BSIERP Project O4.35, Seabird Telemetry

Project Title: Seabird Telemetry

Contact Information

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Summary

We will compare seabird foraging location and trip duration for Black-legged Kittiwakes and Thick-billed Murres nesting on two geographically associated islands in the Pribilof group, St. Paul and St. George. The maximum edge of the winter ice on the Bering Sea shelf is generally nearer to St. Paul than to St. George. St. George is nearer the productive edge of the Bering Sea shelf. To the extent that the influence of ice is greater in the vicinity of St. Paul, seabirds nesting on that island might be differentially affected by the loss of that influence if future warming reduces the incidence of ice in the area. This study will allow us to confirm where birds from each island forage, and to look at foraging location and trip duration variability among years of differing sea ice extent. This study will work closely with the seabird colony study (O4.37) to determine the effects of foraging behavior on diets, reproductive success and adult survival.

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

The two most common, and well-studied seabird species in the southeastern Bering Sea are thick-billed murres (*Uria lomvia*) and black-legged kittiwakes (*Rissa tridactyla*). Their sensitivity to changes in climate have been shown at the population and individual levels (Benowitz-Fredericks *et al.* 2007; Byrd *et al.* 2007; Shultz and Kitaysky 2007; Takahashi *et al.* 2007). We have chosen to examine a diving seabird (thick-billed murre) and a surface-feeding seabird (black-legged kittiwake) because temporal dynamics and locations of available food differ at the surface and at depth (Kitaysky *et al.* 2000). To fully characterize effects of climate on foraging resources we need to rely on information obtained for both feeding ecotypes, rather than a single species of piscivorous seabird. Additional data on the distribution and abundance of all seabird species will also be obtained at both the northern and southeastern study sites, by placing seabird observers on the NSF and PDS vessels.

Considerable data on seabirds were collected in the Bering Sea as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) during the 1970's. This work forms the foundation of our current understanding of seabird trophic relationships (Hunt *et al.* 1981; Sanger and Jones 1984; Sanger 1986, 1987; Hunt *et al.* 2000). During the late 1980s and 1990s, data on birds at sea were more restricted to specific study sites, but a broad-scale seabird observer program was reinstated in 2006 and 2007 (NPRB #637). The North Pacific Seabird Pelagic Database (NPPSD), maintained by USGS and USFWS, is the repository for at-sea survey data of seabirds (North Pacific Pelagic Seabird Database 2006). Work on seabirds in the Bering Sea has continued with funding by the USFWS (Byrd *et al.* 2007) and NPRB (Kitaysky *et al.* 2007).

We will compare seabirds nesting on two geographically associated islands in the Pribilof group, St. Paul and St. George, where apex predators apparently respond to different environmental regimes. This comparison will allow us to predict how changes in sea ice conditions and associated food-web responses in the Bering Sea may affect apex predators. For central place foraging seabirds, the positions of St. Paul and St. George relative to the typical maximum edge of sea ice and to the edge of the Bering Sea shelf may be important factors in how seabirds breeding on the two islands are affected by changes in climate. The maximum edge of the winter ice on the Bering Sea shelf is generally nearer to St. Paul than to St.

George. St. George is nearer the productive edge of the Bering Sea shelf. To the extent that the influence of ice is greater in the vicinity of St. Paul, seabirds nesting on that island might be differentially affected by the loss of that influence if future warming reduces the incidence of ice in the area (Byrd *et al.* 2007).

Hunt et al. (2002) speculated that the Bering Shelf ecosystem may be regulated by different mechanisms during cold vs. warm climate regimes. Although St. George and St. Paul are situated close to each other, they appear to be responsive to different oceanographic processes, potentially driven by proximity to the shelf break and/or movement of water masses across the shelf (P. Stabeno, unpubl. data). The long term consequences of these inter-island differences are striking: since the mid-1990s populations of piscivorous seabirds breeding at the Pribilof Islands have rebounded at St. George (continental shelf-break region), while continuing to decline at St. Paul (shelf region) (Byrd *et al.* 2007). Comparing responses of piscivorous seabirds nesting on these islands may provide insights into whether shelf and oceanic systems respond in tandem (Benowitz-Fredericks *et al.* 2007) or independently to inter-annual climate differences.

