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FINAL REPORT

Top predator hotspot persistence

NPRB BSIERP Project B92 Final Report

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Abstract

Predictable prey locations reduce search time and energetic costs of foraging; thus marine predators often exploit locations where prey concentrations persist. In our study, we examined whether this association is influenced by differences among predator species in foraging modes (travel cost, surface feeder or diver) or whether the predator species is a central place forager or not. We examined distributions of two seabird species during their nesting period, the surface-feeding black-legged kittiwake (*Rissa tridactyla*) and the pursuit-diving thick-billed murre (*Uria lomvia*), and two baleen whale species, the humpback whale (*Megaptera novaeangliae*) and the fin whale (*Balaenoptera physalus*), in relation to two key prey, age-1 walleye pollock (*Theragra chalcogramma*) and euphausiids (Euphausiidae). Prey surveys were conducted once each year during 2004 and 2006–2010. Concurrent predator surveys were conducted in 2006–2010 (seabirds) and 2008 and 2010 (whales). We compared the seabird and whale sighting locations to where age-1 pollock and euphausiids were concentrated and considered the persistence of these concentrations, where the time-scale of persistence is year (i.e., a comparison among surveys that are conducted once each year). Euphausiids were widespread and concentrations often were reliably found within specific 37 km X 37 km blocks ('persistent hot spots of prey'). In contrast, age-1 pollock were more concentrated and their hot spots were persistent only on coarser scales (437 km). Both seabird species, regardless of foraging mode, were associated with age-1 pollock but not with euphausiids, even though age-1 pollock were less persistent than euphausiids. The higher travel cost central place foragers, thick-billed murres, foraged at prey concentrations nearer their island colonies than black-legged kittiwakes, which were more widespread foragers. Humpback whales were not tied to a central place and mostly were located only where euphausiids were concentrated, and further, often in locations where these concentrations were persistent. Fin whales were associated with locations where age-1 pollock were more likely, similar to black-legged kittiwakes and thick-billed murres, but their association with euphausiids was unclear. Our results suggest that a predator's foraging mode and their restrictions during breeding affect their response to prey persistence.

Key Words

Seabirds, Whales, Prey, Persistence, Hot spots

Citation

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Study Chronology

The study period was January 1, 2008 – September 30, 2012. Progress reports were submitted semi-annually from September 2008 – April 2012. The project was reported as complete in the April 2012 report.

Data for this study were collected during June-July of 2008-2010 as part of BSIERP projects B58 (acoustic surveys), B66 (broad-scale whale surveys) and B64 (broad-scale seabird surveys). This study also included earlier data sets from acoustic surveys in 2004, 2006 and 2007 and seabird surveys in 2006 and 2007 (NPRB Project No. 637). A preliminary analysis was completed by the time of the April 2009 progress report with data collected through 2008. A second preliminary analysis was completed by the time of the April 2010 progress report by adding data collected in 2009. A final analysis was completed by the time of the April 2011 progress report by adding data collected in 2010; the final analysis was described in a manuscript submitted for the first Bering Sea Project synthesis volume. The manuscript was accepted for publication and the study data submitted to the BSIERP data manager by the time of the October 2011 progress report.

By the time of the April 2012 progress report, the results were published: SIGLER, M. F., K. J. KULETZ, P. H. RESSLER, N. A. FRIDAY, C. D. WILSON, and A. N. ZERBINI. 2012. Marine predators and persistent prey in the southeast Bering Sea. Deep-Sea Res. II. 65-70:292-303.

Introduction

Many piscivorous apex predators are central place foragers that benefit from reliable prey concentrations near their breeding sites for maximal reproductive success and offspring growth. For example, kittiwakes, fur seals and murres need reliable prey concentrations during the breeding, post-natal and post-fledging periods. At the Pribilof Islands, capelin virtually disappeared from fur seal, kittiwake and murre diets by the early 1980s, coincident with increased occurrence of pollock and sand lance during the 1980s and 1990s (Hunt et al. 2002); pollock has become almost uniquely important in the fur seal diet with some variation associated with foraging domain (Zeppelin and Ream 2006). In the late 1980s, capelin moved well north of the Pribilof Islands (Brodeur et al. 1999) and pollock, Pacific cod, rock sole and arrowtooth flounder also shifted northward within the southeast Bering Sea (Hunt et al. 2002). Seabirds have higher reproductive success when provisioning chicks with capelin (Baird 1990) or other, lipid-rich forage species (Golet et al. 2000), implying that the carrying capacity for piscivorous seabirds has decreased at the Pribilof Islands (Hunt et al. 2002). Chick growth rates, mass at fledging, fat reserves at fledging and post-fledging survival are all dependent on the lipid content of the diet (Romano et al. 2006). Capelin, sand lance and herring generally have higher lipid content than juvenile gadids, such as pollock, Pacific cod and tomcod (Anthony et al. 2000). As a consequence, seabirds have been widely recognized for their ability to indicate changes in marine ecosystems due to their sensitivity to food availability (Cairns 1987; Croxall et al. 1999; Harris and Wanless 1990). Seabird response to these changes is reflected in changes in diet composition (Hatch and Sanger 1992; Croxall et al. 1999; Carscadden et al. 2002; Suryan et al. 2002), foraging behavior (Cairns 1987; Burger and Piatt 1990; Suryan et al. 2000) and nesting success (Jodice et al. 2006). Seabirds are often monitored at their breeding colonies (e.g., Dragoo et al. 2012), yet they spend most of the year widely dispersed over vast areas offshore; overall, non-breeding seabirds consume greater biomass than breeding birds (Hunt et al. 2000, 2005).

