Project #: B68

Title: Trophic Interactions - Retrospective analysis

Principal Investigator(s) and Recipient Organization(s):
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$ 95,325

Report Period:
1 April 2009 through 30 September 2009

Report Date:
1 October 2009

Lead Author of Report:
Franz J. Mueter

Proposed timeline and milestones within report period:

The following milestones were scheduled to begin or to be completed within the current report period

1. Complete analyses of covariation and prepare manuscript on covariation & trophic interactions
2. Develop hypotheses and conceptual models for variability in gadid and flatfish productivity (recruitment) and conduct analyses using appropriate indicators.
3. Develop crab hypotheses and conceptual models
4. Manuscript preparation – climate & fish productivity

In addition, new indices that were identified as relevant to the analyses were developed and incorporated into the database.

Project Summary:

The productivity of upper trophic level species in the eastern Bering Sea varies in response to climate variability and human forcing, although the relative contribution of these drivers and the underlying mechanisms remain poorly understood. This retrospective analysis will (1) quantify past patterns of variability and covariation among time series of productivity of selected fish, seabird, and marine mammal species; (2) test whether historical patterns and trends in these series are consistent with existing hypotheses; (3) suggest new hypotheses based on relationships among the productivity of different ecosystem components and relationships between their productivity and observed climate variability; and (4) provide functional forms and parameter estimates (and their uncertainty) that link the productivity of different ecosystem components to climate variability. The analysis will utilize existing data on productivity, including measures of recruitment, survival, and growth or condition, of major upper trophic

level species. Results will contribute to the overall research program in two important ways. First, results will directly support the proposed modeling projects by providing parameters linking the productivity of individual species to climate variability, which is essential for predicting the effects of future climate variability. Second, identified relationships between climate and productivity can be incorporated into existing stock assessment models.

Progress Summary:

With the exception of milestone 4 above, all of the above milestones have been met or work towards meeting these milestones is proceeding as planned. During this reporting period we continued to compile, refine, and document relevant time series (monthly or annual indices) of environmental and biological variability in the eastern Bering Sea as needed for the retrospective analyses. A total of approximately 150 updated indices were delivered to data management in mid-September for posting on the BSIERP webpage. The data are posted in the form of a spreadsheet with a brief description of each index.

We completed the analysis of covariation among fish (walleye pollock, Pacific cod, arrowtooth flounder, yellowfin sole, rock sole, flathead sole), crab (Bristol Bay red king crab, snow crab), seabirds (common & thick-billed murre, red-legged & black-legged kittiwakes) and fur seal productivity (Milestone 1). Previous analyses were updated with seabird data from the 2008 field season and a draft manuscript is in progress (Milestone 1). A multivariate, explanatory analysis of the main patterns of variability in productivity and environmental variability did not suggest any obvious (linear) relationships. In particular, measures of temperature variability accounted for a small proportion of the observed variability in fish, crab, and seabird productivity.

Results from the analysis of productivity trends suggest strong positive and negative patterns of covariation within the fish community (as reported in April), but no significant covariation between recruitment of groundfish stocks and the productivity of seabirds on the Pribilof Islands. There was weak evidence of positive covariation between gadid productivity and (detrended) fur seal pup production. It appears that productivity of seabirds on the Pribilofs is driven by processes unrelated to those driving fish productivity in the eastern Bering Sea. The analysis of seabird trends suggested that trends in productivity are decoupled from trends in abundance. Kittiwakes and murres show very different trends in productivity, but in both cases these trends are very similar between St. Paul and St. George Island (Fig. 1A). In contrast, abundance trends are similar for all species on a given island, but differ markedly between islands (Fig. 1B). These results suggest that processes driving productivity affect seabirds on both islands in very similar ways and that the differences in abundance trends may be driven by migration.