The pattern of oceanographic response described above may be driven by climate regime. For example, the shelf and oceanic systems may respond similarly during warm regimes, but are regulated differently during cold regimes. There is a need for a better understanding of the causal links between climate and patterns of productivity among oceanographic regions in the Bering Sea. It is critical to investigate this on a fine scale because responses by nesting seabirds to climate fluctuations are localized. The project proposed here addresses this goal by examining effects of inter-annual climate changes on patch dynamics for seabirds preying on forage fishes (including juvenile walleye pollock) at two major colonies situated in two distinct oceanographic regions on the continental shelf of the southeastern Bering Sea — St. Paul and St. George islands. The telemetry component of BSIERP will determine whether birds nesting on the two islands do indeed utilize different foraging areas.

Seabirds have been widely recognized for their ability to indicate changes in marine ecosystems (Boersma 1978; Crawford and Shelton 1978; Ricklefs *et al.* 1984; Cairns 1987; Croxall *et al.* 1988; Chapdelaine and Brousseau 1989; Monaghan *et al.* 1989; Harris and Wanless 1990; Hamer *et al.* 1991; Montevecchi 1993). Changes in ocean conditions affects the food supply of seabirds, while a chronic imbalance between energy demands and its availability affects population processes of the seabirds (Kitaysky *et al.* 2007). Seabird response to these changes is reflected in changes in diet composition (Hatch and Sanger 1992; Ballance *et al.* 1997; Bryant *et al.* 1999; Carscadden *et al.* 2002; Suryan *et al.* 2002), foraging behavior (Cairns 1987; Burger and Piatt 1990; Suryan *et al.* 2000), nutritional stress (Kitaysky *et al.* 2007), nesting success (Jodice *et al.* 2006), and survival (Kitaysky *et al.* 2007). Changes in diet composition, foraging behavior, and nutritional stress reflect short-term (hours-days) changes in food availability. Each of these parameters alone, however, would not provide sufficient information to characterize short-term changes in patch dynamics. For example, changes in diets do not always result in shortages of energy (Benowitz-Fredericks *et al.* 2007), and relying on poor quality food is not always nutritionally stressful (Kitaysky *et al.* 1999b). Yet when these three parameters are used together, they can characterize bird responses to changes in patch dynamics. Longer-term changes in food availability (days – weeks) are reflected in reproductive parameters, such as nest initiation date, hatching success, brood reduction, chick growth rates, and fledging success. Population responses of long-lived seabirds are sensitive to long-term changes in food availability and typically reflect oceanographic changes on inter-annual and decadal scales (Thompson and Ollason 2001). However, nutritional status of breeding individuals (assessed by measurements of stress) reflects changes in food availability during the reproductive season and determines post-reproductive survival of adult birds, providing a mechanistic link between changes in forage patch dynamics and population processes in seabirds (Kitaysky *et al.* 2007).

Species and Geographic Scope

This project examines breeding Black-legged Kittiwakes and Thick-billed Murres in the southeastern Bering Sea at St. George and St. Paul islands.

Hypotheses

This project addresses BSIERP hypotheses 2b, 2d, 3a, 3b, 3c, 4a, and 4b (Table 2).

Project Description

Foraging routes locations and distance from colony, trip duration and frequency, will be monitored for breeding thick-billed murres and black-legged kittiwakes at St. George and St. Paul islands. Foraging locations will be analyzed in relation to data on oceanography, prey type and abundance, and fur seal foraging location to determine the habitat characteristics and prey densities for prey patches used by foraging seabirds and fur seals, and look for temporal and spatial overlap in use areas.

Three diet parameters are likely to shift in response to climate variation: i) composition (prey type), ii) quality (energy content), and iii) availability (abundance and distribution). Changes in any or all of these parameters will reflect changes in patch dynamics and have consequences for seabird productivity.

