Subject: Revised Statement of Work for RO320

May 6, 2003

Revised statement of work for the project

ReFER Phase II: Effects of inter-annual climate change on food availability, diet and productivity of planktivorous and piscivorous seabirds

The three PI-s (Alan Springer, Sara Iverson and Alexander Kitaysky) have met in a series of conference calls and, finally, meetings in-person this week. We have all reached an agreement about the work we will be able to conduct on the combined reduced budget of $900 K and how best we can make use of the funds and our combined emphases. Although, obviously not ideal, we have had to cut several field sites due to insufficient funds to cover field work and associated collections and analyses. We have also reduced the number of students, and have combined all field expenses such that there is no overlap.

You will be receiving an official budget from UAF in the near future with all costs and breakdowns. Please note that the budget for 2003 is somewhat different than that in 2004 and 2005 due to start-up costs and differences in overheads in 2003. All together the budgets for all 3 years totals exactly $900,000.00.

As described in detail in the initial two proposals, our now combined project will describe diets and quantify food availability of seabirds during the breeding season at nesting colonies in the Bering Sea, with the aims to reveal how pelagic food webs are organized and to yield insights on patterns of food web productivity at four trophic levels, from phytoplankton to zooplankton, fishes, and birds, between habitats and over time. Our project has four main components: 1) We will assess food availability by measuring concentrations of the stress hormone corticosterone in free-living birds at focal nesting colonies. Corticosterone levels in undisturbed individuals ("baseline levels") indicate current food availability, and the rise in corticosterone levels in response to a standardized stressor ("acute stress-induced levels") indicates recent nutritional history. 2) We will conduct concurrent assessments of diet composition using quantitative fatty acid signature analysis (QFASA) and stomach contents analysis. 3) We will compare the quality of aggregate diets of seabirds and of important species of forage fishes and zooplankton in continental shelf and oceanic habitats and will determine seasonal and interannual changes in the quality of individual key forage species. 4) Finally, we will measure productivity of seabirds through this and collaborative projects and will relate seabird diets and prey quality and availability to characteristics of habitats, individual seabirds and populations, and physical variability over time and space.

We will conduct our studies at three primary sites in the Bering Sea, which represent distinct oceanographic characteristics, and will undertake 3 years of sampling at each of these sites. The primary sites will be Bulduir Island (deep ocean basin) and the Pribilof Islands St. George (continental shelf edge) and St. Paul (continental shelf). Additionally, some prey collections and bird sampling will occur as opportunity provides at Kasatochi (for instance in 2003, associated with the SMMOCI cruise), Bogoslof (years 2004 and 2005, associated with cruises already scheduled for that area) and Talan I. (years 2004 and 2005, associated with projects supported through the Russian Academy of Sciences and Institute of Arctic Biology UAF). At each of the three focal sampling sites, two people will be stationed for the entire summer nesting and chick-rearing periods. These people will represent a combination of graduate students associated with the project (two), hired technicians, and volunteers, for a total of 6 people each summer. The additional sampling at Kasatochi, Talan and Bogoslof, as well as some assistance with sampling at the focal sites, will be conducted by the PIs. The seabirds species we will focus on for complete sampling (i.e., at each of 3 periods during the breeding season) will represent a combination of piscivores and planktivores: red- and black-legged kittiwakes, common and thick-billed murres, and least, crested and whiskered auklets. As opportunity provides some sampling will also be done on puffins and parakeet auklets. The full sampling and analysis schemes, as well as time-lines, for both stress hormones and diet analyses, along with our intended sample sizes, are described in the two original proposals.

Our budget includes:
Salaries:
- 4 months per year for A. Springer to oversee portions of the project, participate in field work, supervise technicians, analyze data, and prepare reports, presentations, and publications.
- 11 months per year for a research associate to oversee and conduct all stress hormone analyses.
- 21 months per year for two graduate students participating in the project and each assigned to oversee one of the field collection sites
- 6 months in the first year for 2 techs and 3 months for 1 tech in each of the following years to oversee the third focal field site.

Travel: includes all travel for students, techs, volunteers and PIs to the field sites for purposes of sample collection, and funding for the PIs to attend the NPRB annual meetings.

Services:
- $40,000 for subgrant/subcontract with the Co-PI, S. Iverson at Dalhousie University. Dr. Iverson will be responsible for all fatty acid analyses and QFASA modeling, and will participate equally with A. Springer and A. Kitaysky in the analysis and interpretation of combined data sets and in the preparation of reports and publications.
- $1,000 for CHN analyses of prey to determine protein content for proximate analyses.
- miscellaneous charges for communications, publications and public outreach.

Supplies and Equipment:
- $ 16-19 K per year is budgeted for all field and laboratory supplies required.
- $ 9.6 K per year is budgeted for food, gas and propane for field work.
- $2.0-3.3 K per year is budgeted for necessary equipment including portable freezers, generators and miscellaneous other items.

Tuition:
- $7.3 K per year is budgeted for tuition for two students.

NPRB BUDGET SUMMARY FORM

PROJECT TITLE:
Regime Forcing and Ecosystem Response in the Bering Sea (ReFER): Phase II
PRINCIPAL INVESTIGATOR: Alan Springer; Alexander Kitaysky

FUNDING SOURCE	YEAR 1	YEAR 2	YEAR 3	TOTAL
NPRB Funding	313,311	291,397	295,294	900,002
Match/In Kind				0
TOTAL	313,311	291,397	295,294	900,002

Annual cost category breakdowns will be requested for matching funds only if project is funded

Cost Categories	NPRB Year 1	NPRB Year 2	NPRB Year 3	NPRB TOTAL	Match/In kind TOTAL (all years)
1. Personnel Salaries	92,651	90,000	93,958	276,609	
2. Personnel Fringe Benefits	20,325	20,631	21,402	62,358	
3. Travel (include 1 trip to review meeting in Anchorage)	15,120	15,120	15,120	45,360	
4. Equipment				0	
5. Supplies	30,651	27,881	25,955	84,487	
6. Contractual/Consultants	39,590	39,590	39,590	118,770	
7. Other (Include $1500 for education and outreach)	18,460	16,352	16,268	51,080	
Total Direct Costs	216,797	209,574	212,293	638,664	0
Indirect Costs	96,514	81,823	83,001	261,338	
TOTAL PROJECT COSTS	313,311	291,397	295,294	900,002	0

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5/19/08

NPRB Use Only
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NPRB PROPOSAL SUMMARY PAGE
(To be filled in by applicant)

Project Title:
Effects of inter-annual climate change on food availability, diet composition and productivity of planktivorous and piscivorous seabirds

Project Period: From Date: 05/01/2003 To: 06/30/2006

Name, Address, Telephone Number and Email Address of Applicant:
Dr. Ted DeLaca, Vice Provost for Research
University of Alaska Fairbanks, P.O. Box 757880
Fairbanks, AK 99775-7880
(907) 474-7314; fyosp@uaf.edu

Principal Investigator(s): (Include full contact information here or in CVs, including email address)
Dr. Alexander S. Kitaysky, Assistant Professor (CV attached)
Institute of Arctic Biology, University of Alaska Fairbanks
311 Irving I, P.O. Box 757000, Fairbanks, AK 99775-7000
(206) 543-7623; kitaysky@u.washington.edu

Research Priorities Addressed: Identify up to three priorities from list in RFP (a-g):
a, b

Summary of Proposed Work (250 words or less):
The proposed study will test the hypothesis that climate-induced changes in availability of macro-zooplankton and forage fish determine opposite trends in productivity of planktivorous and piscivorous birds in the continental shelf ecosystems in the North Pacific. Inter-annual variations in the North Pacific Index, timing of ice retreat and summer water temperatures are positively correlated with productivity of piscivorous and negatively with productivity of planktivorous seabirds breeding on Talan I. in the shelf ecosystem in the north-western Pacific. We predict that similar processes occur in the shelf ecosystems in the south-eastern Bering Sea, but are weakly defined in the ocean basin in the Aleutian Is. We propose a three-year field program to examine temporal dynamics of food availability in seabirds breeding on the Pribilofs, Aleutian Is., and Talan I. We will quantify food availability by measuring concentrations of the stress hormone corticosterone in free-living birds. Corticosterone levels in undisturbed individuals ("baseline levels") indicate current food availability, and the rise in corticosterone levels in response to a standardized stressor ("acute stress-induced levels") indicates recent nutritional history. Concurrent assessments of diet composition and productivity of seabirds will be conducted through collaborative projects, which are specifically designed to address these issues. Our study will provide insight on the relationships between climate and food web dynamics at several trophic levels from zooplankton to forage fishes and seabirds, and in several distinct oceanographic sites. This information will help our understanding of how the Bering Sea ecosystem functions and how upper trophic level predators may respond to long-term climate changes and global warming.

Funding: Total NPRB Funding Requested: $923,236

Total Matching Funds Used: $0

Legally Binding Authorizing Signature and Affiliation:

Ted E DeLaca

Ted DeLaca, Vice Provost for Research

Date 1/9/03

NOT TO EXCEED ONE PAGE

Project Title: Effects of inter-annual climate change on food availability, diet composition and productivity of planktivorous and piscivorous seabirds

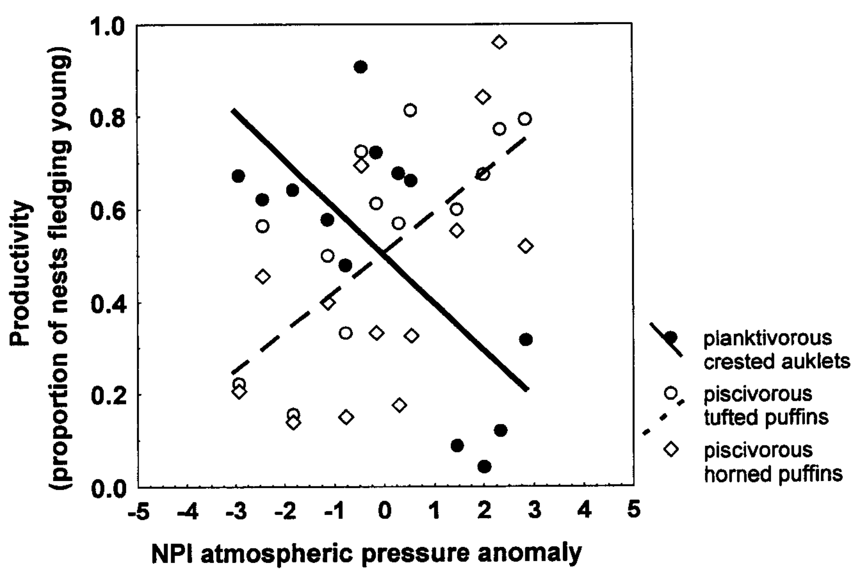
Project Summary: The proposed study will test the hypothesis that climate-induced changes in availability of macro-zooplankton and forage fish determine opposite trends in productivity of planktivorous and piscivorous birds in the continental shelf ecosystems in the North Pacific. Inter-annual variations in the North Pacific Index, timing of ice retreat and summer water temperatures are positively correlated with productivity of piscivorous and negatively with productivity of planktivorous seabirds breeding on Talan I. in the shelf ecosystem in the north-western Pacific. We predict that similar processes occur in the shelf ecosystems in the south-eastern Bering Sea, but are weakly defined in the ocean basin in the Aleutian Is. We propose a three-year field program to examine temporal dynamics of food availability in seabirds breeding on the Pribilofs, Aleutian Is., and Talan I. We will quantify food availability by measuring concentrations of the stress hormone corticosterone in free-living birds. Corticosterone levels in undisturbed individuals ("baseline levels") indicate current food availability, and the rise in corticosterone levels in response to a standardized stressor ("acute stress-induced levels") indicates recent nutritional history. Concurrent assessments of diet composition and productivity of seabirds will be conducted through collaborative projects, which are specifically designed to address these issues. Our study will provide insight on the relationships between climate and food web dynamics at several trophic levels from zooplankton to forage fishes and seabirds, and in several distinct oceanographic sites. This information will help our understanding of how the Bering Sea ecosystem functions and how upper trophic level predators may respond to long-term climate changes and global warming.