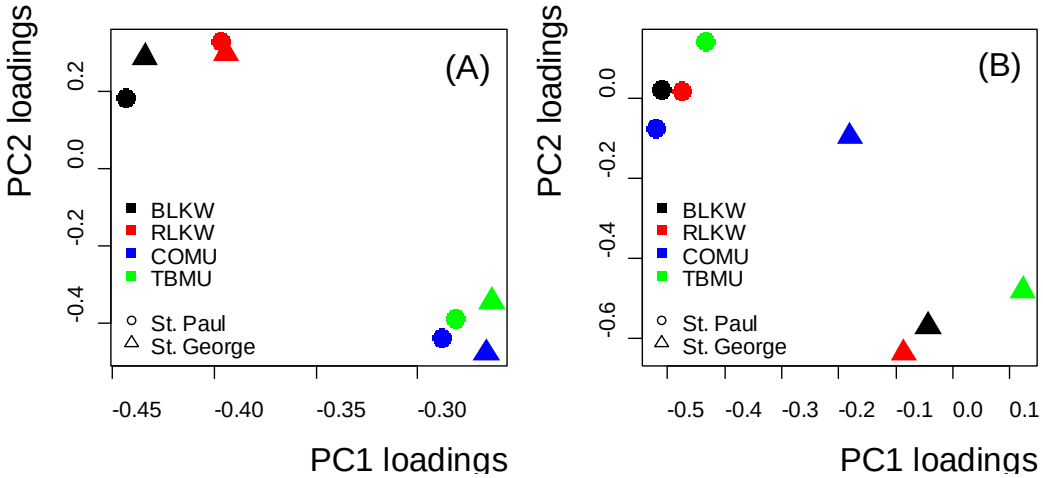

Figure 1: Plot of major principal components of variability in the productivity (A) and abundance (B) of four species of seabirds on two islands. Productivity trends clearly separate kittiwakes from murres (A), whereas abundance trends clearly distinguishes islands (B).

Much of our analyses on factors driving fish (gadid and flatfish) and shellfish productivity in the eastern Bering Sea (Milestone 2), as well as overall ecosystem productivity, focused on three aspects of variability: (1) Variability in the onset of spring, water column stratification, and the spring bloom (2) Variability in the strength of summer stratification, and (3) variability in the spatial distribution of fish and shellfish populations. Here we briefly summarize some of the results with respect to the timing of events in the spring.

There has been a pronounced trend in the timing of water column warming in the spring ("spring transition") and cooling in the fall, which we defined as the first and last day, respectively, when smoothed SSTs, averaged over the eastern Bering Sea shelf, were above 4°C (Fig. 2). The mid-point of the "warm season" has not shifted over time, but the length of the warm season has increased (Figure 1) as evident in significant trends towards both earlier spring transition dates (first day above 4˚C, Linear regression with AR1 errors, t = -3.80, n=108, p <0.0001) and later fall transition dates (last day above 4˚C, Linear regression with AR1 errors, t = 3.82, n=108, p =0.0002).

The earlier onset of summer (SST>4˚C) and a later end date translate into a substantial increase in season length (Figure 2, Linear regression with AR1 errors, t = 4.28, n=108, p <0.001) and in the number of degree-days above 4˚C, which increased from 400-500 in the early part of the century to over 700 in recent years (Figure 3, Linear regression with AR1 errors, t = 4.28, n=108, p <0.001). Such a substantial increase in growing degree days is expected to have important consequences for growth of fish and other marine organisms.

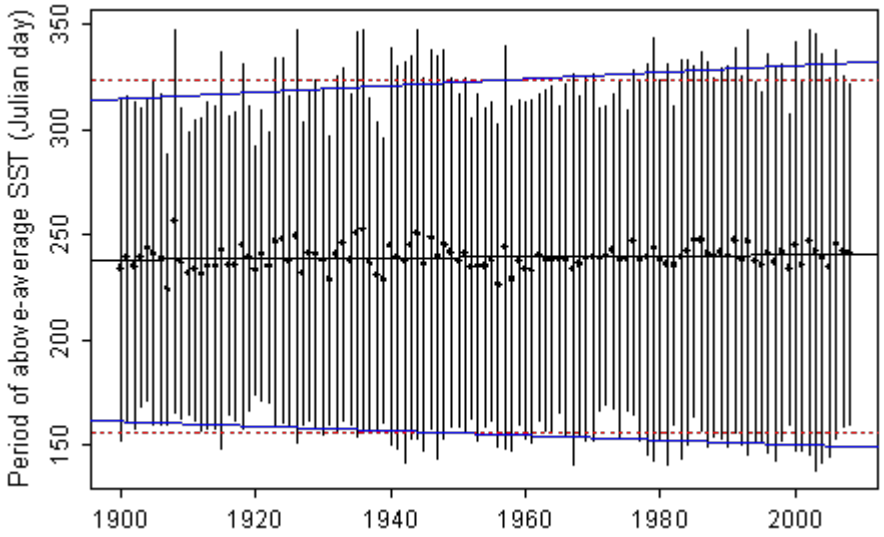

Figure 2: Estimated periods with above 4˚C sea-surface temperatures by year with linear trends (blue lines) for the first and last day of the season when smoothed SST exceeded 4˚C. Red lines denote average begin and end date of above 4˚C period. Dots denote mid-points of range and black line denotes linear trend in mid-points.

