ford	Department of Fisheries and Oceans, Canada
Stephane Gauthier	NIWA, New Zealand
Michael Gregg	University of Washington
Sarah Hinckley	NOAA Alaska Fisheries Science Center
J. Michael Jech	NOAA Northeast Fisheries Science Center
Rudy J. Kloser	CSIRO, Australia
Sandra Parker-Stetter	University of Washington
Kouchi Sawada	NRIFE, Japan
Richard Towler	NOAA Alaska Fisheries Science Center
Paul D. Walline	NOAA Alaska Fisheries Science Center

Graduate Advisors and Postdoctoral Sponsors

Stephen B. Brandt	NOAA Great Lakes Environmental Research Laboratory
David C. Schneider	Memorial University of Newfoundland
Steven E. Campana	Department of Fisheries and Oceans, Canada

Graduate Thesis Advisor (total: 15) and Postgraduate-Scholar Sponsor (total: 6)

Patrick Adam	University of Washington
Elizabeth Atwood	University of Washington
Stephen Barbeaux	University of Washington
Julian Burgos	University of Washington
Elliott Hazen	University of Washington
Mark Henderson	University of Washington
Patrick Nealson	University of Washington
Sam Urmy	University of Washington
Cairistiona Anderson	University of Washington
Carlos Alvarez-Flores	Univeristy of Washington
Stephane Gauthier	University of Washington
Carolina Parada	University of Washington
Sandra Parker-Stetter	University of Washington
Tracey Smart	University of Washington

Olav Aleksander Ormseth
Alaska Fisheries Science Center, National Marine Fisheries Service
7600 Sand Point Way NE, Seattle, WA * 206-526-4242* olav.ormseth@noaa.gov

Current position and relevant activities

Research Fisheries Biologist, Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA, 2007- present. Lead scientist for non-target species and assessment scientist for GOA and BSAI forage fishes, squids, and skates. Currently engaged in research on nearshore fish distribution, GOA eulachon biology, electronic and conventional tagging, and development of fish sampling gear.

Education

Ph.D., Fisheries Oceanography, University of Alaska Fairbanks, Fairbanks, AK, December 2007
Dissertation: Reproductive potential of Pacific cod in Alaska

M.S., Wildlife Biology, University of Alaska Fairbanks, Fairbanks, AK, August 1997
Thesis: The role of leptin hormone in the regulation of seasonal body weight in the arctic ground squirrel

B.A., Biology, Bates College, Lewiston, ME, May 1991, Minor in German
Junior Year Abroad, Luwig-Maximiliens Universitaet, Munich, Germany, 1989-1990.

Past positions

Instructor in Marine Biology, Alaska Pacific University, Anchorage Alaska, 2006. Taught two courses in marine biology and fisheries.

Research fellow, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 2001-2006 (Ph.D. research)

Lead Project Technician, Institute of Arctic Biology, UAF, Fairbanks, AK, 1998-2000
Collaborated in design and implementation of research on river otters at the Alaska Sealife Center, Seward, AK.

Fisheries Technician II, Alaska Dept. of Fish & Game, Fairbanks, AK, 1999

Wildlife Technician II, AK Dept. of Fish & Game, Soldotna, AK, 1997

M.S. research, Institute of Arctic Biology, UAF, Fairbanks, AK, 1995-1997
Designed and conducted research projects on the physiology and molecular biology of hibernation in field and laboratory settings.

Relevant refereed publications

Ormseth OA and BL Norcross (2009) Causes and consequences of life-history variation in North American Pacific cod stocks. *ICES Journal of Marine Science* 66: 349-357

Ormseth OA, Buck CL, and Norcross BL. *In preparation*. Proximate, lipid class, and free amino acid composition of Pacific cod eggs. For submission to Marine Biology.

Ormseth OA, Buck CL, and Norcross BL. *In preparation*. Influence of geographic area and maternal attributes on the lipid and fatty acid composition of Pacific cod eggs. For submission to Canadian Journal of Fisheries and Aquatic Sciences.

Ormseth OA and M Ben-David (2000) Ingestion of crude oil: effects on digesta retention times and nutrient uptake in captive river otters. *Journal of Comparative Physiology B* 170(5/6): 419-428

Ben-David M, TM Williams, and OA Ormseth (2000) Effects of oil ingestion on exercise physiology and diving behavior in river otters: a controlled study. *Canadian Journal of Zoology* 78(8): 1380-1390

Relevant reports

Stock assessment and fishery evaluation reports for BSAI squids, BSAI skates, GOA squids, GOA skates, and GOA forage fish. North Pacific Fishery Management Council, December 2008

Stock assessment and fishery evaluation reports for BSAI squids, BSAI skates, GOA squids, GOA skates, and GOA forage fish. North Pacific Fishery Management Council, December 2007

Field Experience

Multiple research cruises in the Gulf of Alaska and Bering Sea, including a 2-week nearshore survey in northern Bristol Bay in summer 2009. Chief scientist on 2 cruises.

Commercial salmon fisherman, Prince William Sound and Bristol Bay, Alaska, 2000-2006.