Project Responsiveness to NPRB Research Priorities: This project will contribute to the greater goal of understanding how the Bering Sea ecosystem functions and how upper trophic level predators breeding in the North Pacific may respond to long-term climate changes and global warming. In collaborations and coordination with other projects (collaborators: Dr. Alan Springer UAF, Dr. Sara Iverson, Dalhousie University; Dr. Ed Murphy UAF; Vernon Byrd, Alaska Maritime National Wildlife Refuge) we will integrate information on seasonal dynamics of food availability and levels of physiological stress with diet composition and productivity in seabird populations in the Bering Sea. In addition, we will assess food-related stress in populations of seabirds across their reproductive range in the Bering Sea to identify which populations are currently experiencing high levels of physiological stress or are at greatest risk for additional environmental (climate change or human-induced) stressors. This directly meets the NPRB Legislative Criteria, because the proposed study will improve our understanding of the dynamics of the Bering Sea ecosystem and our ability to protect and manage populations of seabirds. This study is also directly connected to the NPRB research priorities ***a*** (Marine Ecosystem structure and processes – our study addresses the influence of climate variability across the Bering Sea on populations of marine upper trophic level predators) and ***b*** (Endangered and stressed species – our study directly addresses the issue of food-related stress in seabirds).

Project Design and Conceptual Approach: Seabirds are important constituents of marine ecosystems, but they are also valuable monitors of changes in environmental conditions. In the past three decades, major climatic and biological transformations have occurred in the marine ecosystems of the Northern Pacific (Springer 1998; Anderson and Piatt 1999; Hare and Mantua 2000; Hunt et al. 2002). During the same period, precipitous population declines occurred among fish-eating (piscivorous) seabirds in the continental shelf areas of the central and south-eastern Bering Sea (Springer 1998; Hunt and Byrd 1999; Hunt et al. 2002; Byrd et al. unpublished), whereas population numbers of zooplankton-eating (planktivorous) birds increased (Springer et al. 1986; Piatt *et al.* 1990; Konyoukhov 1991; Springer 1992). Furthermore, though piscivorous seabirds at the Pribilof Is. declined, populations of the same species in the ocean basin regions in the south-eastern Bering Sea and in the Aleutian Is. increased (Hunt and Byrd 1999). During this same period, population and/or reproductive trends of piscivorous and planktivorous seabirds breeding in the ocean basin environments in the Aleutian Is. were unrelated (Williams et al. 2002). Thus, responses of seabirds to climatic changes in the North Pacific are not uniform and vary dramatically across Bering Sea ecosystem. There is a need for better understanding of the causal links between climate and patterns of productivity at different trophic levels and among oceanographic locations in the Bering Sea. It is critical to investigate this on a fine scale since seabirds' responses to climate fluctuations are clearly localized. A study of a single colony, or a comparative study of two colonies within a particular oceanographic region will not suffice to understand these relationships. The project proposed here addresses this goal by examining effects of inter-annual climate changes on dynamics of food availability in seabirds preying on meso-zooplankton (calanoid copepods), predatory macro-zooplankton (euphausiids and gelatinous zooplankton) and forage fish (juveniles of large species and small fish species) at several colonies in the continental shelf and ocean basin regions in the North Pacific.

Several hypotheses have been proposed to explain the population declines of piscivorous seabirds in the south-eastern Bering Sea (e.g., Straty and Haight 1979; Springer 1992; Decker *et al.* 1995; Hunt *et al.* 1996, 1996a; Springer 1998; Kitaysky and Golubova 2000; Hunt et al. 2002). The project proposed here addresses "bottom-up" hypotheses, which predict that the observed variation in seabird reproduction may be controlled by variation in the distribution and abundance of forage fish (small fish species and juveniles of larger species) following changes in the productivity of meso-zooplankton communities. Hunt and co-authors (2002) hypothesized that the timing of ice retreat and water temperatures during zooplankton production may influence abundance of forage fish available to upper trophic level predators in the continental shelf ecosystems in the south-eastern Bering Sea. There is evidence that meso-zooplankton biomass is higher during "warm" compared to "cold" regimes in the middle domain of the Bering Sea (Walsh and McRoy 1986; Stockwell et al. 2001; Napp et al. 2002, Coyle and Pinchuk 2002a, b). This may increase the availability of food to forage fish and facilitate their better survival and growth during "warm" regimes (Walsh and McRoy 1986). One can predict, that during "warm" regimes the availability of small pelagic fish to piscivorous foraging seabirds should be higher compared to "cold" regimes. Correspondingly, productivity of piscivorous kittiwakes breeding on the Pribilof Is. has been higher during periods with warming SSTs compared to periods with cooling SSTs, and there was a strong positive correlation between SSTs and productivity of kittiwakes during the most recent high pressure state of Aleutian Low (Springer 1998).

Fig. 1. The relationship between North Pacific Index of atmospheric pressure anomaly and reproductive success of planktivorous and piscivorous seabirds in the north-western North Pacific during 1987-2002 (Kitaysky & Golubova, in prep).



Effects of climate variability on abundance of macro-zooplankton in the south-eastern Bering Sea are not well known (Stockwell et al. 2001; Coyle and Pinchuk 2002a, b; Napp et al. 2002). However, it is possible that competitive interactions and/or trophodynamic phasing affect abundance of predatory euphausiids and gelatinous zooplankton. Kitaysky and Golubova (2000) hypothesized that changes in marine climates in the North Pacific may favor the productivity of one group of upper trophic level predators over another through fluctuations in the availability of their prey. They found that in the continental shelf ecosystems in the north-western Pacific (Talan I., northern Okhotsk Sea), birds foraging on macro-zooplankton (euphausiids and gelatinous zooplankton) and birds foraging on forage fish have shown opposite reproductive trends during the past 15 years (Kitaysky and Golubova, in preparation). This pattern was strongly correlated with inter-annual climate variability in the North Pacific. In particular, inter-annual variation in the North Pacific index of atmospheric pressure anomaly (NPI) was positively correlated with productivity of piscivorous and negatively correlated with productivity of planktivorous seabirds (Fig. 1). During this period there were two distinct sets of oceanographic conditions in the northern Okhotsk Sea. A positive NPI anomaly, early dates of ice disappearance (ID) and warm water temperatures defined a "warm" regime, whereas a negative NPI, late ID and cold water temperatures defined a "cold" regime of the ecosystem. A "warm" regime was associated with high abundance of meso-zooplankton, a potential prey of forage fish. Macro-zooplankton organisms, which are the main prey of planktivorous seabirds, were more abundant during a "cold" regime. During a "warm" regime, when in-flow of oceanic waters into shelf areas was weak, proportions of oceanic copepods in seabird diets were lower compared to those during a "cold" regime when in-flow of oceanic waters was relatively strong (Kitaysky and Golubova 2000). Thus, climate-driven alternations in a composition and timing of peak of zooplankton communities and abundance of forage fish probably represent causal mechanisms responsible for opposite trends in reproductive performance of piscivorous and planktivorous seabirds. However, there are no data to address whether productivity of seabirds in this system was directly limited by food-related stress, and the causal links between climate variability and productivity of seabirds are yet to be elucidated.

Biological responses to physical forcing are known to vary according to regional habitat and community characteristics (Frances et al. 1998; Springer 1998; Hare and Mantua 2002). In the central Bering Sea and northern Okhotsk Sea, planktivorous and piscivorous seabirds have shown opposite responses to inter-annual oceanographic change (Springer et al. 1986; Kitaysky and Golubova 2000). On the other hand, in the subarctic North Pacific, planktivorous and piscivorous seabirds breeding on Triangle I. (British Columbia), appeared to have similar reproductive responses to the same suit of oceanographic changes (Bertram et al. 2001). In particular, growth rates of chicks in planktivorous Cassin's and piscivorous Rhinoceros auklets were negatively correlated in both species with the spring timing index and SSTs. Likewise, long-term reproductive trends of Cassin's and Rhinoceros auklets (and other piscivorous seabirds) were parallel on Southeast Farallon I. (California Current system, Sydeman et al. 2001; W. Sydeman, PRBO, personal communications). However, causal factors determining either similarity (in the subarctic North Pacific regions and western Aleutian Is., Williams et al. 2002) or dissimilarity (e.g. northern Okhotsk Sea and central Bering Sea) of reproductive responses between planktivorous and piscivorous seabirds to the same suits of oceanographic conditions are not known. The presence of ice-cover during the winter may be a key factor. The timing of spring primary production is determined predominantly by the timing of ice retreat in the Arctic regions of North Pacific, whereas subarctic regions are ice-free during the winter and the timing of phytoplankton blooms is ice-independent. It is possible that ice-associated phytoplankton blooms in cold waters are decreasing abundance of meso-zooplankton and forage fish (Hunt et al. 2002), while simultaneously increasing macro-zooplankton (e.g. euphausiids) production and abundance, which may enhance food availability for planktivorous seabirds (Coyle and Pinchuk 2002a, b). This would explain higher productivity of seabirds feeding on euphausiids during seasons of late ice retreat, ice-associated phytoplankton blooms and cold water temperatures. It would also explain similar reproductive responses of planktivorous and piscivorous seabirds to the same suits of oceanographic conditions in subarctic areas where ice-associated primary production does not occur. We believe that the study proposed here will provide important clues as to why planktivorous and piscivorous seabirds show opposite reproductive responses to the inter-annual climate changes in the northern continental shelf ecosystems (a large portion of primary production is ice- and ice edge- associated) but their responses are similar in the ocean basin ecosystems in the Aleutian Is. (primary productivity is not dependent on ice).

Work in Progress: Under 1998-2002 EVOS Trustees and 1999-2000 NPMR funding, one of our major goals was to develop a new technique for a reliable assessment of variations in food availability in free-living seabirds: quantitative analysis of the relationship between concentrations of the stress hormone corticosterone and food availability. Using intensive sampling of food abundance (Piatt 2002), endocrinological characteristics of seabirds in Cook Inlet, and a combination of captive and field experiments, this goal has been achieved (Kitaysky et al. 1999a, b; 2001 a, b; in press; Wingfield and Kitaysky 2002). The technique was tested during 1999-2000 on several species of seabirds breeding under varying foraging conditions in the south-eastern Bering Sea (Kitaysky, Piatt and Wingfield 2002b). In combination with diet and productivity assessments, this new field endocrinology technique allowed us to reconstruct ecological conditions of a bird's reproductive season at the Pribilofs and Bogoslof I. in a most efficient way and answer three critical questions – (1) what type of food was available; (2) was there enough food and, if not, when did the food shortage occur; and (3) was food a major factor determining a bird's reproductive performance? Since 1999 we have maintained endocrinological and diet studies at the Pribilofs and Bogoslof I., and as proposed to NPRB in 2002, we have obtained samples from piscivorous and planktivorous seabirds breeding at Bogoslof, Pribilof, St. Matthew and St. Lawrence Is., and at Bluff to assess physiological condition and diet in relation to a geographical location of colonies. Since 1987 we have been also monitoring productivity and diet composition of planktivorous and piscivorous seabirds breeding on Talan I. in the northern Pacific (Kitaysky and Golubova 2000; Andreev, Golubova and Kitaysky, in press; Kitaysky et al. in preparation). This proposal is also directly connected to long-term studies of seabirds populations conducted by USFWS (Alaska Maritime National Wildlife Refuge, Vernon Byrd). Thus, by the end of this currently proposed study we will obtain a time series that would allow us to quantitatively examine the relationship between inter-annual climate change, availability of food and productivity in seabirds breeding in the continental shelf and ocean basin ecosystems in the North Pacific.