Each year of the study, 30 birds of each species at each location (St. Paul and St. George islands) will be fitted with a GPS data logger during the period July 1 to August 15, just before and concurrent with the fine-scale forage fish cruise and northern fur seal studies. These birds will also be used to collect diet samples (Seabird Colony Component). Irons (1998) used a similar sample size of 26 birds to successfully identify foraging locations and habitats of black-legged kittiwakes in Prince William Sound. Each GPS data logger will record latitude and longitude every 5 minutes during a foraging trip. Data logger batteries last only a few days because of their small size, so loggers will be retrieved after one or two foraging trips. Thick-billed murres and black-legged kittiwakes will be captured while at their nest site with an 8-meter noose-pole — a method used successfully on both seabird study species (Irons 1998). The GPS data loggers will be attached to the birds' back or tail feathers by means of cyanoacrylate glue, Tesa tape, and/or cable ties (see Benvenuti *et al.* 1998; Irons 1998; Daunt *et al.* 2002).

Seabirds nesting at the Pribilof Islands have never before been tracked at sea and, therefore, foraging locations, as determined from birds fitted with GPS data loggers, are a critical data gap for this major seabird breeding area. The foraging locations of tagged birds can also be used to help direct fine-scale surveys of prey patch dynamics, where at-sea bird observers can determine the level of seabird occupation in those areas in conjunction with characteristics of the prey patch. The seabird telemetry component ties the colony of origin to foraging behavior and prey availability/patch use. Knowing colony of origin is critical to the focal research on the Pribilof Islands and its relevance to testing BSIERP hypotheses regarding effects of climate change.

Data Analyses: Foraging locations will be identified by latitude, longitude, date and time. Trip duration will be recorded in hours and minutes and averaged by bird and by season. Water depth will be recorded from marine charts for foraging locations. Water chararcteristics, i.e., temperature and salinity, will be obtained from vessels conducting broad-scale surveys and patch dynamics. Foraging locations, distances and trip duration will be compared to diets, and reproductive parameters as well as to water characteristics and prey abundances (Patch Dynamics component)

Project Reporting

Research Products: Foraging locations of breeding seabirds will be determined by tracking breeding birds at St. Paul and St. George islands in July and August to coincide with the forage fish cruise and the fur seal tracking. Seabird foraging behavior, including location of feeding sites, distance of feeding site from breeding site, foraging trip duration and number of trips per day.

Research Links: This project depends for interpretation particularly on seabird reproductive success and diets from the seabird colony study (04.37) and both stress measures and at sea diets from the patch dynamics study (04.62). It also depends on data on the summer spatial distribution and abundance of juvenile pollock, forage fish, euphausiids, and other forage species (02.26, 02.28, 02.19, 02.17) as well as nutritional energy data from the seasonal bioenergetic project (02.24). It provides data for determining where breeding seabirds feed in relation to available prey patches (04.62) and broadscale distributions of birds at sea (04.36). The specific links to modeling components are yet to be determined, but should be relevant to behavioral foraging (M.54), and retrospective analyses of broad-scale distribution of apex predators (03.30).

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.

Dissemination:

- Foraging and prey of central place foragers at the Pribilof Islands and affects on their productivity and activity patterns.
- The effects of changing sea ice on seabird foraging at the Pribilof Islands.

Graduate Students and Post-docs: One graduate student, Ph.D. (4-5 years).

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
	Forage distribution & ocean conditions	O2.17	Hollowed, Wilson, Kotwicki, DeRobertis, Ressler, Cokelet	$ 567,123	$ 553,311
Trophic interactions	Fish, birds & mammals	O3.30	Mueter, Kruse	$ 286,913	$ -
	Hot spot persistence	O4.40	Sigler, Kuletz, Wilson	$ -	$ 55,200
Seabirds	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
Patch	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	
	potential		***potential***		
	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 murres, 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 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.

References

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