Broad-scale Distribution of Seabirds in Response to Physical and Biological Factors (04.36)

Contact Information

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Summary

This project will examine seabird distribution relative to oceanographic and biological features of the eastern Bering Sea. Size, location, and composition of seabird foraging flocks at sea and diet composition (at-sea and at colonies) can change immediately when prey resources change in either distribution or abundance, or physical forcing agents affect the availability of prey to seabirds. This broad-scale component (04.36) is closely coordinated with the colony-based seabird projects (04.35, 04.37, 04.62). At-sea observations will provide data on seabird abundance, distribution, and diet. We will determine seabird responses to changes in oceanographic properties of water masses (01.01) and to prey type and distribution (02.26, 02.23, 02.28), and will contrast the patterns of central place foragers (breeding kittiwakes and murres) to that of non-breeding birds (such as shearwaters and albatrosses). Data collected for this project (04.36) will also be used to examine Seabird and Cetacean Foraging Response to Prey Persistence (04.40), and retrospective analyses of trophic interactions among fish, birds, and mammals (03.30).

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

Seabirds are often monitored at their breeding colonies, yet they spend most of the year widely dispersed over vast areas offshore, and indeed, in the Gulf of Alaska, non-breeding seabirds consume greater biomass than breeding birds (Hunt et al. 2005). Seabirds can show abrupt spatial changes in abundance as they follow prey, especially if they are not tied to a colony. Bathymetric features and currents that concentrate prey influence the type of seabird species and numbers of birds that forage under different tidal conditions (Ladd et al. 2005) and can also affect prey size selection (Vlietstra et al. 2005). Subsequently, the size and nutrient value of prey alters the amount of biomass removed by seabirds (Hunt et al. 2000).

The biomass removed by seabirds from the Bering Sea ecosystem depends on the type of prey available to seabirds, and possibly also on competition with other apex predators. During summer, the amount of biomass consumed by birds in the eastern Bering Sea shelf during the 92-day breeding season was estimated to vary from 656,000 mt (assuming all prey were high energy density, 7 kjg^{-1}) to 1,530,000 mt (if prey were low energy density, 3 kjg^{-1}) (Hunt et al. 2000). These summer estimates are only a portion of the annual total taken by birds in the Bering Sea. Data collected for this project (04.36) can be used to examine models of trophic relationships and energy transfer in the Bering Sea ecosystem (M.61), specifically how these relationships will be affected by prey type and seasonal changes in the relative abundance of seabirds.

Considerable data on seabirds were collected as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) during the 1970's; thousands of birds were collected for dietary analyses. This work resulted in several publications on seabird trophic levels and trophic relationships (Hunt et al. 1981, Sanger 1987, Sanger and Jones 1984), and forms the foundation of our current understanding of seabird food habits in Alaska. After the conclusion of OCSEAP, the rate of collection of seabird data declined. Since the 1970's there have been dramatic climate shifts in the Bering Sea and many seabird species have declined, and changes have occurred in ocean ecosystems. These changes may have affected the foraging patterns of seabirds. Further changes due to predicted Arctic climate change are anticipated. More recently, NPRB #637 conducted seabird surveys in 2006-2007 in conjunction with BEST, SLIP, and NOAA research cruises.

Our goal is to examine the current influence of oceanographic and prey dynamics on the distribution and abundance of seabirds as top predators. By using multiple years of data to examine seabird response to these variables, we aim to predict how changes in the Bering Sea ecosystem will alter the distribution of apex predators. We will test for spatial and temporal changes in seabird species composition at sea, with respect to spatial and temporal dynamics of the prey field.

Species and Geographic Scope

The focal species for the seabird components based at the colonies are black-legged kittiwake and thick-billed murres, and the broad-scale seabird component will examine distribution and abundance of these two species, as well as all other seabirds. We will also obtain data on all marine mammals encountered during surveys. The broad-scale component will include the eastern Bering Sea shelf covered by NOAA fisheries surveys (Unimak Pass to St. Mathew Island) and the northern Bering Sea covered during BEST cruises (St. Mathew Island to St. Lawrence Island). The range of cruises used to conduct broad-scale seabird surveys will result in a large temporal scale as well, from spring (April) through early fall (September-October).

Both thick-billed murres and black-legged kittiwakes are present throughout the year in the Bering Sea, although their distribution shifts offshore during the non-breeding season (North Pacific Pelagic Seabird Database 2006). Species composition of the diet changes dramatically with season, and there are spatial shifts in seabird species abundances as well, likely reflecting both changes in their breeding status (shifting from dispersed or 'hot spot' foragers to central place foragers during the breeding season) and changes in prey fields.

Half or more of seabird populations are non-breeders that spend the entire year at sea (Coulson 2002). During summer in the Bering Sea, short-tailed and sooty shearwaters comprise the largest seabird biomass, and consume the largest biomass of seabird prey (Hunt et al. 2000). These birds do not breed in the northern hemisphere, but migrate to Alaska waters to feed during the summer, much like the large cetaceans. Not being tied to colonies, shearwaters act as classic 'hot spot' foragers, and at times can be found aggregated in the thousands as they feed on euphausiids, copepods, and forage fish at high-advection sites such as Unimak Pass (Hunt et al. 1996, Jahncke et al. 2005).

