Effects of food stress on survival and reproductive performance of seabirds

Project Number:	02479
Restoration Category:	Research
Proposed By:	USGS, University of Washington
Lead Trustee Agency:	DOI
Cooperating Agencies:	University of Washington
Duration:	final year, 4-year project
Cost FY 02:	$50,000
Geographic area:	Cook Inlet, Gulf of Alaska
Injured resource:	Common Murre,
	Black-Legged Kittiwake

ABSTRACT

Traditional field methods of assessing effects of fluctuations in food supply on the survival and reproductive performance of seabirds may give equivocal results. In this project we applied an additional tool: The measure of stress hormones in free-ranging seabirds. Food stress can be quantified by measuring base levels of stress hormones such as corticosterone in the blood of seabirds, or the rise in blood levels of corticosterone in response to a standardized stressor: capture, handling and restraint. We applied these techniques to seabirds breeding in Lower Cook Inlet and also used captive birds for controlled experiments. This study provided a unique opportunity for a concurrent field and captive study of the behavioral and physiological consequences of stress in seabirds. Moreover, this study provides the basis for management of seabird populations in the areas affected by the *Exxon Valdez* oil spill, which will have broader applications for seabird monitoring programs. This year represents production of a synthesis of the project.

INTRODUCTION

During the last decade, reduced productivity, increased mortality and subsequent population declines occurred among some seabirds and marine mammal species in the Gulf of Alaska. It has been suggested that declines in food availability resulted in food-related stress (Merrick *et al.* 1987, Piatt & Anderson 1996). Oil pollution from the Exxon Valdez oil spill may have exacerbated these stress-related effects. In this context, nutritional stress can be defined as changes in the physiological conditions of individuals that experience a long-term shortage of food or rely on low quality and/or contaminated food resources that impair their ability to reproduce successfully. Alternatively, less severe food shortages may allow reproduction to proceed, but additional stress such as from anthropogenic sources may precipitate reproductive failure. It is frequently difficult, or impossible, to detect these possible types of perturbations by using traditional field methods (Piatt & Anderson 1996).

An approach using well-characterized responses of hormones to stress can provide a sensitive indicator of chronic stress in the environment, or the potential impact of future stressors (Wingfield et al. 1997). Food-related stress is associated with elevated levels of corticosteroids (also known as "stress hormones") in the peripheral system of affected animals (Axelrod & Reisine 1984; Wingfield, 1994). In seabirds, corticosterone levels were elevated in free-living Magellanic penguins exposed to oil pollution (Fowler et al. 1995), and in Black-legged Kittiwakes breeding under poor foraging conditions (Kitaysky et al., 1999*a*). 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 oil pollution and decreased food availability can have similar debilitative effects on foraging and reproductive behaviors in seabirds. The effects of the stress can be detected and monitored through measurements of baseline plasma levels of corticosterone in the peripheral system of potentially affected seabirds. The pattern and extent of a corticosterone increase following application of a standardized stressor such as capture, handling and restraint then indicate potential for stress effects. Furthermore, experimental manipulations with corticosterone levels in captive seabirds provide a way to examine the mechanisms by which increased mortality and decreased reproduction are expressed.

In this study we have examined the possible consequences of food-related stress by measuring circulating levels of plasma corticosterone as an indicator of current and potential stress. We also proposed to investigate the effects of stress on survival and reproduction of several species of seabirds that breed in the Gulf of Alaska and have been affected by the *Exxon Valdez* oil spill. The results of our preliminary results show clearly that the hormone aspects of the study are effective and are powerful indicators of current stress state and equally important, point to populations that are vulnerable to future stress.

NEED FOR THE PROJECT

A. Statement of the Problem

Immediate and potential long-term effects of food-related stress on foraging and reproductive behavior in seabirds are not completely known. Recent declines of seabird populations in the Gulf of Alaska may be a result of a decrease in reproductive success due to an elevated mortality of food-stressed chicks after fledging, and/or the increased mortality of parents that rear their young under poor feeding conditions. Traditional field methods of assessing potential pollution-related stress on the survival and reproductive performance of seabirds may give equivocal results. Lack of knowledge of the long-term effects of pollution-related stress on physiology and behavior prevents us from developing a successful rehabilitation program for seabird populations in the areas affected by the *Exxon Valdez* oil spill. The basic problem is that we do not know the mechanisms of how and at what stage of a bird's life the effects of stress might most strongly affect survival and reproductive performance. Furthermore, we know even less about the recovery of populations from stressful episodes in their life cycles. The latter is critical if we are to implement future programs to successfully manage seabird populations.

B. Rationale

Long-term effects of pollution and stress on seabird reproductive biology are poorly known mostly because, to date, there have been no possibilities for a concurrent study of stress, survival and the monitoring of foraging conditions in seabirds. A critical concurrent assessment of variation in survival of seabirds in Lower Cook Inlet will be provided by on-going project that is designed specifically for these purposes (Restoration Project #01338). An ideal natural experiment to study effects of food stress can be conducted in Cook Inlet because seabirds at one study colony (Chisik Island) are chronically deprived of food, while seabirds at another study colony (Gull Island) have a surplus of food. From these studies, we will develop a protocol to monitor populations of seabirds at other colonies for possible effects of both natural and human-induced environmental perturbations.