Nonetheless, a uniform response of all seabird rookeries to ecosystem-wide changes in the location and timing of food production in response to climate change is not envisioned by our hypotheses, as the strength of coupling of trends in any given rookery to food resources depends on its location. Rookeries of significant interest are those that have evolved in close proximity to the ice edge. Specifically, seabird productivity at St. Paul Island has been linked to extent of sea ice. In years of little ice, seabirds did poorly (Byrd et al. 2008). Overall, trends in seabirds that breed in the Bering Sea are hypothesized to be negative under warming, with declines to be seen first in those rookeries with geographically limited food resources.

Large baleen whales follow a different background story from seabirds. Large baleen whales were severely depleted by commercial whaling until the late 20th century (Clapham et al. 1999), but since protection was afforded, many populations have been increasing, including humpback and fin whales feeding in the Bering Sea and the Aleutian Islands (Moore et al. 2002; Zerbini et al. 2006). Whales consume large quantities of prey, so that their increased abundance likely will modify community structure through increased predation at mid-trophic levels and increased inter-specific competition among plankton and forage fish consumers (Bowen, 1997). Most data on Bering Sea baleen whale prey (Nemoto 1957, 1959, 1970) are outdated because the Bering Sea has undergone major climate and oceanographic (regime) shifts (e.g., Francis and Hare 1994; Overland et al. 1999; Trites et al. 2007). Trophic effects of predation by large whales cannot be assessed without updated research, including a description of the whale's foraging behaviour (i.e., functional response; e.g., Piatt and Methven 1992; Piatt et al. 1989) and prey and habitat characteristics.

Foraging behavior of seabirds and marine mammals can be linked to prey distribution and identifiable habitat features. In air-breathing vertebrates, finding concentrated prey patches are important to an individual's energy budget. Predictable prey locations reduce search time and thus energetic costs of foraging (Gende and Sigler 2006). At a fine scale, the diving depth of murres depended on whether they were associated with patches of krill or pollock, and murres altered their diel diving behavior in response to diel vertical migrations of krill (Benoit-Bird et al. 2011). At the larger scale, foraging Steller sea lions return to geographic locations where prey are reliably found (Sigler et al. 2004; Womble and Sigler 2006) and vary their dive behavior in response to oceanographic changes (Fadely et al. 2005). During the pup-rearing season of July-November, adult female fur seals generally exhibit rookery-specific foraging area segregation among several Bering Sea domains (Robson et al. 2004), with varying foraging strategies among domains (Call et al. 2008). Foraging within different domains may influence reproductive success, as shorter maternal foraging trip durations are associated with increased pup growth rates that may also vary between warm and cold oceanic years (Banks et al. 2007). Planktivorous seabirds and baleen whales are dependent on reliable concentrations of prey (hot spots) that are affected by the climate-mediated processes described above (e.g., Croll et al. 1998; Lovvorn et al. 2001; Baumgartner et al. 2003).

This project addresses BSIERP hypothesis 4. Hypothesis 4 states that: 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).

Overall Objectives

Baleen whales consume large quantities of plankton and fish and are not tied to a central place to raise their young. In contrast, seabirds are central place foragers when breeding and breeding success is tied to foraging success. This project compared the two groups of endothermic predators and their prey. Both the cetacean and the seabird components used at-sea visual surveys (project B66 and B64, respectively). At-sea locations of cetaceans and seabirds were compared to forage species abundance and distribution from standard acoustics surveys (project B58), including analysis of how hot spot persistence affects foraging location (this project). This was the first attempt to follow two major groups of apex foragers simultaneously, in relation to their prey base, in Alaskan waters.

The specific objectives of this project were to:

1 Quantify the distributions of pelagic forage fish

2 Determine whether apex predators are associated with locations where prey concentrations persisted across years (hot spots).

Objective 1) quantified the distributions of pelagic forage fish using the full data set (2004, 2006-2010). Data were collected during acoustic surveys (project B58) of the southeastern Bering Sea shelf and resulted in estimates of age-1 pollock and euphausiid density (in weight; Ressler et al., 2012).

Objective 2) determined whether apex predators are associated with locations where prey concentrations persisted across years using the full data set (seabirds 2006-2010, whales 2008 and 2010). Data on the broad-scale distribution of apex predators (whales [project B66], seabirds [project B64]) were collected concurrently with the acoustic surveys and resulted in estimates of black-legged kittiwake, thick-billed murre, humpback whale and fin whale density (in numbers). The prey and predator data were analyzed to determine where densities were highest each year and whether these hotspots persisted from year to year.