Hypotheses

This project responds primarily to elements of BSIERP Hypotheses 2b, 2d, 3a, 3c, 4a, and 4b (Table 2). The broad-scale distribution of seabirds will be used to examine the relationship between the extent of the cold pool and overlap among piscivores (2b). Seabird distribution during 2008-2010, and comparisons to historic data on seabird distribution, can be used to examine the impact of reversals in cold conditions on interannual variability in abundance of piscivorous seabirds (2d). Hypothesis 3a & 3c predict that kittiwakes and murres will decline due to competition with abundant piscivorous fish for forage species, and the relative abundance over time of all seabird species will be captured during broad-scale surveys. If climate-ocean changes displace seabirds from predictably located, abundant prey necessary for seabirds (hypothesis 4a), changes in distribution will be tracked via broad-scale seabird surveys. Central place foragers may be most sensitive to changes in diet and foraging locations (4b), and broad-scale seabird surveys will examine shifts in central place (murres, kittiwakes) and hot spot (shearwaters) foragers.

Project Description

This project will compare the spatial distribution and abundance of seabirds to the spatial distribution of pelagic forage species in the eastern Bering Sea. Seabird surveys will be conducted during BEST surveys in spring (approximately April - May), during NOAA fisheries surveys in June and July (02.26), and during the BASIS program (02.23, 02.28) in late summer and early fall (August – October). The BEST program provides coverage of the northern Bering Sea onboard the USCGC Healy. NOAA fisheries stock assessment surveys (02.26) cover the Bering Sea shelf south of St. Mathew Island to Unimak Pass. The BASIS program (02.23, 02.28) covers the Bering Sea and extends into the Chukchi Sea.

At-sea surveys will use US Fish and Wildlife Service standard operating procedures for strip transects (Gould and Forsell 1989), with adaptations to improve density estimates (see Hyrenbach et al. 2001, Spear et al. 2004). While in transit or on established transect lines, all birds and marine mammals in a 90^0 arc out to 300 m from one side of the vessel will be recorded in a gps-integrated computer using the DLOG (Ford Ecological Consulting, Portland, OR) data entry program. Observers will record all species, including marine mammals, using strip transect methodology (standard for seabirds, but not for marine mammals). Birds on the water will be recorded continuously, while flying birds will be recorded during periodic 'snap shots' at approximately one minute intervals, depending on the speed of the vessel (Gould and Forsell 1989). Observations will be binned into 100m distance intervals to develop species-specific detection curves.

In preparation for analysis, observations will be binned into selected transect lengths to calculate densities, typically 1 – 3 km, depending on the distribution of prey and seabirds, and on the type of analyses. The DLOG program allows us to record environmental conditions associated with the track line and with each observation. These variables include weather, sea state, ice coverage, wind, and observation conditions. The survey track lines can also be matched with the continuous variables collected by the vessel (sea surface temperature, sea surface salinity, chlorophyll, ship speed, etc). Spatial analysis will be used to compare broad-scale patterns in seabird distribution to water characteristics and prey distribution. For continuous environmental variables we calculate average values for each transect. We will use linear regression and multivariate analyses to examine factors influencing seabird species composition and associations, location, abundance, and diet.

Diet of seabirds will be assumed to be forage species the birds are associated with during concurrent hydroacoustic (02.26) and trawl sampling (02.23). Validation of this assumption will depend on birds collected at prey patches during the Patch Dynamics Study (04.62) at the Pribilof Islands. Diet studies of birds collected at the patch scale will validate the link between seabird and prey associations, and will define seabird diet and seabird response thresholds relative to prey abundance. (See Project Description, 04.62 for details). Three tissue samples will also be taken from each collected bird for stable isotope analysis (whole blood, liver, and muscle). This is necessary to integrate immediate and longer time-frame diet composition (Hobson and Clark 1992; Sydeman et al. 1997). Stable isotope analysis of seabird tissues (04.62), by integrating seabird diet over a longer time frame, will link the fine-scale process studies of the Patch Dynamics Study to the broad-scale observations of BSIERP (04.36).

Project Reporting

Research Products: For research cruises with seabird observers, we will provide seabird survey track lines, numbers of birds by species, latitude/longitude for each record, and survey conditions associated with the track lines and observations. The bird and marine mammal observations will also be available as densities (birds km^{-2}), at transect lengths of 3 km, with the option to recalculate bird densities at other intervals (i.e., 1 nm or greater).

Research Links: This project depends on securing vessel space for two observers on the BEST, NOAA, and BASIS cruises. It will depend on temperature, salinity, and chorophyll measurements from the biophysical moorings project (O1.1) and those collected during vessel transits. It will require 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), which will be related to seabird (O4.36) broad-scale distributions. The direct sampling of seabird diet at the forage patches depends on the fine-scale Patch Dynamics Study (04.62).

The broad-scale seabird data will be used to examine trophic interactions (03.30) and hot spot persistence (04.40). The specific links to modeling components are yet to be determined, but should be relevant to behavioral foraging (M.54), Biomass dynamics (M.61), 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 of 2008 - 2010), and the field data will be delivered to the modeling group January 15 after each field season. Annually, data will be prepared and submitted to the North Pacific Pelagic Seabird Database. Final analysis will begin in 2010, and papers submitted for publication by 2012.

This project will also provide maps and data on distribution of seabirds for management applications such as commercial fisheries interactions, vessel traffic and accidents, oil spills, oil and gas exploration, delineation of marine protected areas, management of waters associated with federal and state refuges.

Dissemination:
Researchers will prepare presentations for the Alaska Marine Science Symposium, GLOBEC, and the Pacific Seabird Group.

Likely peer-reviewed manuscripts:

- The effects of changing sea ice on seabird distribution and diets.
- Seabird distribution relative to changes in the Bering Sea ‘cold pool’ and implications for seabird populations.
- Broad-scale seasonal changes in seabird species composition with respect to seasonal changes in their prey.

Graduate Students and Post-docs: There will be full time support for one Ph.D. student (4 years), and the potential for an additional M.Sc student with partial support.

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.

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