The field endocrinology approach substantially enhances traditional methods used to assess food availability in seabirds. Various at-sea surveys have been used successfully to assess abundance of prey potentially available to seabirds. However, these methods have constraints that prohibit their implementation on large spatial and temporal scales. Because at-sea surveys are extremely expensive, they are usually limited to short periods of time and constrained to relatively small sampling areas. In contrast, the physiological measure of food availability is relatively inexpensive, which allows sampling on large spatial scales and targeting of focal breeding sites, and sampling can be conducted as frequently as desired. Most importantly, the field endocrinology approach provides insight on changes in recent food availability and foraging history integrated over periods of weeks. Specifically, temporal changes in food availability can be quantified by measuring concentrations of the stress hormone corticosterone in the blood of undisturbed individuals ("baseline levels", indicate current food availability), and the rise in blood levels of corticosterone in response to a standardized stressor: capture, handling and restraint ("maximum acute stress-induced levels", indicate recent nutritional history). A long-term study of seabirds breeding in Cook Inlet has revealed direct relationships among corticosterone levels, food abundance, reproductive performance and persistence of individuals in populations (Kitaysky, Piatt and Wingfield, in preparation). For instance, in Common Murres, baseline levels of corticosterone were negatively correlated with current food abundance (Fig. 1a), whereas acute stress-induced levels of corticosterone were negatively correlated with food abundance 4 weeks prior (Fig. 1b). Corticosterone levels were also negatively correlated with reproductive performance (Fig. 2), and baseline levels accurately predicted persistence of adult individuals affected by food shortages in a population (Fig. 3).

Fig. 2. The relationship between current (**A**) and former (**B**) food abundance and concentrations of corticosterone in common murres breeding on Duck (D) and Gull (G) islands in Cook Inlet, Alaska. (From Kitaysky et al. in prep).

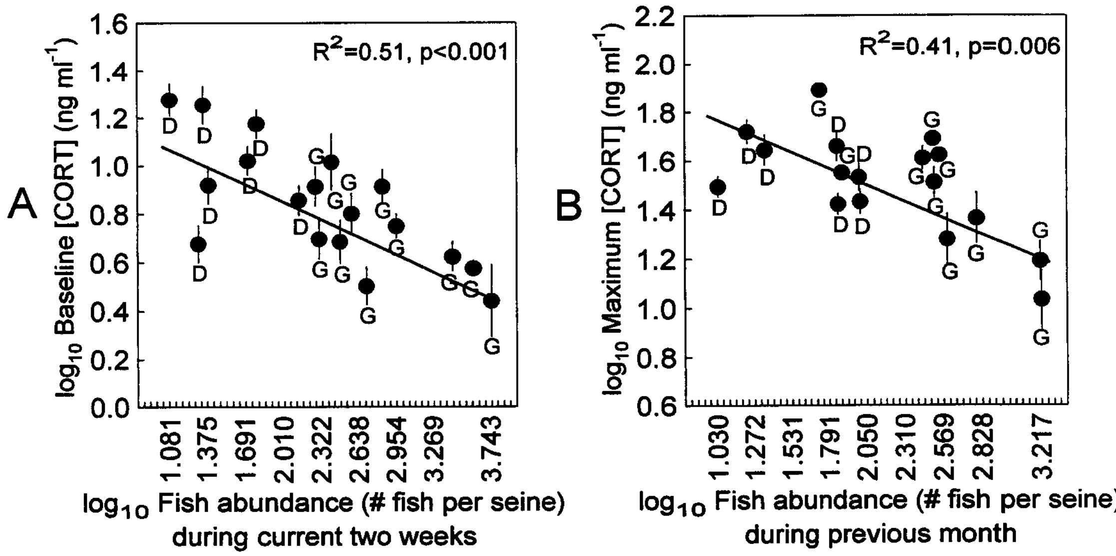
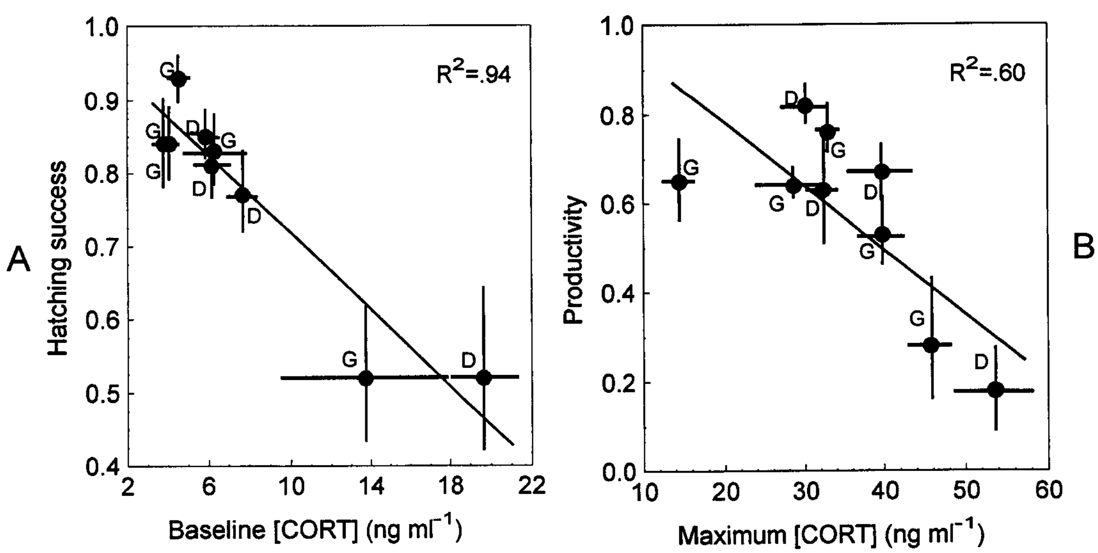
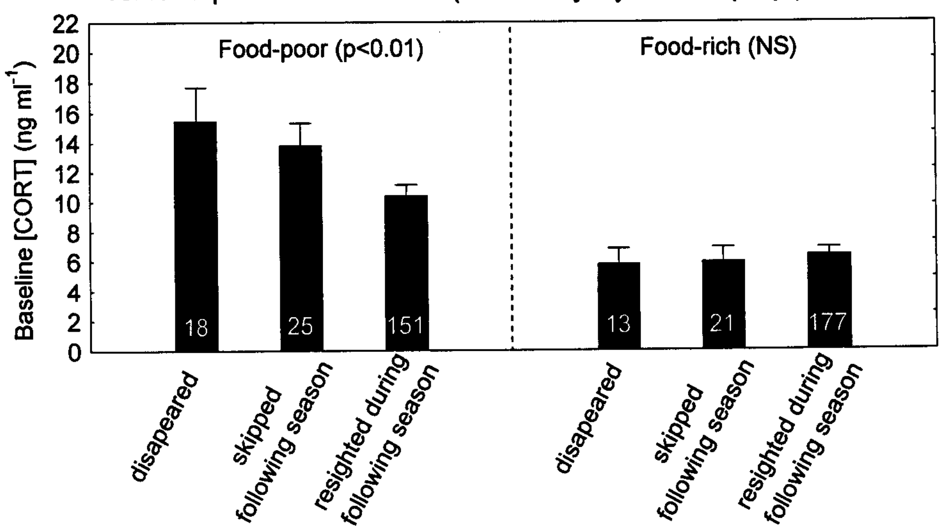


Fig. 3. Corticosterone levels in incubating common murres (Cook Inlet, 1997-2000) as a predictor of their success in hatching of chicks (A), and overall productivity (B).
(From Kitaysky et al. in prep)



We have been also investigating the mechanisms by which food availability translates into reproductive success. In seabird chicks, chronically elevated corticosterone levels were documented in individuals experimentally reared on low-quality and/or reduced-quantity food (Kitaysky et al. 1999b; 2001a; 2002). Specifically, these experiments established an empirical relationship between daily energy intake and corticosterone levels in Black-legged kittiwake, Red-legged kittiwake, and Common murre chicks. Chronically elevated corticosteroid levels are known to result in regression of the reproductive system, suppression of memory and immune systems, lead to muscle wasting and cause neuronal cell death (e.g. Sapolsky 1987, Wingfield 1994). Exposure to poor quality food and/or decreased food availability can have similar debilitative effects on foraging and reproductive behaviors in seabirds. Recent studies of young kittiwakes provide evidence that even a short episode of nutritional stress during development has long-lasting detrimental effects on birds' foraging efficiency (Kitaysky et al., in press). Reduced foraging abilities are likely to translate into a decreased survival and reduced fitness of birds that in turn would further exacerbate declines of seabird populations.

Fig. 4. The relationship between baseline corticosterone levels and persistence of adult common murres in the food-rich vs. food-poor environments (from Kitaysky et al. in prep.)



Thus, the field endocrinology technique provides a quantitative and relevant measure of food availability in populations of free-living seabirds even in the absence of independent data on abundance of their food. It also provides a reliable assessment of current stress status of seabirds and their susceptibility to future stressors.

Hypotheses and Predictions: The major goal of the study proposed here is to examine whether planktivorous and piscivorous seabirds breeding in the south-eastern Bering Sea differ in their reproductive responses to the same suite of oceanographic changes, characterized by the timing of ice retreat, NPI and Aleutian Low anomalies, and SSTs. We will test the hypothesis that climate-driven changes in availability of macro-zooplankton and forage fish determine opposite trends in productivity of planktivorous and piscivorous birds in the continental shelf ecosystems in the North Pacific. We predict that atmospheric pressure anomalies, the timing of ice retreat and SSTs result in two distinct "regimes", one of which enhances stocks of macro-zooplankton and the other meso-zooplankton and forage fishes. We hypothesize that the location of colonies relative to the continental shelf–ocean basin boundaries defines the relationships between climate and dynamics of zooplankton and forage fish abundances. Physical forcing, biological communities and food web structures are distinctly different between continental shelf and ocean basin ecosystems (Cooney and Coyle 1982; Springer et al. 1986, 1996a, b).

We expect that contrasting trends in availability of zooplankton and forage fish will be most strongly pronounced in seabirds breeding at colonies situated in the continental shelf areas (Pribilof Is. in the south-eastern Bering Sea and Talan I. in the northern Okhotsk Sea). In ocean basin areas in the Aleutian Is. (Buldir I.), trends in food availability will be similar between planktivorous and piscivorous seabirds.

Objectives:

1. Examine the effects of inter-annual climate variability (atmospheric pressure anomalies, the timing of ice retreat and SSTs) on inter-annual and intra-seasonal variation in food availability, diet composition and productivity of seabirds at St. Paul I. and Talan I. (continental shelf regions), St. George I. (shelf/oceanic basin boundary), and Buldir I. (ocean basin).
2. In coordination and cooperation with other projects (collaborators: Alan Springer UAF; Sara Iverson, Dalhousie University; Ed Murphy UAF; Vernon Byrd Alaska Maritime National Wildlife Refuge), examine the relationships between stress status and diet compositions in seabirds across their reproductive range in the Bering Sea (south-north axis: from the south-east, the Pribilofs, to central, St. Matthew I., and to the north-east, Bluff; east-west axis: from the eastern Aleutians, Bogoslof I., to the central Aleutians, Kasatochi I., and to the western Aleutians, Buldir I.).

Table 1. Proposed collection of samples for objective 1

Species	Diet composition	Continental shelf		Shelf/ocean basin boundary	Ocean basin
		Talan I.	St. Paul I.	St. George I.	Buldir I.
Least Auklet, *Aethia pusilla*	Meso-zooplankton[1]	A, C	A, C	A, C	A, C
Crested Auklet, *A. cristatella*	Macro-zooplankton[1]	A, C	A	A	A, C
Parakeet Auklet, *Cyclorinchus psittacula*	Macro-zooplankton[1]	A, C	A	A	A, C
Thick-billed Murre, *Uria lomvia*	Forage fish[1]	A	A	A	A
Common Murre, *U. aalge*	Forage fish[1]	A		A	
Horned Puffin, *Fratercula corniculata*	Forage fish[1]	C			C
Tufted Puffin, *F. cirrhata*	Forage fish[1]	C			C
Black-legged Kittiwake, *Rissa trydactila*	Forage fish[2]	A, C	A, C	A, C	A, C
Red-legged Kittiwake, *R. brevirostris*	Forage fish[2]	A, C	A, C	A, C	A, C

Numbers indicate foraging techniques: 1 – pursuit-diving foragers, 2 – surface foragers.
Letters indicate proposed collection of samples: A – seasonal collection of blood and diet/fat biopsy samples from adults; C – collection of blood and diet/fat biopsy samples from chicks. The choice of species and age categories is based on feasibility and logistics for each location.

