

## **Functional Foraging Response, O2.16**

### **Contact Information**

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### **Summary**

As a component of the Bering Sea Integrated Ecosystem Research Program (BSIERP), this project will provide biological and physical data on the food habits of groundfish relative to predator and prey fields. This information will be used to evaluate whether competition for common prey or predator avoidance influences the spatial and temporal distribution of forage fish. Understanding these processes will provide the information needed to parameterize models to assess the potential impact of climate change on forage fish movement and seasonal distribution.

**This project is one component of the Bering Sea Integrated Ecosystem Research Program (BSIERP). The integrated program hypotheses and projects are listed in Tables 1 and 2.**

### **Species and Geographic Scope**

This project examines the food habits of pollock, Pacific cod, arrowtooth flounder and other forage species within the southeastern Bering Sea.

### **Hypotheses**

This project addresses BSIERP hypotheses: 1b, 2b, 3a, and 3c (Table 2).

### **Project Description**

This proposal is strongly linked to projects surface trawl survey (O2.23), bottom trawl survey (O2.25), acoustic survey (O2.26), surface trawl survey acoustics (O2.28) and forage distribution and ocean conditions (O2.17). The projects provide platforms for seasonal diet information and the relative abundance of prey (euphausiids). The core focal species for this project will be Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*, (hereafter referred to as pollock), gadoid forage fish (juvenile pollock and cod), non-gadoid forage fish (capelin, *Mallotus villosus* and Pacific herring, *Clupea pallasii*), and arrowtooth flounder (*Atheresthes stomias*).

It is not clear if summer distributions of pollock are driven by environmental gradients or prey availability. **This project is aimed at distinguishing between temperature related and prey density related responses of juvenile and adult pollock.** Summer euphausiid distributions will be derived based on analysis of multi-frequency acoustic survey data (O2.17) using datasets collected in 2004, 2006, 2008, 2009 and 2010. We will provide new information on: fish diet, fish condition and energy content. In addition we will examine the energy content of mesoplankton prey collected seasonally. These data will contribute to the development of our conceptual model describing forage fish survival.

Predator/prey interactions are a key component of the hypotheses governing the IERP. Hypothesis 2c directly examines the effects of climate-ocean conditions on predator/prey interactions as does Hypothesis 3. However there are little data describing seasonal shifts in diet for juvenile and adult fish in the Bering Sea. For example, the Trophic Ecology Laboratory of the Alaska Fisheries Science Center has collected and analyzed over 250,000 stomachs from the Bering Sea since 1982, but relatively few of these data were collected outside of summer. Consequently, application of these data to modeling efforts necessarily assumes that diet does not change seasonally. An additional difficulty with these data has been in measuring functional responses between predator density and prey density, as estimates of predator and prey biomass have rarely been taken simultaneously, due to gear differences associated with capturing

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each trophic level. Understanding the functional response of fish to their prey is essential to understanding how populations will change as ocean conditions modify prey fields.

We propose to collect and analyze stomach contents of fish collected on surveys designed to assess the densities of several trophic levels simultaneously. For example, the acoustic survey (O2.26) will measure the abundance of euphausiids and their predators (e.g., pollock). This allows examination of the functional response of these predators to euphausiid abundance and energetic quality. They will also relate those responses to simultaneously observed oceanographic conditions and observed spatial distributions. The shapes of the functional responses will be determined by relating predator and prey abundances. These shapes will subsequently be used to refine the models described in the Linked Models Integrated Project.

### **Project Reporting**

**Research Products:** Diets and functional foraging responses (relationship between diet and prey availability) of pollock, cod, arrowtooth flounder and salmon. These data will be reported as maps, graphs and data files of diet composition by area from the surface trawl, acoustic and bottom trawl surveys and of diet and consumption and evacuation rates for selected forage species. These research products also will serve as input to the integrated modeling.

**Research Links:** This project depends on data collection platforms during the acoustic survey (O2.26), surface trawl survey (O2.23) with acoustics (O2.28), and the bottom trawl survey (O2.25). This project will collaborate with pollock and cod distribution (O2.19) and forage distribution and ocean conditions (O2.17) projects and provide data necessary for the integrated modeling.

**Research Reporting:** Deliverables include semi-annual reports (due January 15 and July 15 each year), the final project report and delivering field data to the modeling group due January 15 each year. Diet analyses will be completed within one year following data collection. Analyses for estimation of functional foraging responses will be completed during the spring of 2011.