The spatial patterns of predators and prey then were compared to determine their degree of association. The full results of these analyses can be found in the Sigler et al. 2012 manuscript listed below.

Manuscripts

SIGLER, M. F., K. J. KULETZ, P. H. RESSLER, N. A. FRIDAY, C. D. WILSON, and A. N. ZERBINI. 2012. Marine predators and persistent prey in the southeast Bering Sea. Deep-Sea Res. II. 65-70:292-303.

Conclusions

The higher travel cost central place foragers, thick-billed murres, foraged at prey concentrations nearer their island colonies than black-legged kittiwakes, which were more widespread foragers. Humpback whales were not tied to a central place and mostly were located only where euphausiids were concentrated, and further, often in locations where these concentrations were persistent. Fin whales were associated with locations where age-1 pollock were more likely, similar to black-legged kittiwakes and thick-billed murres, but their association with euphausiids was unclear. Our results suggest that a predator's foraging mode and their restrictions during breeding affect their response to prey persistence.

The study objectives were fully met. However we were surprised that the relationships of prey persistence and predator location were weaker for the southeast Bering Sea than a similar study in southeast Alaska (Gende and Sigler 2006). There are two possible reasons for this difference that could be investigated in future research. First, the broad Bering Sea shelf is much more homogeneous than the diverse habitats of southeast Alaska, so that prey and predators in the southeast Bering Sea have less distinct topography to reference their location. One exception was the persistent concentration of euphausiids east of Unimak Pass (Sigler et al. 2012, Churnside et al. 2011). Second, our study occurred only during summer, yet persistent concentrations of prey can occur in the Bering Sea in other seasons (e.g., Pacific cod spawning concentrations northwest of Unimak Island during winter) and in southeast Alaska (e.g., Sigler et al. 2004, Womble et al. 2006, Sigler et al. 2009).

BSIERP and Bering Sea Project connections

This project could not have taken place without three other projects occurring (acoustic survey [B58], seabird [B64] and whale [B66] broad-scale surveys). These three projects were large field studies that occurred over several years and took two months to complete each year. In turn, these projects benefited from our study (B92) in three ways. First, our study provided a secondary analysis of the data collected from these large field studies, in addition to the primary analysis of the survey data. Second, our study applied data from multiple species from the food web including zooplankton, fish, seabirds and whales.

Third, our study brought together scientists from three marine science disciplines including fish, seabirds and marine mammals.

Management or policy implications

This study provides information on foraging locations of black-legged kittiwakes, thick-billed murres, humpback whales and fin whales. These results could be used to assess some of the ecological consequences of future management actions such as new fishery closures, opening of existing fishery closures, and vessel traffic management in high traffic areas. These results also would provide useful information for their management if, sometime in the future, an Endangered Species Act status review was necessary due to a population decline in one of these predator species and it was determined that prey abundance was a factor in the decline.

Publications

SIGLER, M. F., K. J. KULETZ, P. H. RESSLER, N. A. FRIDAY, C. D. WILSON, and A. N. ZERBINI. 2012. Marine predators and persistent prey in the southeast Bering Sea. Deep-Sea Res. II. 65-70:292-303.

Poster and oral presentations at scientific conferences or seminars

Poster presentation at the Alaska Marine Science Symposium, January 2010: A Broad-scale Perspective for Seabird Predator-Prey Dynamics on the Bering Sea Shelf. Kathy J. Kuletz, Elizabeth A. Labunski, Patrick Ressler, Anne Hollowed, and Mike Sigler.

Oral presentation at the Pacific Seabird Group meeting, February 2010: The big picture in Alaska: a broad-scale perspective on predator-prey dynamics on the Bering Sea shelf. Kathy J. Kuletz, Elizabeth A. Labunski, Patrick Ressler, Anne Hollowed, and Mike Sigler.

Oral presentation at the World Seabird Conference, September 2010. Using broadscale distributions of murres, kittiwakes, and their prey on the Bering Sea shelf to inform decisions on MPA’s. Kathy J. Kuletz, Patrick Ressler, Elizabeth A. Labunski, Mike Sigler, Martin Renner, and Anne Hollowed

Poster at the Bering Sea Project Principal Investigators’ meeting, March 2011. Apex predators and hot spot persistence in the southeast Bering Sea. Sigler, Kuletz, Ressler, Friday, Wilson, Zerbini.

Poster presentation at the May 2011 Ecosystem Studies of Sub-Arctic Seas meeting, March 2011. Apex predators and hot spot persistence in the southeast Bering Sea. Sigler, Kuletz, Ressler, Friday, Wilson, Zerbini.

Outreach

Mike Sigler traveled to St. George Island with Francis Wiese (NPRB) and Vernon Byrd (USFWS) to learn about seabird biology during June 2008. While there, they met with community members. Mike and Francis provided photos to Carolyn Rosner.

The results of this project were distilled into a two-page summary for NPRB that is intended for program outreach.

Acknowledgements

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