Methods: We will assess temporal changes in food availability (inter-annual and intra-seasonal) by monitoring levels of corticosterone and diet composition in adults and chicks of several species of piscivorous and planktivorous seabirds breeding in different oceanographic regions (Table 1). The study design presented in Table 1 will allow us to conduct necessary comparisons: (1) between shelf ecosystems in the south-eastern Bering Sea and northern Okhotsk Sea (a comparison between Talan I. and the Pribilofs); and (2) between shelf and ocean basin regions in the Bering Sea (a comparison between the Pribilofs and Buldir I.). The proposed field studies will be coordinated with long-term monitoring programs (PI Vernon Byrd, Maritime National Wildlife Refuge; PIs Alexander Andreev and Elena Golubova, IBPN Russian Academy of Sciences) based out of field stations at the Pribilofs, Buldir I. and Talan I. A broader comparison among shelf and ocean basin systems in the North Pacific will be conducted through a collaboration with other projects, which will collect blood and diet samples of planktivorous and piscivorous seabirds breeding on Bogoslof I., Kasatochi I., St. Matthew Is., and at Bluff. Laboratory analyses will be conducted at the University of Alaska, Fairbanks.

Adult birds will be captured at the breeding colonies with noose poles, mist-nets and noose-mat traps. We will collect a blood sample (approximately 400 µL) from the brachial vein of the wing immediately after capture (baseline corticosterone levels, indicate current food availability). We will measure circulating levels of corticosterone in response to a standardized stressor, capture, handling and restraint (maximum acute stress induced levels, integrate foraging history integrated over periods of weeks). For that, additional samples of blood (100 µL) will be collected from the same birds over a period of 1 h after capture (at 5, 10, 30 and 60 min intervals). To collect blood samples from chicks we will use similar methods as for adult birds, except that the first sample will be smaller (150 µL). For all samples, plasma will be separated from blood cells in the field, and then frozen at –20°C.

The results of our previous studies indicate that a sample size of N≥10 (per species, per sampling period) is sufficient to detect significant inter- and intra-seasonal differences in baseline concentrations of corticosterone in adult birds and juveniles (see references cited and various Figures presented in this proposal). Therefore, approximately 10-15 adult birds of each species (see Table 1) will be sampled at the early incubation, late incubation –early chick-rearing, and at late chick-rearing stages at each colony. Chicks will be sampled prior to fledging. After sampling, adult birds will be released at the colony and chicks returned to their nests. Previous field and captive studies have demonstrated that taking the proposed blood volume (less than 1% of a bird's body mass) is harmless to birds and does not affect the long-term physiological condition or behavior of birds (A. Kitaysky and J. Wingfield, University of Washington, personal observations). Adult kittiwakes, murres, and auklets in Lower Cook Inlet and south-eastern Bering Sea were sighted at their nests within 1-10 min after release. Similarly, bleeding of chicks does not appear to affect their behavior or development.

In parallel to the field research we will conduct the laboratory analyses of blood samples taken from the birds during the experimental manipulations. All plasma samples will be transported to the laboratory at the University of Alaska Fairbanks and processed using radio-immunoassay techniques (see Wingfield and Farner 1976, 1980 for the details). These assays have already been validated for our species of interest.

Project Management: The field experiments and laboratory analyses will be carried out under supervision and active involvement of Dr. A.S. Kitaysky (CV attached) with the aid of one full-time laboratory technologist, three graduate student research assistants and four field assistants. Radio-immunoassay analyses of blood samples collected during the proposed research will be conducted in Kitaysky's laboratory at the University of Alaska, Fairbanks. The principal investigator is responsible for preparation of reports and publications.

Project Milestones: The study will be completed in July of 2007, after three reproductive seasons at the colonies in the Bering Sea, laboratory analyses, and sufficient time for analyses of results, preparation of manuscripts for publication, and preparation of final report. We are committed to publish interim and final results of this study in conference proceedings and peer-reviewed scientific journals.

Project Tasks for Year 1 (May 1, 2003 - June 30, 2004)	
May – September:	preparation for field work, collection of field samples
October-June:	laboratory analyses of blood samples, data analysis
May-June:	report writing
June 30:	Annual Report
Project Tasks for Year 2 (July 1, 2004 – June 30, 2005)	
May – September:	preparation for field work, collection of field samples
October-June:	laboratory analyses of blood samples, data analysis
April-June:	report preparation
June 30:	Annual Report
Project Tasks for Year 3 (July 1, 2005 – June 30, 2006)	
May – September:	preparation for field work, collection of field samples
October-June:	laboratory analyses of blood samples, data analysis
April-September:	report and manuscripts preparation
September 30:	Draft Final Report
June 1, 2007:	Final Report

Coordination and Integration with Other Studies:

The proposed research is a component of a multi-disciplinary, process-oriented research program "Regime Forcing and Ecosystem Responses in the Bering Sea: Phase-2", which includes other components: (1) assessments of diet composition from fatty acid composition, regurgitations, and stomach samples (PIs Dr. Alan Springer and Dr. Sara Iverson, and Dr. Ed Murphy UAF) (2) long-term monitoring of seabird productivity (Alaska Maritime National Wildlife Refuge, Vernon Byrd; IBPN, Russian Academy of Sciences, A. Andreev and E. Golubova), which will provide logistics for field operations. Talan I. is the only long-term (since 1987) monitoring biological station in the north-western Pacific region but no longer has adequate funding. NPRB support of field work at this key colony will enable continued collection of valuable data on population responses of seabirds to climate change and global warming. In coordination with the collaborators, samples will be collected at Kasatochi I., Bogoslof I., St. Matthew, and Bluffs, based on annual and semi-annual cruises aboard M/V Tiglax USFWS, and charter boats as proposed in Springer and Iverson proposal. This study will be also coordinated with the on-going programs in the south-eastern Bering Sea (project leader - Dr. G.L. Hunt, Jr., UC Irvine), and work proposed to NPRB in the Gulf of Alaska (project leader – Dr. J.F. Piatt, USGS).

<u>Outreach and Education:</u>

Three graduate and four undergraduate students from UAF will be supported by the grant. We will generate a website providing a photographic travelogue of our field expeditions, along with a description of the project and its goals, natural history of the relevant species, and photographs with explanations of the field and laboratory techniques used. The accompanying text will be geared toward the general public. The site will be linked to appropriate educational institutions (UAF, Maritime Refuge, USGS, Sealife Center etc.). The money allocated in the budget will buy a site license, camera and pay an undergraduate student to construct and develop the website. In addition, active involvement of Russian colleagues will have a large impact on scientific communities and the general public awareness of environmental changes in the Far-eastern region of Russia.

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Wingfield, J.C. and Kitaysky, A.S. 2002. Endocrine responses to unpredictable environmental events: stress or anti-stress hormones? Integ. Comp. Biol. 42, 600-609.
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Curriculum Vitae

Dr. Alexander Stanislav Kitaysky

Institute of Arctic Biology, University of Alaska Fairbanks; 311 Irving I, P.O. Box 757000; Fairbanks, AK 99775; 206-543-7623; kitaysky@u.washington.edu

EDUCATION

1992-1996 Ph.D., University of California, Irvine, USA

GRANTS, FELLOWSHIPS and AWARDS

Project on the relationship between diet quantity and quality in captive Steller Sea Lions, funded by NOAA/Marine mammal consortium, 2002-2003.

Project on the relationship between diet composition and stress hormones in the Steller Sea Lion, funded by School of Fisheries and Ocean Sciences, PCC, UAF Alaska, 2000-2001.

Project on stress physiology of Steller Sea Lion in the south-eastern Bering Sea, funded by NOAA/Marine mammal consortium, 1999-2001.

Project on population biology and stress physiology of seabirds at Bering Sea colonies, funded by the NPMR, University of Alaska, Fairbanks, 1999-2000.

Project on ecology and stress physiology of seabirds, funded by Exxon Valdez Oil Spill Trustee Council, Alaska, 1998-2002.

Elton Prize for best paper of the year from British Ecological Society, 2001.

EMPLOYMENT

2003-current	Assistant Professor, Department of Biology & Wildlife & Institute of Arctic Biology, UAF
2000-2003	Research Assistant Professor, Department of Zoology, UW
1997-2000	Research Associate, Department of Zoology, UW, Seattle

RECENT RESEARCH EXPERIENCE

1996-2002	Studying effects of the Exxon Valdez oil spill on ecology and stress physiology of seabirds in Lower Cook Inlet, Gulf of Alaska
1999-current	Ecology and Stress physiology of seabirds in the Bering Sea
1999-current	Stress physiology of Steller Sea Lions and Northern Fur Seals in the Bering Sea

RECENT INVITED COLLABORATIONS, LECTURES AND SYMPOSIA

2002 Kitaysky, A.S. Population endocrinology of seabirds. Simon Fraser University, Burnaby, Canada

2002 Kitaysky, A.S. Physiological methods of studying free-living seabirds. Canadian Wildlife Service, Burnaby.

2002 Kitaysky, A.S. Are top-predators breeding in the Bering Sea food-limited? PICES, Quingdao, China.

2001 Kitaysky, A.S. Stress physiology of seabirds: from individuals to populations. UBC, Vancouver, Canada

2001 Regime forcing and Ecosystem Response in the Bering Sea. NPMRP, Fairbanks, Alaska.

2000 Kitaysky, A.S. Cost/benefit analyses of the adrenocortical response of seabirds to food shortages, UC Santa Cruz, CA.

1998 Kitaysky, A.S., J.C. Wingfield, and J.F. Piatt. Behavioural responses of chick and parent Black-legged Kittiwakes to food-related stress. An international conference on foraging behaviour, UC Santa Cruz, July 1998.

Kitaysky, A.S., J.C. Wingfield, and J.F. Piatt. Does parent or chick determine the time of fledging in the Common Murre? 7th International Behavioural Ecology Congress. Pacific Grove, CA, USA, August 1998.

1995 Kitaysky, A.S. Relationship between predictability of food and juvenile traits in planktivorous and piscivorous alcids. Joint conference of the Colonial waterbird society and the Pacific seabird group. Victoria, British Columbia, Canada. November, 1995.

1993 G.L. Hunt, A.S. Kitaysky, M.B. Decker, and D. Dragoo. Characteristics of walleye pollock consumed by seabirds nesting on the Pribilof Islands, Alaska, in 1975-1979 and 1985-1989.

Workshop on the importance of pre-recruit walleye pollock to the Bering Sea and North Pacific ecosystems. Seattle, Washington, USA. October 1993.

RECENT PUBLICATIONS

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Kitaysky, A.S., J.F. Piatt, J.C. Wingfield. 2002. Are seabirds breeding in the southeastern Bering Sea food-limited? Final report to the North Pacific Marine Research Program. University of Alaska, Fairbanks. 41pp.

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Kitaysky A.S., E.V. Kitaiskaia, J.C. Wingfield, J.F. Piatt. 2001. Dietary restriction causes chronic elevation of corticosterone and enhances stress-response in Red-legged Kittiwake chicks. J Comp Physiol B, 171:701-709.

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Kitaysky, A.S. 1999. Metabolic and developmental responses of alcid chicks to experimental variation in food intake: Functional significance of juvenile traits in varying environments. J. Physiological Zoology 72(4):462-473.

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Hunt, G.L., M.B. Decker and A.S. Kitaysky. 1996. Fluctuations in the Bering Sea ecosystem as reflected in the reproductive ecology and diets of kittiwakes on the Pribilof Islands, 1975 to 1990. Pp. 142-153. In: Aquatic Predators and Their Prey (eds. S.P.R. Greenstreet and M.L. Tasker). Blackwell Scientific Publications, Oxford.