Changes in the timing of the 'spring transition' affect the timing of water column stratification, which in turn is strongly related to the onset of the spring bloom on the inner and middle shelf as estimated from SeaWiFS data (Fig. 3). The timing of the spring transition and the onset of the spring bloom are also closely correlated with the mean hatch date of kittiwakes on the Pribilof Islands (r = 0.73, p = 0.038, corrected for autocorrelation).

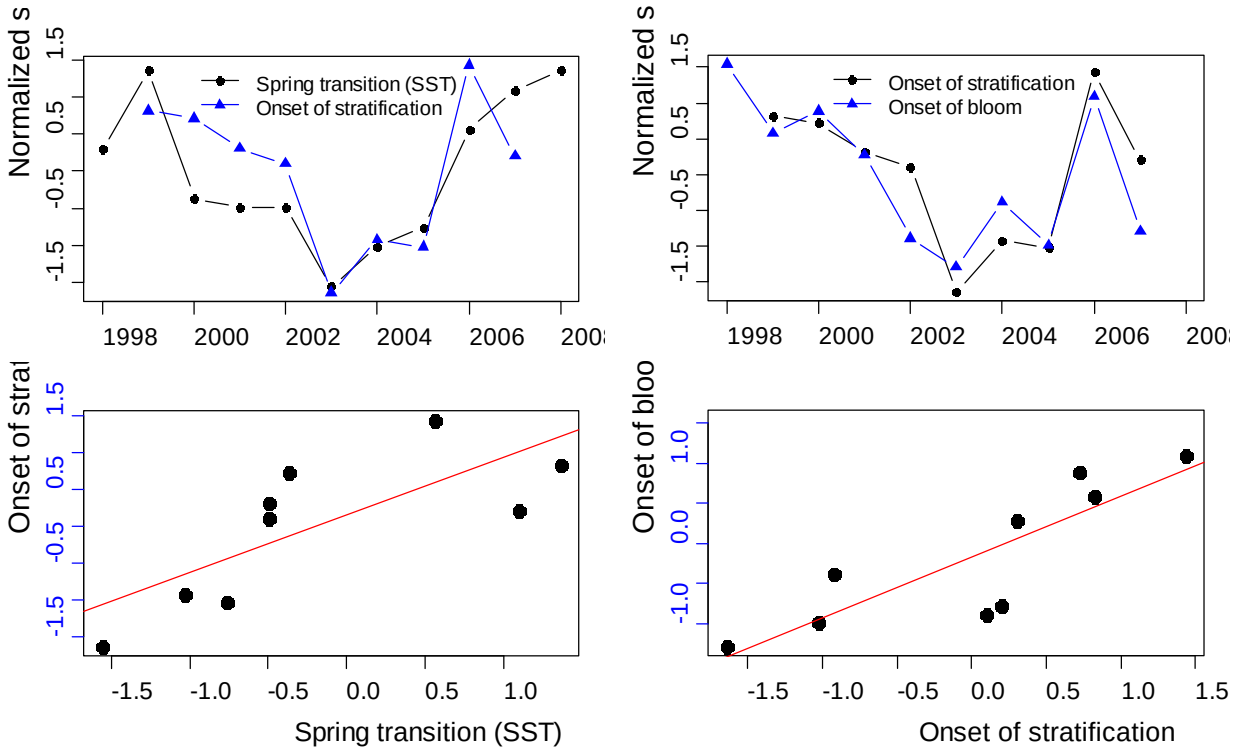

Figure 3: Onset of water column stratification at Mooring 2 relative to "spring transition" in SST (left) and onset of the spring bloom on the middle shelf as estimated from SeaWiFS data relative to onset of stratification.

A manuscript on the impact of variability in timing, summer stratification, spatial shifts in distribution, and other aspects of climate variability such as ice and wind conditions on fish and shellfish populations is in progress (Milestone 4).

Some of the analyses have been delayed due to delays in obtaining suitable indices of stratification. There is increasing evidence from several BSIERP components that strong water column stratification in recent warm years has had important effects on lower trophic level productivity and on the survival of pollock and cod juveniles. While we have estimated stratification on the middle shelf from the available time series of Mooring 2 data (1998-2007), we intend to use a model-based proxy derived from ROMS NEP 5 hindcasts to obtain a much longer time series of the strength of stratification. These analyses will be completed as soon as we obtain ROMS NEP 5 output for the M2 location.

The analysis of climate variability relative to crab productivity (Milestone 3) has not yet begun because much of the analytical effort over the summer was focused on lower trophic level variability and crab were considered a lower priority as they are not focal species of the overall BSIERP project.