**Dissemination:** Deliverables include semi-annual reports (due January 15 and July 15 each year), the final project report and delivering field data to the modeling group due January 15 each year. Tentative manuscripts are "Functional foraging responses of groundfish and salmon in the Eastern Bering Sea" by K. Aydin and E. Farley and one or more collaborative papers with other projects.

**Graduate Students and Post-docs:** None.

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Table 1. Project list.

Project	Project Components	Label	Principal Investigators	NPRB (\$)	In-kind (\$)
<b>Lower trophic level</b>	Biophysical moorings (4)	O1.1	Stabeno, Whitledge, Napp	\$ 732,259	\$ 1,707,106
<b>Ichthyoplankton</b>	Ichthyoplankton surveys	O2.7	Hillgruber, Duffy-Anderson, Napp, Matarese, Eisner	\$ 1,068,052	\$ 1,245,612
	Seasonal bioenergetics	O2.24	Heintz	\$ 250,000	\$ 373,400
<b>Fish</b>	Acoustic survey	O2.26	Wilson	\$ 154,499	\$ 2,349,000
	Surface trawl survey	O2.23	Farley	\$ -	\$ 1,516,200
	Surface trawl survey acoustics	O2.28	Horne, Parker-Stetter, Farley	\$ 425,731	\$ -
	Bottom trawl survey (epi-benthic)	O2.25	Lauth	\$ -	\$ 3,240,000
	Pollock & cod distribution	O2.19	Ciannelli, Bailey	\$ 332,313	\$ -
	Functional foraging response	O2.16	Aydin, Farley	\$ 258,260	\$ 23,040
	Forage distribution & ocean conditions	O2.17	Hollowed, Wilson, Kotwicki, DeRobertis, Ressler, Cokelet	\$ 567,123	\$ 553,311
<b>Trophic interactions</b>	Fish, birds & mammals	O3.30	Mueter, Kruse	\$ 286,913	\$ -
	Hot spot persistence	O4.40	Sigler, Kuletz, Wilson	\$ -	\$ 55,200
<b>Seabirds</b>	Seabird telemetry	O4.35	Irons, Byrd, Roby	\$ 600,000	\$ 303,000
	Seabird broad-scale distribution	O4.36	Kuletz	\$ 550,438	\$ 555,000
	Seabird colony-based	O4.37	Byrd	\$ 350,000	\$ 1,179,000
<b>Patch</b>	Patch Dynamics	O4.62	Trites, Jay, Grebmeier, Benoit-Byrd, Heppell, Sampson, Irons, Byrd, Roby, Kytasky, Kuletz	\$ 2,300,000	
<b>Marine mammals</b>	Whale broad-scale distribution	O4.38	Friday, Moore, Zerbini, Clapham	\$ 300,000	\$ -
	Fur Seal colony-based		Ream	\$ -	\$ -
<b>Local and Traditional Knowledge</b>	Local & traditional knowledge	O5.41	Sepez, Hunn, Huntington, Langdon, Zavadil, Fall	\$ 1,000,000	\$ 49,190
<b>Modeling</b>			to be determined	\$ 2,500,000	
	<i>potential</i>		<i>potential</i>		
	Forage euphausiid (FEAST)	M.47	Aydin		
	Behavioral foraging	M.54	Mangel		
	Biomass dynamics	M.61	Mueter, Kruse		
	Integrate economic-ecological	M.48	Dalton, Aydin, Haynie		
	Spatial fishery choices	M.49	Haynie		
	Management strategy resilience	M.50	Criddle, Valcic, Greenberg		
Blended forecasts, Management strategy evaluation	M.55	Punt			
<b>Education and Outreach</b>			Deans (NPRB)	\$ 100,000	
<b>Data Management</b>	Data Management		Coyle	\$ 800,000	
<b>Program Management</b>			NPRB	\$ 600,000	
<b>Total</b>				<b>\$ 13,175,588</b>	<b>\$ 13,149,059</b>

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Table 2. BSIERP hypotheses: Climate models predict warming over the next 30 years (IPCC 2007). Predictions from climate models show no indication of a strengthening of summer winds. In fact, there has been a decrease in wind strength and lengthening of summer conditions over the last decade (Overland and Stabeno 2004; Stabeno and Overland 2001). Projected warming on the southeastern shelf of the Bering Sea will profoundly alter ecosystem structure by changing pathways of energy flow and the spatial distribution and species composition of fish, seabird and marine mammal communities, thereby affecting commercial and subsistence fisheries.