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NPRB BUDGET SUMMARY FORM

PROJECT TITLE: Effects of inter-annual climate change on food availability, diet composition and productivity of planktivorous and piscivorous seabirds

PRINCIPAL INVESTIGATOR: Sasha Kitaysky

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	287,094	308,923	327,219	923,236
[illegible]				0
[illegible]	287,094	308,923	327,219	923,236

Annual cost category breakdowns will be requested for matching funds only if project is funded

Cost Categories	NPRB Year 1	NPRB Year 2	NPRB Year 3	NPRB TOTAL	Match/In kind TOTAL (all years)
1. Personnel Salaries	124,640	139,934	150,082	414,656	
2. Personnel Fringe Benefits	19,544	23,597	26,090	69,231	
3. Travel (include 1 trip to review meeting in Anchorage)	15,400	15,400	15,400	46,200	
4. Equipment				0	
5. Supplies	22,050	16,500	15,800	54,350	
6. Contractual/Consultants				0	
7. Other (Include $1500 for education and outreach)	12,908	13,235	13,572	39,715	
Total Direct Costs	194,542	209,166	221,444	625,152	0
Indirect Costs	92,552	99,757	105,775	298,084	
TOTAL PROJECT COSTS	287,094	308,923	327,219	923,236	0

WMF
1-7-03

Appendix

Program: REGIME FORCING AND ECOSYSTEM RESPONSE IN THE BERING SEA - Phase 2
Project Title: Effects of inter-annual climate change on food availability, diet composition and productivity of planktivorous and piscivorous seabirds

Principal Investigator and Project Leader - Dr. Alexander S. Kitaysky, Assistant Professor at the University of Alaska, Fairbanks, IAB and Department of Biology and Wildlife. Obtained a Ph.D. in Ecology and Evolutionary Biology from the University of California in 1996 (dissertation on behavioral, physiological and reproductive responses of seabirds to environmental variability). Since 1986, has studied physiological, environmental and behavioral ecology of marine predators in the Okhotsk Sea, Aleutian Islands, Bering Sea, and in Gulf of Alaska. Implemented first large-scale study validating use of corticosterone levels in free-living animals as indicators of food-availability for practical monitoring and conservation purposes. Has extensive experience with large-scale, multi-site field projects.

Budget Justification

Salaries – PI funds are requested for time (2 months) in years 2 and 3 and no funds are requested in year one for the project leader, Kitaysky. Funds requested to hire one laboratory technologist for 12 months. Funds requested to support three graduate research assistants for 12 months, and four field assistants for 4 months. The PI, research and field assistants in coordination with collaborative projects and Maritime Refuge personnel and participation of Alan Springer and Sara Iverson, will conduct collection of the field samples. The field collection will generate large number of plasma samples (ca ~4,000/year) that can be analyzed for hormone concentrations in a 12-month period. Involvement of the PI and research assistants in the radio-immunoassay analyses is also required for the successful accomplishment of the task. Salaries increase 3% annually.

Travel – includes costs for two RT Fairbanks to Magadan; two RT Fairbanks to Dutch Harbor, and four RT Fairbanks to the Pribilofs for conducting field work; also includes travel to national meetings and conferences. Funds also requested to hire a charter boat to access field sites.

Supplies and Services – Essential items include a freezer and portable centrifuges, tools for capture and handling, and misc. scientific required for this project – they will be purchased in the first year. Camera will be purchased to document field and laboratory operations as requested by Education and Interpretation criteria in the call for the proposals.
Also includes costs of radio-immunoassay analyses (hormone analysis ca 4000 samples @$2.00 each), waste disposal and equipment maintenance services.

Education and interpretation – $1500, includes web site (license, building, maintenance) as requested by the call for the proposals. Three graduate students will be supported by the grant, and participation of undergraduate students from UAF as field assistants is anticipated.

Publication costs – includes costs for publication of the results.

Shipping – includes shipping samples from the field to the UAF.

Indirect Costs (F&A) – UAF negotiated agreement with ONR for FY03-FY04 is 50.4% MTDC for sponsored research, effective March 05, 2002.

NPRB Use Only
Reference No: ________________
Date Received: ________________

NPRB PROPOSAL SUMMARY PAGE
(To be filled in by applicant)

Project Title: Regime Forcing and Ecosystem Response in the Bering Sea (ReFER): Phase II

Project Period: From Date: 1 May 2003 to 30 April 2006

Name, Address, Telephone Number and Email Address of Applicant:
University of Alaska Fairbanks
109 Administrative Services Center
3295 College Road
Fairbanks, AK 99775 - 7880
Attn: Tania Clucas, (907) 474-6736 *proposals@sfos.uaf.edu*

Principal Investigator(s): (Include full contact information here or in CVs, including email address)
Alan Springer, Institute of Marine Science, University of Alaska Fairbanks
Phone: 907-474-6213; Fax: 907-474-7204; email: ams@ims.uaf.edu

Research Priorities Addressed:

Identify up to three priorities from list in RFP (a-g): A (2); B (1, 2)

Summary of Proposed Work (250 words or less): This project would describe diets of seabirds during the breeding season at nesting colonies in the Bering Sea, would reveal how pelagic food webs are organized, and would yield insights on patterns of food web productivity at 4 trophic levels, from phytoplankton to zooplankton, fishes, and birds, and between habitats and over time. Contrasting trends in abundances of several species of seabirds, as well as fur seals, between colonies in two distinct habitats are thought to have been caused by variability in prey populations. Numbers of some seabirds and fur seals at the Pribilof Islands, on the outer continental shelf, have undergone substantial declines in the decades following the mid-1970s, whereas the same species at Bogoslof Island and Buldir Island, in the oceanic Aleutian Archipelago, have experienced equally dramatic increases. The different trends in productivity of food webs supporting seabirds and fur seals in the shallow continental shelf compared to the deep basin might in turn have been caused by distinct ecosystem processes in the two habitats and the way these processes respond to climate change. The information obtained in this study, coupled with that collected since 1999, would make a substantial contribution to the greater goal of understanding how the Bering Sea ecosystem functions and how it may respond to decadal-scale climate change and to long term global warming, a goal captured in the mission statement of the NPRB.

Funding: Total NPRB Funding Requested: $726,862

Total Matching Funds Used: $

Legally Binding Authorizing Signature and Affiliation:

1. **Project Title:** Regime Forcing and Ecosystem Response in the Bering Sea (ReFER): Phase II

2. Proposal Summary

This project would describe diets of seabirds during the breeding season at nesting colonies in the Bering Sea, would reveal how pelagic food webs are organized, and would yield insights on patterns of food web productivity at 4 trophic levels, from phytoplankton to zooplankton, fishes, and birds, and between habitats and over time. Contrasting trends in abundances of several species of seabirds, as well as fur seals, between colonies in two distinct habitats, are thought to have been caused by variability in prey populations. Numbers of some seabirds and fur seals at the Pribilof Islands, on the outer continental shelf, have undergone substantial declines in the decades following the mid-1970s, whereas the same species at Bogoslof Island and Buldir Island, in the oceanic Aleutian Archipelago, have experienced equally dramatic increases. The different trends in productivity of food webs supporting seabirds and fur seals in the shallow continental shelf, compared to the deep basin, might in turn have been caused by distinct ecosystem processes in the two habitats and the way these processes respond to climate change. The information obtained in this study, coupled with that collected since 1999, would make a substantial contribution to the greater goal of understanding how the Bering Sea ecosystem functions and how it may respond to decadal-scale climate change and to long term global warming, a goal captured in the mission statement of the NPRB.

3. Project Responsiveness to NPRB Research Priorities

This project will provide information on diets of seabirds at colonies in the Bering Sea that are sites of intensive, long-term studies of population dynamics and productivity. The information we obtain will also provide temporal and geographic insight into the magnitude of variability in abundances of several ecologically critical species of zooplankton and forage fishes, underpinning explanations of why seabird populations fluctuate, and thus an informative view of ecosystem form and function.

The project responds to NPRB enabling legislation that calls for research addressing marine ecosystems of the Bering Sea. In collaboration with related ongoing and proposed studies, this proposal further responds to the call for cooperative research addressing marine ecosystem information needs. The specific NPRB research priorities addressed are:

a. Marine ecosystem structure and processes
   2. Influence of climate variability on…biological processes
b. Endangered and stressed species
   1. Factors including fisheries affecting survival of stressed and endangered species particularly mammals seabirds and sea ducks.
   2. Responses to ocean climate trends and prey availability.

4. Project Design and Conceptual Approach

Introduction

"Taken as a whole, increasing abundance across a number of species and functional groups suggests that total energy storage in benthic/demersal components of the Bering Sea ecosystem has increased in recent decades. Whether this increase represents an overall gain in the system's productivity or a redirection of energy flows from pelagic to benthic subsystems is unknown."

Connors et al. 2002

This statement was offered recently as an interpretation of the ecological significance of dramatic increases in biomass of a collection of major species of groundfish and benthic invertebrates in the Bering

Sea since the mid-1970s. In addition, and especially, it was offered as a contrast to the conclusion reached by Schell (2000) that productivity of the Bering Sea ecosystem has fallen by some 30% in the past 50 years and that such a change might explain even more extreme declines at higher trophic levels. Despite conclusions reached by Trites et al. (1999), it is difficult to imagine, and there is no empirical evidence for, an alternate, equivalent biomass of silvery forage fishes (in the order of 10 million tonnes) over the continental shelf of the eastern Bering Sea prior to the 1970s.

More than anything else, these conflicting views of ecosystem structure and behavior restate the frustrating questions before us: What IS going on out there? Does the apparent magnitude of change at lower and intermediate trophic levels in the Bering Sea even matter to dynamics of seabird and marine mammal populations—is the bottle neck production processes in a traditional bottom-up context, or is it predation and/or sources of catastrophic mortality operating from the top down or otherwise unrelated in principle to strictly bottom-up mechanisms (Estes et al. 1998; Hunt and Byrd 1999; Williams et al. in review)? Is the bottleneck even in the Bering Sea? —Arguments have been made that it is not (Trites and Bigg 1996).

In the face of this uncertainty, one thing has become clear: answers to these questions will not be found in a year or two. Rather, answers will require time scales proportional to those over which changes have occurred (i.e., decades), and, equally importantly, that a coherent, coordinated attack on the problem be mounted and sustained.

Thus, we propose to continue with a program of research aimed at detecting and understanding variability in the ecosystem of the Bering Sea by viewing that ecosystem through the eyes of seabirds. This program, Regime Forcing and Ecosystem Response (ReFER), was funded in 1999/2000 by the precursor to the NPRB, the North Pacific Marine Research Initiative. It brought together a group of scientists with special skills and knowledge in a collective, but short-term, effort to develop field and laboratory methods to test specific and conceptual hypotheses about how the Bering Sea ecosystem works.

Conceptual Framework

Abundances of several populations of marine birds and mammals in the Bering Sea have varied considerably during the past 3 decades, with examples of both coherence and a lack of coherence between locations and species. For example, Steller sea lions, harbor seals, and sea otters are now much less abundant throughout the region. In contrast, fur seals have declined dramatically on the Pribilof Is., site of the greatest concentrations in their range, yet they have increased even more dramatically on Bogoslof I. in the eastern Aleutians. In a similar manner, piscivorous red-legged and black-legged kittiwakes have declined substantially on the Pribilofs and St. Matthew I., while increasing at Bogoslof I. and Buldir I. in the western Aleutians. Common and thick-billed murres have declined at St. Matthew I., exhibited various trends at the Pribilofs, and increased at Bogoslof and Buldir.

These examples fall into two groups: species that have declined everywhere, i.e., across habitats, and species that exhibit different trends depending upon habitat. Sea lions, harbor seals, and sea otters constitute one group—they have declined at locations in continental shelf habitat, oceanic habitat, and kelp forest habitat. The other group, fur seals and piscivorous seabirds, consists of species that have declined, for the most part, at locations in continental shelf habitat but uniformly increased at locations in oceanic habitat.

This dichotomy suggests that distinct processes are responsible for population trends of species in the two groups. For the first group, top-down mechanisms have been proposed (Estes et al. 1998; Loughlin and York 2000; Williams et al. in review; Springer et al. in review). For the second group, bottom-up processes are more likely explanations of the opposing behavior of populations in different habitats. The project proposed here addresses the second group.