B. Location

The project will use laboratory-based location for analyses of samples collected during summer of 2001 and office-based location for writing.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

None in this phase of the project, which will draw only upon existing data.

PROJECT DESIGN

We propose to investigate whether profiles of corticosterone in free-living seabirds reflect stress

status and vulnerability to environmental stress, and how increased corticosterone levels affect reproduction and survival of individual seabirds. To address these questions we will investigate hypotheses and predictions on the relationships among stress physiology, behavior and reproduction in seabirds that breed in the areas affected by the *Exxon Valdez* oil spill. The first set of hypotheses states that the observed population declines are due to a decrease in post-breeding survival or reduced reproductive performances of adult seabirds that reproduce in the areas affected by the *Exxon Valdez* oil spill. In particular, parent seabirds that rear their chicks in the area affected by pollution complete the reproductive season in poorer physiological conditions and suffer greater post-breeding mortality compared with birds that rear young under favorable environmental conditions. These hypotheses predict that: (a) pollution-related stress results in chronically elevated concentrations of corticosterone in the peripheral system of parent seabirds; (b) prolonged increases in concentration of corticosterone cause reproductive failure and an increase in the post-breeding mortality. The second set of hypotheses states that the observed population declines are due to a decrease in post-fledging survival of juvenile seabirds in the areas affected by the *Exxon Valdez* oil spill. In particular, seabirds chicks that were reared in the area affected by pollution complete the reproductive season in poorer physiological conditions and suffer greater post-fledging mortality compared with young reared under favorable environmental conditions. These hypotheses predict that the recovery of seabirds from pollution or food-related stress depends on: (a) age- and species-specific responses to stress in general; (b) the degree to which individuals are stressed and how debilitated they may become by exposure to chronically high corticosterone levels; and (c) foraging conditions after exposure to stress.

Thus, our main objective is to explore the relationships among endocrinological parameters, foraging conditions and survival of seabirds that breed in the areas affected by the *Exxon Valdez* oil spill

A. Objectives

1. Produce a synthesis that summarizes the results of the four-year project and publish major findings in refereed scientific journals.
2. Develop a protocol to monitor populations of seabirds for possible effects of both natural and human-induced environmental perturbations.

C. Methods

All activities will involve analyses of data and samples and writing up of the materials. Details of the original sub-projects are available in the previous FY98-01 Detailed project descriptions.

SYNTHESIS OUTLINE

1. General concept. Endocrine responses to varying foraging conditions: stress or anti-

stress hormones?

Authors: Wingfield JC, Kitaysky AS. In preparation for publication in *American Zoologist*.

In addition to seasonal changes in physiology and behavior that occur in predictable annual cycles, there are facultative responses to unpredictable events such as food shortages. These rapid behavioral and physiological changes represent the emergency life-history strategy and serve to enhance life-time fitness of individuals. Glucocorticoids (corticosterone is a primary glucocorticoid hormone in birds) interacting with other hormones in the hypothalamus-pituitary-adrenal cascade, initiate and orchestrate the emergency life history strategy within minutes to hours. Components of the emergency life history strategy include: re-direction of behavior from a normal life history stage to increased foraging, elevated gluconeogenesis and recovery once the food shortage passes. These physiological and behavioral changes allow an individual to avoid potential deleterious effects of stress that may result from chronically elevated levels of circulating glucocorticoids over days and weeks. In other words, acute rises in glucocorticoids following food shortages allow individuals to avoid chronic stress and serve primarily as anti-stress hormones. Although it is clear that elevated secretion of corticosterone allows an individual to survive "stressful" events, there is a severe cost of prolonged high blood corticosterone levels. There is massive evidence that chronic elevation of corticosterone over weeks or longer has dramatic and debilitating effects including: inhibition of the reproductive system, suppression of the immune system, promotion of severe protein loss, neuronal cell death, and suppression of growth. Therefore it is possible that the stress response only increases fitness during relatively short-term responses (hours to days) to food shortages, and is detrimental to the animal during protracted challenges to homeostasis (days to weeks).

The frequency and magnitude of food shortages vary along environmental gradients. Behavioral responsiveness (or latency of response) of animals to environmental changes might reflect this variability. For instance, behavioral and physiological responses of seabirds to variability in food resources reflects their phylogenetic and ecological characteristics as well as that of their prey (Kitaysky 1999; Kitaysky and Golubova 2000; Kitaysky et al. 2000). In seabirds relying on continuously available food resources, even a short-term decrease in food availability might trigger an emergency life history strategy. So, the more predictable the environment (less stochastic), the quicker physiological and behavioral response to food shortage would be, whereas in less predictable environments (more stochastic) those responses are expected be delayed.

