

BSIERP Project O2.19, Wintertime cod, pollock and arrowtooth flounder distribution

Project Title: O2.19: Wintertime cod, pollock and arrowtooth flounder distribution

Contact Information

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Summary

As a component of the Bering Sea Integrated Ecosystem Research Program (BSIERP) (Table 1), this project will conduct a retrospective analysis of ichthyoplankton catches of pollock, cod, and arrowtooth flounder and wintertime fisheries data to create species spawning distribution models.

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.

Background

Spawning timing and distribution set the initial conditions for a series of events that eventually lead to year class strength. The timing and locations of spawning can affect recruitment variability of marine pelagic and demersal fish species through a variety of processes, including egg and larval drift to favorable nursery areas. Physical and biological factors present at the spawning locations affect egg buoyancy and first feeding larval nutrition. The spawning locations of cod, pollock and arrowtooth flounder in the Bering Sea are poorly identified. As a consequence we are not aware of how the important early life processes mentioned above can influence the recruitment success of these species in the Bering Sea. We are also not aware of whether changes in spawning distribution have occurred during the last several decades and their potential effects on year class variability. This information also is critical for developing Individual Based Models (IBMs).

Species and Geographic Scope

This project examines pollock, cod and arrowtooth flounder within the southeastern Bering Sea.

Hypotheses

This project addresses BSIERP hypotheses: 2a, 2b, 2d (Tables 2 and 3).

Project Description

We will combine retrospective analysis of ichthyoplankton distributions with historical wintertime fisheries data to examine the relationship of spawning time and location to fixed and labile landscape and environmental features. These analyses will be used to create species spawning distribution models (SSDMs) using nonlinear regressions analysis (i.e., GAMs). Field data collections incorporating spatially and temporally referenced maturity data collected by observers, roe quality data collected from the commercial fisheries records, and temperature-at-depth collected by commercial fishing vessel net sensors will be assimilated in the models. We propose to back-track larvae to their spawning locations using ocean current models. We will use the results of the project to evaluate the alternative hypotheses that there is environmental flexibility in gadid spawning locations versus fixed sites, or whether there are species or stock-related differences in this spawning strategy.

A preliminary and parallel effort will be dedicated to examine the spawning distribution of arrowtooth flounder and Bering flounder combined. Historical foreign fisheries catches report offshore flounders and the current ichthyoplankton identification techniques are not able to distinguish eggs and larvae of the two species. With successful separation of the species using molecular techniques in Project O2.7, we may make progress in characterizing the spawning distributions of the individual species.

Project Reporting

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Research Products: Scientific papers, bi-annual progress reports and presentation of research results at international meetings.

Research Links: This project is linked to the Ichthyoplankton project O2.7 and we will work together to backtrack the origin of eggs and larvae. We will also depend of the results of O2.7 to identify eggs and larvae of arrowtooth flounder. We are integrated into the Fish project with an overall objective of clarifying the seasonal movements of fish. This work is also integrated with NPRB projects involving tagging and movements of cod, and summertime species distribution models of flatfishes. Results of the project will be integral to modeling efforts that require information on the spawning locations of cod, pollock and arrowtooth flounder.

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 (Table 4).

Dissemination: titles of three potential papers:

- 1) Spawning locations of cod and pollock in the Southeast Bering Sea
- 2) Early life drift pathways of cod, pollock
- 3) Early life drift pathways of arrowtooth flounder and Greenland halibut

Graduate Students and Post-docs: 1 post-doc (2 years starting 2008)

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Figures and Tables

Table 1. Project list.

Project	Project Components	Label	Principal Investigators	NPRB (\$)	In-kind (\$)
Lower trophic level	Biophysical moorings (4)	O1.1	Stabeno, Whitledge, Napp	\$ 732,259	\$ 1,707,106
Ichthyoplankton	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
Fish	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
Trophic interactions	Forage distribution & ocean conditions	O2.17	Hollowed, Wilson, Kotwicki, DeRobertis, Ressler, Cokelet	\$ 567,123	\$ 553,311
	Fish, birds & mammals	O3.30	Mueter, Kruse	\$ 286,913	\$ -
Seabirds	Hot spot persistence	O4.40	Sigler, Kuletz, Wilson	\$ -	\$ 55,200
	Seabird telemetry	O4.35	Irons, Byrd, Roby	\$ 600,000	\$ 303,000
	Seabird broad-scale distribution	O4.36	Kuletz	\$ 550,438	\$ 555,000
Patch	Seabird colony-based	O4.37	Byrd	\$ 350,000	\$ 1,179,000
	Patch Dynamics	O4.62	Trites, Jay, Grebmeier, Benoit-Byrd, Heppell, Sampson, Irons, Byrd, Roby, Kytasky, Kuletz	\$ 2,300,000	
Marine mammals	Whale broad-scale distribution	O4.38	Friday, Moore, Zerbini, Clapham	\$ 300,000	\$ -
	Fur Seal colony-based		Ream	\$ -	\$ -
Local and Traditional Knowledge	Local & traditional knowledge	O5.41	Sepez, Hunn, Huntington, Langdon, Zavadil, Fall	\$ 1,000,000	\$ 49,190
Modeling			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			
Education and Outreach			Deans (NPRB)	\$ 100,000	
Data Management	Data Management		Coyle	\$ 800,000	
Program Management			NPRB	\$ 600,000	
Total				\$ 13,175,588	\$ 13,149,059

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 of

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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.

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Table 3. Project links to BSIERP hypotheses. The BSIERP hypotheses are numbered 1-5 and are described in the BSIERP study plan.

Projects	Label	1a	1b	1c	2a	2b	2c	2d	2e	3a	3b	3c	4a	4b	5a	5b	5c
Biophysical moorings (4)	O1.1	■	■														
Summer plankton survey	O1.2		■														
Ichthyoplankton	O2.7, O2.24		■	■			■	■									
Fish	O2.26, O2.23, O2.28, O2.25, O2.19, O2.16, O2.17		■	■	■	■		■	■								
Trophic interactions	O3.30					■	■	■	■	■		■	■	■			
Seabirds	O4.35, O4.36, O4.37									■	■	■	■	■			
Patch dynamics	O4.62									■	■	■	■	■			
Marine mammals	O4.38									■	■	■	■	■			
Local and Traditional Knowledge	O5.41, O5.42	■	■	■	■	■	■	■	■	■	■	■	■	■		■	
Lower trophic level modeling	M.3, M.4, M.5	■	■														
Forage euphausiid (FEAST)	M.47			■	■	■	■	■	■	■	■	■	■	■			
Behavioral foraging	M.54									■			■	■			
Biomass dynamics	M.61									■		■					
Economic-ecological spatial	M.48, M.49														■	■	
Management strategy resilience	M.50																■
Blended forecasts, Management strategy evaluation	M.55																■

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Table 4. The proposed timeline for research reporting by quarter is summarized below. Highlighted cells denote quarters when activities occur, x's denote specific deliverables to be completed by the end of the indicated quarter as described below. The schedules for some research activities are generalized; for example, seasonal bioenergetics (O2.24) samples are collected during several surveys (e.g., Spring ichthyoplankton survey) and analyzed in the laboratory (Laboratory analysis activity). Semi-annual reports are due January 15 and July 15 each year.

Research activity or project	2007				2008				2009				2010				2011				2012			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Initial planning meeting																								
Annual meeting																								
Laboratory analyses																								
Data analyses																								
Modeling & retrospective analyses																								
Field data to models																								
Model outputs to fieldwork planning																								
Preparation of manuscripts																								
Synthesis																								
Semi-annual reports																								
Final report																								