Outcomes of ecosystem processes, and thus functional biological relationships nested within the processes, are known to vary spatially according to regional habitat and community characteristics (Francis et al. 1998; Springer 1998; Hare and Mantua 2002). Based on our knowledge of production regimes in the Bering Sea (e.g., Cooney and Coyle 1982, Springer et al. 1996a), we believe the location of islands on the continental shelf and in the Aleutians, and in relation to the shelf/ocean basin boundary, are crucial to explaining the divergent behavior of seabird and fur seal populations. That is, St. Matthew and St. Paul lie highest on the continental shelf, where food web production is comparatively low; St. George also lies on the shelf, but nearer the shelf edge and the highly productive Green Belt; whereas Bogoslof and Buldir are oceanic islands rising abruptly from the sea floor off the Aleutian Arc, also a highly productive region of the Bering Sea. Biological communities and food webs in such oceanic habitats are distinctly different from those on continental shelves, or from those in shelf-like habitats that occur in the Aleutian Arc (Springer et al. 1996b).

Either of two possibilities could explain the observations of divergent population trajectories: the communities, shelf and oceanic, respond differently to broad-scale physical forcing; or, the nature of forcing (e.g., the translation from meteorological to oceanographic) is different over the shelf than over the basin. In either case, we view the opposing trends in populations on the continental shelf compared to the basin to be important clues to ecosystem behavior and response to climate change.

Work in Progress: The Program

ReFER initially focused on black-legged and red-legged kittiwakes and thick-billed and common murres, all of which are primarily piscivorous, all occur at the Pribilofs and several colonies in the Aleutians, and are the species showing divergent population trends on the shelf and basin. Each species samples the environment in different ways and in aggregate provide a detailed view of fluctuations in forage fish populations.

In 2002 we added planktivorous auklets to the suite of target species. Data from auklets will provide insight into conditions one level lower in the food chain—auklets feed primarily on euphausiids and copepods of key importance to food webs of the N. Pacific and Bering Sea (Springer and Roseneau 1985; Hunt et al. 1983). Moreover, they are very sensitive to fluctuations in the abundance of zooplankton prey (Springer and Roseneau 1985, Springer et al. 1986). Auklet populations in the Bering Sea and Sea of Okhotsk vary inversely to murres and kittiwakes (good conditions for piscivores are commonly bad conditions for planktivores) (Springer et al. 1986; Kitaysky and Golubova 2000). Such behavior could be explained by competitive interactions, trophodynamic phasing, or both, and suggests that a combination of studies of these two guilds will further improve our understanding of ecosystem processes in the Bering Sea.

Work in Progress: This Component

Under the 1999/2000 NPMR funding, one of our primary aims was to adapt and develop a new technique (quantitative fatty acid signature analysis, QFASA) for accurately and quantitatively assessing diets of free-ranging seabirds. This technique had previously been used only in marine and carnivorous mammals (e.g., Iverson et al. 1997, 2001b, Iverson et al. in review).

The QFASA method of estimating diets has numerous advantages over traditional approaches. 1) It provides quantitative information on the contribution of individual prey species to diets integrated over periods of weeks. Traditional approaches of analyzing stomach contents and regurgitations can provide similarly detailed information but on only the most recent meal, while stable isotope analyses provide information on diets integrated over periods of weeks to years, but only on the trophic level of prey. 2) Samples for QFASA can be obtained with minimal invasiveness by taking a biopsy from a subcutaneous lipid reservoir, thus eliminating the need to kill individuals to obtain stomach contents. 3) It provides opportunities for longitudinal and comparative studies of diet and physiological condition of individuals, where data are obtained from every individual sampled regardless of time since feeding.

Using a combination of captive experiments and analysis of free-ranging individuals, we have been able to demonstrate the power of this new technique and validation of diet estimation in seabirds using QFASA (e.g., Fig. 1, Iverson, Springer & Kitaysky, in prep.).

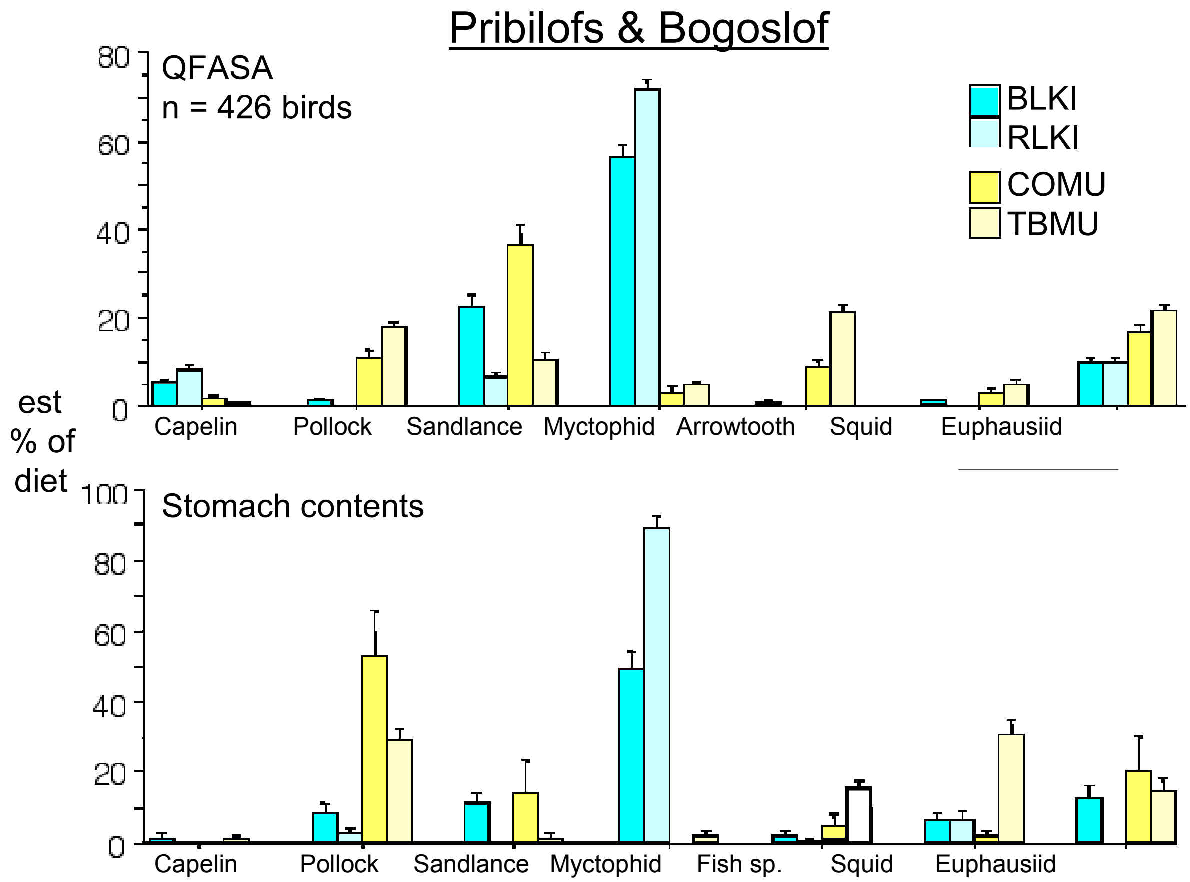

Figure 1. Summary of QFASA estimates of overall diets of free-ranging kittiwakes and murres in comparison to results from stomach contents analysis in a subset of the same individuals.

For example, although the overall diets of murres and kittiwakes were characterized as above, we found significant differences in fatty acid patterns and thus diets both between the two years of study and with geographic region (Fig. 2a, as illustrated for kittiwakes). The differences in diets estimated from QFASA were then used to calculate average fat (and thus energy) content of diets and compared with our collaborative studies of dietary stress and productivity. In 1999, we found that both red-legged and black-legged kittiwakes had significantly lower productivity as measured by indices of clutch size, laying success, hatching success, fledging success, and chick growth. Concurrent with this, kittiwakes had elevated levels of circulating corticosterone, indicating dietary stress in 1999. QFASA studies demonstrated a significantly lower dietary energy content in 1999 compared to 2000 (Fig. 2b). In murres, no differences were found in dietary energy content or productivity between the two years. Although energy content provides an initial and simple basis for comparison, the information on diet diversity and differences between colonies such as Bogoslof, St. Paul and St. George, and shifts in these characteristics over time, will provide finer insight, especially in combination with concurrent measures of stress and productivity.

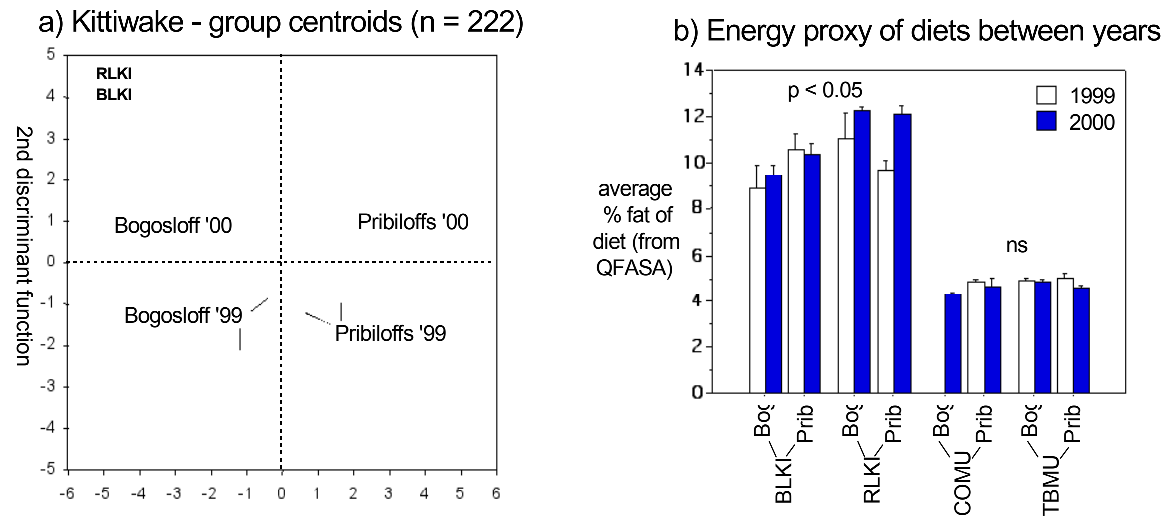

Figure 2. a) Discriminant plot (group centroids) of fatty acid signatures, illustrating differences in diets of red- and black-legged kittiwakes with year and location. The 1st 2 discriminant functions explained 74% of the variance in signatures; 83% of individuals were correctly classified to year and location of collection. b) Relative energy content of diets (using fat content as a proxy) in kittiwakes and murres in the 2 years of study. Energy contents were significantly lower in the kittiwake diets in 1999 compared to 2000.

ReFER received funding for 2 years (1999/2000) from the NPMR initiative. Since then we have maintained diet and stress studies of seabirds at Bogoslof and the Pribilofs with the support of USFWS and contributions of time from the proposers and A. Kitaysky, PI of the collaborating stress hormone project. Funding has not yet been obtained to analyze these samples, which will help us assess the magnitude of spatial and temporal variability in oceanic and shelf habitats that is necessary to understand underlying fundamental ecosystem processes and their relationship to physical variability. In addition, we obtained samples in 2002 from Bogoslof, the Pribilofs, St. Matthew, and Bluff, as proposed to NPRB last year, to test hypotheses about cross-shelf differentials in food web productivity. Thus, we have already obtained a large number of samples, which we propose here to analyze along with new ones obtained with new funding. In aggregate, the samples will yield a time series running from 1999 through 2006.

Hypotheses

- The quality (prey species assemblage and energy density) of seabird diets varies between seasons and years as a function of physical forcing and habitat characteristics.
- Ecosystem processes in the basin have distinct characteristics that contrast with those on the shelf and explain the behavior of populations of conspecifics and functionally related species nesting in the two habitats.
- Conditions favorable for planktivores are unfavorable for piscivores in both habitats.

Thus:

➢ Characteristics of individual seabirds and of populations (e.g., physiological condition, productivity, abundance) at all colonies are determined by diet quality,

Or, alternatively:

- ➢ Overall abundance of prey is more important than quality of prey in constraining seabird populations.

In either case, we hypothesize that:

- ❖ Prey abundance and quality are functions of food web productivity, which is determined by bottom-up processes governing primary production and trophodynamic phasing.