1. Climate-induced changes in physical forcing will modify the availability and partitioning of food for all trophic levels through bottom-up processes. Specifically:
  - a. Earlier sea ice retreat expected as a result of warming will result in a later (May-June), warm-water spring phytoplankton bloom, increased coupling with zooplankton and greater pelagic secondary productivity. Benthic secondary productivity will decrease.
  - b. Reduced frequency and intensity of summer storms will reduce surface mixing and increase sea surface temperature, thereby increasing stratification. A substantial decrease in summer winds will result in a mixed layer that is shallower than the euphotic zone, extensive subsurface primary production and depletion of nutrients in the entire water column. There will be no fall phytoplankton bloom. A moderate decrease or no change in the intensity of summer storms will reduce replenishment of nutrients to the euphotic zone, lowering summer primary and secondary production. Both scenarios will reduce juvenile fish production by reducing their condition (energy density) and over-wintering capability.
  - c. Earlier spring transition will lengthen the period of time of organized onshore flow along the Alaska Peninsula, thus transporting larvae away from outer domain piscivores.
2. Climate and ocean conditions influencing water temperature, circulation patterns and domain boundaries impact fish reproduction, survival and distribution, the intensity of predator-prey relationships and the location of zoogeographic provinces through bottom-up processes. Specifically:
  - a. As heat content increases, the area suitable for spawning and foraging by subarctic species will expand northward and subarctic species will occupy areas formerly occupied by Arctic species.
  - b. Reduced cold pool extent will increase overlap of inner domain forage fish and outer domain piscivores.
  - c. Strength of frontal boundaries will weaken due to absence of the summer cold pool, allowing expansion of the inner domain and juvenile and forage fish habitat there. Weaker winds will enhance this effect.
  - d. Sporadic reversals to cold conditions (e.g., 1999) will have strong effects on the subarctic community and result in increased interannual variability in abundance and pelagic productivity of piscivorous fish, seabirds and marine mammals.
  - e. Expected decreases in benthic productivity will negatively affect feeding and survival of small flatfish and crab thereby lowering population levels.
3. Later spring phytoplankton blooms as a result of early ice retreat will increase zooplankton production, thereby resulting in increased abundances of piscivorous fish (pollock, cod and arrowtooth flounder) and a community controlled by top-down processes [Oscillating Control Hypothesis] with the possible trophic consequences:
  - a. Competition with abundant, piscivorous fish species for forage species will lead to a decline in murre, kittiwakes and fur seals.
  - b. Growing populations of humpback and fin whales increasingly will both consume and compete with forage fish (juvenile pollock) for zooplankton (euphausiids and copepods). By reducing the prey base of forage fish, whales not only reduce the amount of forage fish available to other predators, but also their quality (lipid content).
  - c. In a top-down control community, fishing will reduce the degree of top-down control of forage species (including juvenile pollock) by adult pollock, cod and arrowtooth flounder. Owing to light exploitation rates, top-down control by arrowtooth flounder will increase, as will their level

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- of competition with piscivorous fish, seabirds and marine mammals. As a result of these two processes, arrowtooth flounder will determine ultimate community composition, such that the climax community will be arrowtooth flounder-dominated (similar to the Gulf of Alaska).
4. Climate and ocean conditions influencing circulation patterns and domain boundaries will affect the distribution, frequency and persistence of fronts and other prey-concentrating features and thus the foraging success of marine birds and mammals largely through bottom-up processes. Specifically:
    - a. Climate-ocean changes will displace predictably located, abundant prey (hot spots) necessary for successful foraging by central place (seabirds and fur seals while nurturing young) and hot spot (baleen whales, walrus) foragers.
    - b. Central place foragers will shift their diet, foraging locations or rookery locations to increase foraging opportunities (based on differential foraging success).
  5. Climate-ocean conditions will change and thus affect the abundance and distribution of commercial and subsistence fisheries. Specifically:
    - a. For commercial fishermen, these changes will lead to: 1) a change in home ports and distribution of fishing vessel rents, 2) vessels traveling further, incurring greater fuel costs and peril at sea and 3) greater burden on smaller vessels.
    - b. For subsistence users, these changes will lead to: 1) greater reliance on owners of larger vessels that can travel farther to harvest and distribute subsistence goods, 2) decreased consumption of species with decreased local abundance and 3) adoption of new species into the diet as these species colonize local areas.
    - c. Current management strategies for fish, seabirds and marine mammals in the Bering Sea are robust to climate scenarios (range of frequencies of cold and warm years) and associated range of trophic relationships and spatial redistributions.