<u>Lessons learned and project adjustments</u>:

One lesson learned was that there may be misconceptions among BSIERP PIs that the retrospective analyses will be used in a forecasting sense to predict future responses of fish and shellfish to projected climate variability. While we certainly hope that this will be one of the applications of this work in the future, the proposed work under BSIERP was strictly retrospective in nature to help better understand empirical relationships and provide empirical support for hypothesized mechanisms.

Some adjustments to our timeline were necessary because Dr. Mueter is unable to pursue research in the fall of 2009 due to his teaching load. As a result, some of the tasks have been shifted to spring 2010 as reflected in the revised work plan appended to this report.

Integration activity:

We (Mueter) have participated in most of the monthly lead PI teleconferences. Because we are also the PIs (Kruse lead, Mueter co-PI) for BSIERP Project 75 (Correlative Biomass Dynamics Model), these two projects are fully integrated. Results from this project (B68) will be directly used to inform project B75 in terms of species or species groups to include in the biomass dynamics model, potential interactions to consider in the model, and possible environmental influences on these interactions. To better integrate these two projects with other fish components and modeling efforts, Mueter participated via WebEx in the August 11-13 meeting of the Fish Component and Modelers Meeting, as well as in several phone conferences of the modeling group. To further integrate "competing" modeling activities, we are currently preparing a joint presentation for the BI meeting in Girdwood with the Behavioral Foraging project (Mangel, Satterthwaite) and the MSE project (Punt, Ianelli).

Education and Outreach:

We have participated in a number of outreach activities related to the BSIERP project during this reporting period:

- On August 13, 2009, both Gordon Kruse and Franz Mueter were interviewed by Marc Kagan, video director and producer for NOAA, for a film on climate change and its effects on fish, crabs and other species in the marine ecosystems of Alaska. Gordon spoke about work related to this project, as well as other NPFB-funded research projects, such as Pacific herring. Franz spoke about changes in distribution of fish and shellfish in the eastern Bering Sea and other climate effects on the Bering Sea ecosystem, based in part on results from the retrospective analyses.

- On September 9, 2009, Gordon Kruse was invited to give the following presentation: *Climate Change and Marine Protected Areas: A Fisheries Perspective from Alaska.* Invited presentation to the Marine Protected Areas Federal Advisory Committee (FAC), September 9, 2009, Anchorage, Alaska. Kruse also served on a panel of experts to field questions from the MPA FAC for two hours. This was reported on the evening news on KTUU (Anchorage) on September 9, 2009. Kruse reported on climate change effects on groundfish, crabs, herring, and other marine species and their implications to the design of marine protected areas.

- On June 18, Franz Mueter co-chaired (with Earl Dawe, DFO, St. Johns, Newfoundland) a workshop on gadid-crustacean interactions in subarctic ecosystems at the ESSAS Annual Meeting in Seattle. He presented an overview (with Siddeek Shareef and Jie Zheng) of gadid and crustacean fisheries and dynamics in the Gulf of Alaska and eastern Bering Sea.

- Franz Mueter was invited to give a presentation to a Climate Change seminar in Fairbanks on September 30 and spoke about potential effects of future climate changes on the distribution of fish and shellfish and on the productivity of the eastern Bering Sea ecosystem. His presentation was entitled "*Climate effects on Bering Sea food webs and fisheries*" and used the BSIERP PowerPoint template. A copy of the presentation will be submitted with this report.

Next year's Work plan

BSIERP B68, Trophic Interactions - Retrospective analysis

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2009-2012 Tasks, Assignments, Timeline

What	***Who***	***Start***	***Other key dates***
Prepare presentation for PICES	Mueter	September 2009	PICES XIII Oct 26-30
Complete documentation of new indicator time series	Mueter	October 2009	BSIERP PI meeting
Prepare presentation or poster	Mueter	January 2010	*January*: Alaska Marine Science Symposium
Complete expanded manuscript on covariation & trophic interactions	Mueter	January	
Updated data to Ken Coyle	Mueter	By Feb 15	
Complete draft manuscript on climate effects on fish & shellfish	Mueter Kruse	March	
Data analysis: Developing & testing crab hypotheses	Mueter Kruse w/ Zheng	April	
Data analysis: Developing & testing seabird/mammal hypotheses		June	
Synthesis manuscript preparation	Mueter, Kruse (w/ others)	January 2011	*January*: Presentation at AMSS *April 1*: Report to NPRB
	Mueter		*October 1*: Report to NPRB *October*: PICES Annual meeting
Final report preparation	Kruse, Mueter	Jan 2012	*January*: Presentation at AMSS *April*: Report to NPRB *July*: Final report