Objectives

- Determine diets of seabirds at focal nesting colonies in the Bering Sea.
- Compare the quality of aggregate diets of seabirds and of important species of forage fishes and zooplankton in continental shelf and oceanic habitats between seasons and years.
- Determine seasonal and interannual variability in the quality of individual forage species.
- Integrate these data with indices of productivity and population trends, and indicators of physiological stress in both individuals and populations, from collaborating studies conducted by A. Kitaysky and V. Byrd.
- Relate results of these analyses to characteristics of habitats and physical variability.

Predictions

- Diets of seabirds during the nesting season do not vary between colonies in oceanic habitats in the Aleutian Is.
- Diets of seabirds at oceanic Aleutian Is. colonies are different than diets at the Pribilof Is.
- The quality of aggregate diets is higher in the Aleutians than at the Pribilofs.
- Diets and aggregate diet quality change throughout the nesting season on the shelf and in the basin.
- The quality of individual prey species changes throughout the nesting season on the shelf and in the basin.
- The quality of individual prey species found both in the basin and on the shelf is higher in the basin.

Experimental Design: General

This project takes advantage of ongoing, long-term programs of the U.S. Fish and Wildlife Service (V. Byrd, Alaska Maritime National Wildlife Refuge) that monitor seabird populations at focal nesting colonies in the Aleutian Is. and Bering Sea. Byrd maintains field camps each year at a suite of colonies in Alaska chosen for their geographic/habitat locations (e.g., oceanic, continental shelf, coastal), the assemblage of species nesting at them, and their history of study. A variety of data on seabirds are collected, including productivity and population trends. Included among the sites are Buldir I. and Kasatochi I. in the Aleutians and St. Paul I. and St. George I. in the Pribilofs (Fig. 3). These will be focal colonies for this study, along with Bogoslof I. We have obtained information as part of this work since 1999 at Bogoslof and the Pribilofs. The selection of these colonies will allow us to test hypotheses that environmental/food web/ecosystem conditions are similar at oceanic locations throughout the Aleutians and different from continental shelf locations as reflected at the Pribilofs. Access to study sites on Buldir I. and Kasatochi I. will be provided by the Alaska Maritime National Wildlife Refuge on its vessel M/V*Tiglax*, which will sail from Dutch Harbor. We will charter a vessel out of Dutch Harbor for transportation to Bogoslof Island; access to the Pribilof Island is provided by commercial air carrier.

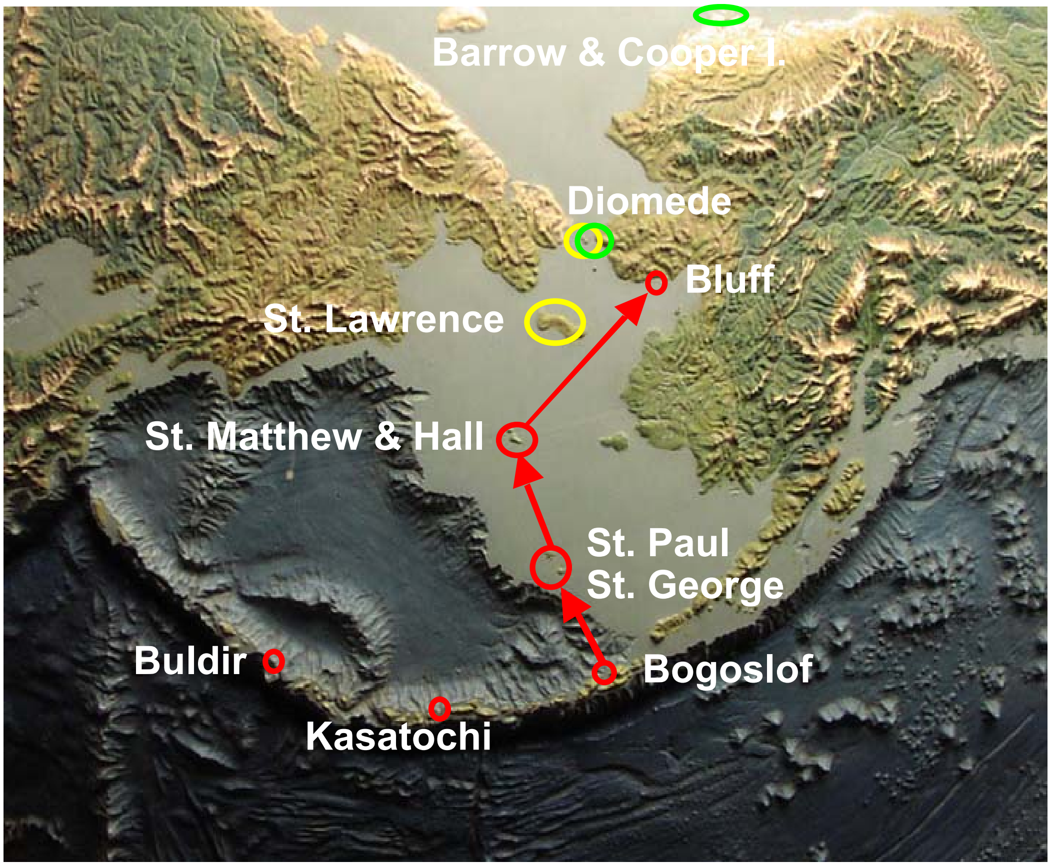

Figure 3. Locations of focal seabird colonies in this study are shown in red. Colonies shown in yellow are sites of collaborative auklet food web studies; those shown in green are sites of ice algae food web studies. Red arrows denote cruise track in 2002

USFWS field crews at Buldir, Kasatochi, St. George, and St. Paul will obtain data on population trends and productivity of seabirds and will contribute to the sampling effort for diet and stress. We will provide one additional person to each of the camps to be responsible for obtaining prey samples for this study. A field crew will not be deployed to Bogoslof, but we will obtain measures of the population status of seabirds and samples for analysis twice during short trips there aboard the *Tiglax* or charter vessel from Dutch Harbor.

We will undertake 3 years of sampling at the focal colonies. Data on diets and stress will be compared between locations and years, as well as to data on trends in abundance and productivity obtained by FWS. In aggregate, the information will inform us about the magnitude of variability between habitats and years in production dynamics of the Bering Sea, and help characterize the mean ecosystem state in the current meteorological regime.

Experimental Design

- Field sampling

Subcutaneous fat samples (synsacral adipose tissue) will be taken by biopsy from live or collected seabirds using methods we developed under the initial project to apply QFASA to seabirds (Iverson, Springer and Kitaysky in prep.). Kittiwakes and murres will be sampled at Buldir, Bogoslof, St. George, and St. Paul (4 species, 10 each 3 times/summer = 480): murres and kittiwakes do not nest at Kasatochi.

Auklets will be sampled at Buldir, Kasatochi, St. George and St. Paul: Buldir – 4 species, 10 each, 3 times/summer; Kasatochi – 3 species, 10 each, 3 times/summer; St. George and St. Paul - 1 species, 10 individuals, 3 times per summer; total = 270. Auklets do not nest at Bogoslof. All birds will also have blood samples drawn for stress hormone analysis.

In addition to using QFASA, the principal method of diet analysis, additional information will be obtained using traditional approaches of stomach content analysis from birds that are collected and from prey regurgitated by adults and chicks during the chick-rearing period.

Prey will be obtained by a variety of means, including vertical plankton tows from the *Tiglax* and skiffs at each field site, bottom and mid-water tows for fish from the *Tiglax*, and by screening puffin burrows and collecting fish dropped by adults during the chick rearing period (see Hatch and Sanger 1992). We will initially focus on two species of copepods as proxies for the zooplankton community—*Neocalanus cristatus* and *N. plumchrus*. Both species are critical prey of auklets and numerous other consumers in the Bering Sea and N. Pacific. They are large, abundant, and can easily be sorted to developmental stage and sex. All samples will be stored frozen for brief periods or preserved in chloroform containing 0.01% BHT in glass vials with teflon-lined caps until analysis can be performed.

- Diet and Prey Analyses

Lipids from all samples will be quantitatively extracted and fat content and fatty acid composition analyzed according to Iverson at al. (1997, 2001a). Data obtained will be analyzed using multivariate discriminant and hierarchical cluster techniques. Simulation studies will be performed, which are an important component of assessing reliability of distinguishing prey species in QFASA (Iverson et al. in review). Finally, quantitative estimates of diets will be obtained using the QFASA model as described in Iverson et al. (in review). These results will then be integrated with those of our collaborative studies with A. Kitaysky and V. Byrd.

Seabird diets will also be estimated using traditional methods of 1) analyzing stomach contents of birds collected for this and other purposes and 2) regurgitations from birds trapped for diet and other studies and from nestling birds handled during weighing. A description of these methodologies can be found in Springer et al. (1984, 1996).

Diets of collected birds will be estimated by both QFASA and stomach contents, as was done in Phase 1, in order to further calibrate the two methods.

Proximate analyses of prey to establish energy density (KJ/g) will be done according to the methodology described by Anthony and Roby (1997) and Van Pelt et al. (1997).

Timeline

Jun-Aug 03	Field work
Sep 03 – May 04	Sample and data analysis
Jan 04	Annual report and manuscripts if appropriate
Jun-Aug-04	Field work
Sep 04 – May 05	Sample and data analysis
Jan 05	Annual report and manuscripts if appropriate
Jun-Aug-05	Field work
Sep 05 – May 06	Sample and data analysis
Jan 05	Annual report and manuscripts
Jun 05	Final report and manuscripts as appropriate

Products of research

We will report results of this research in annual reports and in refereed journals. For example, we have one paper in progress from the initial work validating QFASA for seabird diet studies and describing the field biopsy technique of obtaining fat samples.

5. Project Management and Experience and Qualifications of Personnel

A. Springer will oversee the field portion of the project, diet analyses from stomach contents and regurgitations, and proximate analysis of prey. He has been involved in studies of seabirds and oceanography in Alaska since 1976, and has collaborated with the Co-PI in adapting the QFASA technique to analyses of seabird diets and food web structure in the Bering and Beaufort Seas.

S. Iverson will oversee all laboratory analyses of fat content and fatty acid composition of samples from birds and prey species, and will conduct all modeling and analyses of diets. S. Iverson has a broad background in lipid biochemistry and metabolism, and in the application of physiological and biochemical processes to understanding the ecology and life history of free-ranging vertebrate predators. She has developed the methods and model to use fatty acid signatures as a quantitative tool, through which we can now estimate the species composition of predator diets (Iverson et al., in review). Her laboratory program is currently the center for this area of research worldwide.

6. Coordination and Collaboration

Our approach in ReFER has been to compare relationships between population trend and productivity, diet composition, and stress of individual seabirds in oceanic and shelf habitats as indicators of prey availability and ecosystem state. We obtained information on the full suite of measurements in 2 summers (1999 and 2000) from 3 locations (Bogoslof, St. George, and St. Paul). As noted above, our results, coupled with longer-term abundance trends, indicated a gradient of deteriorating conditions from the basin onto the shelf.

We tested this notion in summer 2002 by sampling at 5 locations across a transect from Bogoslof I. to St. George I. and St. Paul I. as in the past, and continuing across the shelf to St. Matthew I., in the middle shelf domain, and Bluff in Norton Sound in the inner shelf domain (Fig. 3). Replicating the Bogoslof and Pribilofs sampling provided an improved measure of the magnitude of interannual variability in production dynamics in those regions, and provided an additional year to help establish mean conditions in the different habitats during the current climate regime and prior to likely expression of El Nino. Field work in 2002 was supported by the U.S. Fish and Wildlife Service and personnel time was contributed by S. Iverson, A. Kitaysky, and A. Springer, but sample analyses and data analyses are not complete because we received no dedicated funding.

This project remains intimately linked to other components addressing the same questions from different angles. The original ReFER program was comprised of 3 groups addressing: 1) the physiological condition of seabirds by A. Kitaysky; 2) seabird productivity and population status by V. Byrd; and 3) this study. The same group undertook the work in 2002 and would be involved in the studies proposed here. A. Kitaysky is submitting a separate proposal to continue his studies of the physiological condition of seabirds through the use of stress hormones, and V. Byrd will provide logistics support aboard the R/V *Tiglax* and at field camps at his long-term research sites at Buldir I., Kasatochi I., St. George I. and St. Paul I. (see attached letter). He will also provide data on the productivity and status of seabirds.