Recent grants

National Marine Fisheries Service Essential Fish Habitat. “Utilization of nearshore habitat by fishes in Nushagak and Togiak Bays (Bristol Bay)”, 2009. $68,000

NMFS National Cooperative Research Funds. “Pacific cod large-scale movement: testing feasibility of using archival light sensor tags to determine geolocation”, 2009, $58,000

Collaborator on two projects funded by the North Pacific Research Board (618, 808), 2006-2009

National Marine Fisheries Service/Cooperative Institute for Arctic Research. “Reproductive potential of Pacific cod”, 2001-2007, $150,000

Awards and Scholarships

Best Poster, 11th Annual North Pacific Marine Science Organization (PICES) meeting, Qingdao, China, 2002

Rasmuson Fisheries Science Center Graduate Fellowship, 2002-2006

Honor Society of Phi Kappa Phi, member since 1997

Collaborators

C. Loren Buck, UAA; Liz Conners, NMFS/AFSC; Nicola Hillgruber, UAF/SFOS; Jerry Hoff, NMFS/AFSC; Anne B. Hollowed, NMFS/AFSC; Scott Johnson, NMFS/AFSC; Libby Logerwell, NMFS/AFSC; Susanne McDermott, NMFS/AFSC; Peter Munro, NMFS/AFSC; Sandi Neidetcher, NMFS/AFSC; Brenda L. Norcross, UAF/SFOS; Dan Urban, NMFS/AFSC

Shiway W. Wang

Research Biologist
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E-mail: sedna.ecological@gmail.com

Education
M.S. 2005 Marine Biology, University of Alaska Fairbanks
B.S. 1996 Chemical Engineering, University of Colorado Boulder

Professional Experience

2009 – present	*Research Biologist and Owner*, Sedna Ecological, Inc.
2007 – 2009	*Research Associate*, Eider Program, Alaska SeaLife Center
2006 – 2008	*Fishery Biologist*, U.S. Geological Survey/Alaska Science Center
2006	*Research Professional 3*, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks
2005	*Graduate Teaching Assistant*, Department of Biology & Wildlife, University of Alaska Fairbanks
2005	*Research Professional 1*, Department of Biology & Wildlife, University of Alaska Fairbanks
2003 – 2005	*Graduate Student Trainee*, U.S. Geological Survey/Alaska Science Center
1998 – 2002	*Field Biologist/Technician and Research Lab Assistant*, Various Employers (USFWS, USGS, NOAA/NMFS, Point Reyes Bird Observatory, University of Washington)

Publications

Wang SW, Hollmén TE, Iverson SJ (2009) Validating quantitative fatty acid signature analysis to estimate diets of spectacled and Steller's eiders (*Somateria fischeri* and *Polysticta stelleri*). Journal of Comparative Physiology B. DOI 10.1007/s00360-009-0393-x

Wang SW, Iverson SJ, Springer AM, Hatch SA (2009) Spatial and temporal diet segregation in northern fulmars (*Fulmarus glacialis*) breeding in Alaska: insights from fatty acid signatures. Marine Ecology Progress Series 377:299-307. DOI 10.3354/meps07863

Wang SW, Iverson SJ, Springer AM, Hatch SA (2007) Fatty acid signatures of stomach oil and adipose tissue of northern fulmars (*Fulmarus glacialis*) in Alaska: implications for diet analysis. Journal of Comparative Physiology B 177:893-903. DOI 10.1007/s00360-007-0187-y

Meka JM, Zimmerman CE, Heintz RA, **Wang SW** (2007) Body condition and feeding ecology of Kuskokwim River chum salmon (*Oncorhynchus keta*) during freshwater outmigration. Report submitted to Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative, Anchorage, AK. 61pp

Federer RN, Hollmén TE, Esler D, Wooller MJ, **Wang SW**. Stable carbon and nitrogen isotope fractionation factors from diet to cellular blood, blood plasma, feathers, and adipose tissue in spectacled eiders (*Somateria fischeri*). In prep for Canadian Journal of Zoology

Current Activities
Studying diets in threatened eiders using stable carbon isotopes of specific fatty acids: validation of a new technique with controlled feeding experiments. NPRB Project 912.

Field Experience
30+ months on remote islands in Alaska, Antarctica, California, and Hawaii conducting seabird population monitoring, censuses on marine mammals, collecting tissue samples (blood, fat, feathers, feces, stomach oil) from marine birds for various analyses.

8 at-sea surveys in Alaska assisting with mid-water and bottom trawls, beach seines, plankton tows and CTDs.

Lab Experience
Lipid extraction, transesterification, and thin layer chromatography for fatty acid analysis
Radioimmunoassay analysis
Otolith microchemical analysis prep

Professional activities

2006 – 2008	Alaska/Russia Regional Representative, Pacific Seabird Group
2008	National Ocean Science Bowl Volunteer
2004 – 2006	Chair of Silent Auction, 32nd and 33rd Pacific Seabird Group Meetings
2005 – 2006	Local Organizing Committee, 33rd Pacific Seabird Group Meeting
2004 – 2006	Student Representative, Pacific Seabird Group

Professional memberships
American Ornithologists' Union, Pacific Seabird Group, Society of Integrative and Comparative Biology

Certifications
Wilderness First Aid/CPR, Motorboat Operator Certification Course, Hazardous Materials Transportation, Bear Safety, Firearms Training

Collaborators in last 5 years
Loren Buck (UAA), Sue Budge (Dalhousie University), Paul Flint (USGS), Karen Foster (University of Ottawa), Scott Hatch (USGS), Tuula Hollmén (ASLC, UAF), Sara Iverson (Dalhousie University), Sasha Kitaysky (UAF), Jim Lovvorn (University of Wyoming), Margaret Petersen (USGS), Alan Springer (ASLC, UAF), Matthew Wooller (UAF)