The proposed continuation of ReFER is another in a group of studies aimed at describing food web structure and variability in the western Arctic. In the northern Bering Sea, it is closely coordinated with ongoing studies of auklet food webs and temporal variability in the Bering Strait region supported by the U. S. Park Service, Beringian Heritage Program (A. Springer, PI; H. Douglas, Co-PI; S. Iverson, collaborator). The goal of this project is to utilize auklets as indicators of ecosystem state and response to climate change in the most highly productive region of the Bering Sea. ReFER is further collaborating with a study of the importance of ice algae to food web production in the western Arctic, with foci on Bering Strait, Barrow, and Cooper I., funded by IARC/CIFAR (A. Springer, PI; S. Iverson, P. McRoy, and S. Budge, Co-PIs; G. Divoky, collaborator).

This is the only study of its kind we are aware of, and thus there would be no duplication of effort. A proposal has been submitted from A. Springer and H. Douglas to expand upon our studies of auklets, diets, and food web structure with high temporal resolution in the Bering Strait region. Results from that work would be supportive of the work proposed here.

7. Possible Peer Reviewers

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3) Dr. Paul Thompson, Reader in Zoology, University of Aberdeen, School of Biological Sciences, Lighthouse Field Station, George Street, Cromarty, Ross-shire, IV11 8YJ, Scotland.
Phone & Fax: 01381 600 548; Email: lighthouse@abdn.ac.uk; http://www.abdn.ac.uk/zoology/lighthouse

8. Project Costs

Year 1:

Salaries: 3 months are requested for A. Springer to oversee the project, participate in field work, supervise the technicians, analyze data, and prepare reports, presentations, and publications. 21 man months of technician time are requested to provide 4 field assistants for 3 months each at camps in the Aleutians and Pribilofs and for 1 assistant for 9 months to prepare for the field season, undertake field work at one of the camps, and undertake stomach contents analyses and proximate analyses of prey in the laboratory. This lab analysis time is needed in Year 1 to process the back log of samples collected by us and USFWS in 1999, 2001, and especially 2002 when we obtained an excellent series of diet samples from Bogoslof, the Pribilofs, St. Matthew, and Bluff, and an extensive collection of forage/food web species from Norton Sound.

Travel: 5 RT Fairbanks-Dutch Harbor are requested to take personnel to the embarkation point with the *Tiglax* for transportation to Buldir, Kasatochi, and Bogoslof. 3 RT Fairbanks-St. Paul are requested to take 2 technicians and A. Springer to the Pribilofs. 1 RT Fairbanks-Anchorage is requested to take A. Springer to the NPRB annual meeting. Per diem is requested for Dutch Harbor and Anchorage only: expenses at all field camps will be provided by USFWS and NMFS.

Services: $39,590 is requested for a subcontract with the Co-PI, S. Iverson, at Dalhousie University for fatty acid analyses and travel for participation in field work and meetings. Dr. Iverson will be responsible for all QFASA modeling, and will participate equally with A. Springer in the analysis and interpretation of combined data sets and in the preparation of reports and publications. $1,000 is requested for CHN analyses of prey to determine protein content for proximate analyses. $2,000 is requested for freight charges for sending equipment to and from Dutch Harbor and the Pribilofs and from Fairbanks to Dalhousie University. $2,000 is requested for publication costs, and an additional $2,000 is requested for public outreach. $20,000 is requested for vessel charter: 1-2 days of the *Tiglax* and 2-3 days of private vessel in Dutch Harbor for an early season trip to Bogoslof, where we will not have a field camp. A second trip to Bogoslof will be provided by the *Tiglax*.

Supplies: $8,000 is requested for field supplies, including 2 portable freezers, 2 generators, 4 tanks of propane, 4 field-grade dissecting scopes, 4 ring nets (0.5 m diameter, 505µ mesh), vials, preservatives, and miscellaneous other items. $2,500 is requested for lab supplies, including solvents for proximate analysis, glassware, and miscellaneous other items.

Contributed costs from USFWS: V. Byrd has been a principal collaborator on this study since its inception. He will continue in that role and will provide transportation to Buldir and Kasatochi on the *Tiglax*, quarters and food at the camps, dedicated sampling opportunities for forage/food web species in the Aleutians during the summer, and data on productivity and abundance of seabirds at all colonies.

Years 2 & 3:

We anticipate project expenses will be less than Year 1 and have presented budgets accordingly. Adjustments to those budgets will reflect modifications in field schedules and sample numbers and will be submitted to NPRB prior to the beginning of the fiscal year.

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Williams, T.M., J.A. Estes, D.F. Doak, and A.M. Springer. In review. Killer appetites: assessing the role of predators in ecological communities.

Resume—Alan M. Springer

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Education

Ph.D. Biological Oceanography, 1988, University of Alaska Fairbanks
M.Sc. Biology, 1974, University of Alaska Fairbanks
B.A. Zoology, 1969, The Colorado College

Selected Appointments

2002-present - Scientific Steering Committee, Center for Global Change, University of Alaska Fairbanks
2002-present - Affiliate Professor, International Arctic Research Center, University of Alaska Fairbanks
1999-2002 - Core Review Panel, *Exxon Valdez* Oil Spill Trustee Council.
1998-present - Advisor to World Wildlife Fund for the Bering Sea Ecoregion Program.
1998-present - Steller Eider Recovery Team, Department of Interior
1997-present - Steller Sea Lion Recovery Team, National Marine Fisheries Service
1996-present - Spectacled Eider Recovery Team, Department of Interior
1996-present - Editorial Board, *Fisheries Oceanography*
1992-present - Research Committee of the North Pacific Universities Marine Mammal Research Consortium

Selected Publications

Speckman, S.G., A.M. Springer, J.F. Piatt, and D.L. Thomas. 2000. Temporal variability in abundance of marbled murrelets at sea in southeast Alaska. Waterbirds 23: 364-377.
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Academic Degrees: Ph.D. Nutritional Sciences, 1988, University of Maryland, College Park.
B.Sc. Zoology, 1979, Duke University, Durham, North Carolina.

Selected Appointments and Professional Positions:

Associate Professor, Department of Biology, Dalhousie University, Halifax, Nova Scotia. 1999 - present. (Assistant Professor, 1994 - 1999).

Research Associate, Smithsonian Institution, Department of Zoological Research, National Zoological Park, Washington D. C. 1990 - present.

Research Associate and NSERC International Fellow, Canadian Institute of Fisheries Technology, Technical University of Nova Scotia, Halifax, Nova Scotia. 1991 - 1994.

Faculty Research Associate, Georgetown University Medical Center, Division of Developmental Biology and Nutrition, Department of Pediatrics, Washington D. C. 1988-1990.

Selected Academic Awards and Honours:

The Killam Prize for Research, Faculty of Science, Dalhousie University, Halifax, NS, 2000-2001.

NSERC (Natural Sciences and Engineering Research Council, Canada) E. W. R. Steacie Memorial Fellowship Award for Outstanding Research. July 1998-June 2000. (http://www.nserc.ca/programs/steacie/cfn_e.htm; http://www.nserc.ca/success_e.htm)

NSERC Women's Faculty Award (Dalhousie University). August 1994-June 1998, July 2000-August 2001 (interrupted for Steacie Fellowship).

NSERC International Postdoctoral Fellowship (Technical University of Nova Scotia). 1992-1994.

Postdoctoral Research Fellowship, American Heart Association (Georgetown University Medical Center, Washington DC). 1989-1990.

Selected Publications:

Beck, C. A., Bowen, W. D., and Iverson, S. J. (*in press*) Sex differences in the seasonal patterns of energy storage and expenditure in a phocid seal. J. Animal Ecology.

Beck, C. A., Bowen, W. D., McMillan, J. and Iverson, S. J. (*in press*) Sex differences in the diving behaviour of a size dimorphic capital breeder: the grey seal. Animal Behaviour.

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Budge, S. M., Iverson, S. J., Bowen, W. D. and Ackman, R. G. (2002) Among- and within-species variation in fatty acid signatures of marine fish and invertebrates on the Scotian Shelf, Georges Bank and southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 59: 886-898.

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Hood, W. R., Kunz, T. J., Oftedal, O. T., Iverson, S. J., LeBlanc, D. and Seyjagat, J. (2001) Interspecific and intraspecific variation in proximate, mineral, and fatty acid composition of milk in Old World fruit bats (Chiroptera: Pteropodidae). Physiol. Biochem. Zool. 74:134-146.

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Mellish, J. E. and Iverson, S. J. (2001) Blood metabolites as indicators of nutrient utilization in fasting, lactating phocid seals: does depletion of nutrient reserves terminate lactation? Can. J. Zool. 79: 303-311.
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Kirsch, P. E., Iverson, S. J. and Bowen W. D. (2000) Effect of diet on body composition and blubber fatty acids in captive harp seals (*Phoca groenlandica*). Physiol. Biochem. Zool. 73: 45-59.
Kirsch, P. E., Iverson, S. J., Bowen, W. D., Kerr, S. and Ackman, R. G. (1998) Dietary effects on the fatty acid signatures of whole Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquatic Sci. 55:1378-1386.
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Iverson, S. J., Frost, K. J. and Lowry, L. L. (1997) Fatty acid signatures reveal fine scale structure of foraging distribution of harbor seals and their prey in Prince William Sound, Alaska. Marine Ecology Progress Series 151: 255-271.
Smith, S., Iverson, S. J. and Bowen, W. D. (1997) Fatty acid signatures and classification trees: new tools for investigating the foraging ecology of seals. Can J. Fish. Aquatic Sci. 54: 1377-1386.
Koopman, H. N., Iverson, S. J. and Gaskin, D. E. (1996) Stratification and age-related differences in blubber fatty acids of the male harbour porpoise (*phocoena phocoena*). J. Comp. Physiol. 165: 628-639.
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Iverson, S. J. (1993) Milk secretion in marine mammals in relation to foraging: can milk fatty acids predict diet? Symposium of the Zoological Society of London, 66: 263-291.
Iverson, S. J. and Oftedal, O. T. (1992) Fatty acid composition of black bear (*Ursus americanus*) milk during and after the period of winter dormancy. Lipids 27: 940-943

Collaborators (not listed above) and Institutions (last 48 months):

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Graduate and Post-Graduate Advisees:

Dr. Suzanne Budge; Shelley Lang, Greg Thiemann, Strahan Tucker, Margi Copper, Jo-Ann Mellish, Penny Kirsch, Jennifer Goldstein, Matthew Logan, Debbie Austin, Mike Goebel, Charlotte Beck, Tyler Schultz, Heather Koopman, Tammy Adams, Sascha Hooker, Heather Layton, Sara Ellis, Monica Muelbert, David Coltman.

NPRB BUDGET SUMMARY FORM

PROJECT TITLE:
Regime Forcing and Ecosystem Response in the Bering Sea (ReFER): Phase II
PRINCIPAL INVESTIGATOR: **Alan Springer**

FUNDING SOURCE	YEAR 1	YEAR 2	YEAR 3	TOTAL
NPRB Funding	258,891	230,461	237,510	726,862
Match/In Kind				0
TOTAL	258,891	230,461	237,510	726,862

Annual cost category breakdowns will be requested for matching funds only if project is funded

Cost Categories	NPRB Year 1	NPRB Year 2	NPRB Year 3	NPRB TOTAL	Match/In kind TOTAL (all years)
1. Personnel Salaries	65,835	69,146	72,613	207,594	
2. Personnel Fringe Benefits	23,149	24,313	25,533	72,995	
3. Travel (include 1 trip to review meeting in Anchorage)	10,200	10,200	10,200	30,600	
4. Equipment				0	
5. Supplies	10,500	5,500	5,500	21,500	
6. Contractual/Consultants	39,590	39,590	39,590	118,770	
7. Other (Include $1500 for education and outreach)	27,750	17,750	17,750	63,250	
Total Direct Costs	177,024	166,499	171,186	514,709	0
Indirect Costs	81,867	63,962	66,324	212,153	
TOTAL PROJECT COSTS	258,891	230,461	237,510	726,862	0