In contrast to variability of environmental change and diversity of life history traits that allow animals to cope with them, the emergency life history strategy is a remarkably consistent trait among all vertebrates, and is aimed to maximize life-time fitness. However, animals are faced with contrasting trade-offs in different stages of reproductive cycle. For example, outside of the reproductive season, survival seems paramount, whereas when breeding, the number of viable offspring produced during current versus future reproductive attempts must be maximized. Thus, the strategy that animals are pursuing when responding to food shortages should reflect which specific component of lifetime fitness is currently being maximized.

2. Specific tasks to be addressed in the synthesis

I. The relationships among corticosterone levels, reproductive stage and varying foraging

conditions in adult seabirds.

To assess whether Black-legged kittiwakes and Common murres from the different populations are chronically stressed or not, we will examine the relationships among baseline and acute stress induced levels of corticosterone, reproductive stages (pre-incubation, incubation and chick-rearing), and food abundance. Some of the obtained results have been already published (Kitaysky et al. 1999a, Kitaysky et al in press). Also, we are planning to prepare two major papers on this subject by incorporating the data collected during reproductive seasons of 1998-2001 for publication in ecological journals (authors: Kitaysky, Piatt, Wingfield).

II. The relationships among food provisioning, nutritional state and corticosterone secretion in juvenile seabirds.

To address the issue of the physiological response of juvenile seabirds to variability in food provisioning, we will analyze the results of captive experiments and compare them to data collected in the wild. Some of the obtained results have been published (Kitaysky et al. 1999b, Kitaysky et al. in press), and we are planning to prepare two more manuscripts for publication in physiological journals (authors: Kitaysky, Wingfield, Piatt).

III. The relationship between corticosterone secretion, reproductive performance and post-breeding survival of seabirds.

To make a conclusive statement about the relationships between stress and survival in parent Black-legged Kittiwakes and Common Murres in Lower Cook Inlet, we will coordinate this component of the study with the results of EVOS-funded project (Restoration Project #01338) that is specifically designed to address the issue of survival of adult murres and kittiwakes in relation to foraging condition. We are planning to prepare two manuscripts for publication in ecological journals (authors: Kitaysky, Piatt, Shultz).

3. Field endocrinology protocol for monitoring seabird populations.

The major findings of this project are worth formalizing in a protocol for monitoring seabird populations. We will prepare a manuscript summarizing major results and methods for publication at the Journal of Wildlife Management.

D. Contracts and Other Agency Assistance

The laboratory analyses will be carried out by Dr. Alexander Kitaysky, a research associate in the Zoology Department at University of Washington, Seattle, with the aid of one full-time assistant. Dr. John Piatt of the US Geological Survey will provide logistical support and participate in writing. Radio-immuno assay analyses of blood samples collected during summer 2001 will be conducted in Dr. Wingfield's laboratory at UW. Dr. Wingfield will provide the supervision of laboratory analyses, provide logistical support and participate in writing.

SCHEDULE

A. Measurable Project Tasks for FY 01

2002

September - February:	laboratory analyses and finalizing the results
May-August:	Synthesis manuscripts due
September:	Final report due

B. Project Milestones and Endpoints

2002	Final analyses completed.
2003	Synthesis of the results published

C. Completion Date

September 30, 2003

PUBLICATIONS AND REPORTS

See section above for publications. A progress report will be produced by April 15, 2003.

NORMAL AGENCY MANAGEMENT

None of the proposed research described here would normally be conducted by the USGS.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This study addresses a number of questions related to conservation and management of Alaskan seabirds. The proposed research will be coordinated with on-going projects being supported by the Exxon Valdez Oil Spill Trustee Council and US Geological Survey.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

The design of the proposed work has not changed, and the budget is the same as that originally proposed and accepted by the EVOSTC in FY98.

PRINCIPAL INVESTIGATORS

Principal Investigator and Project Leader - Dr. Alexander S. Kitaysky, Research Associate with the University of Washington, Seattle. Obtained a Ph.D. in Ecology and Evolutionary Biology from University of California in 1996 (dissertation on behavioral, physiological and reproductive responses of seabirds to environmental variability). Since 1986, studied seabird behavior and physiology at colonies in Okhotsk Sea and on the Aleutian Islands, and foraging behavior of seabirds at sea in Bering Sea, Aleutian Islands and in Gulf of Alaska.

Dr. John F. Piatt (Research Biologist GS-14, Alaska Biological Science Center, USGS, Anchorage, AK) obtained a Ph.D. in Marine Biology from Memorial University of Newfoundland in 1987. His dissertation involved seabird-forage fish interactions. Since 1987, he has studied seabirds both at colonies and at sea in the Gulf of Alaska, Aleutian Islands, and Bering and Chukchi seas. His is an author on over 75 peer-reviewed scientific publications about seabirds, fish, marine mammals, and effects of oil pollution on marine birds.

OTHER KEY PERSONNEL

Professor John Wingfield (University of Washington, Seattle). Financial and logistic support for laboratory analyses in his lab at UW. He is an author on over 250 scientific publications. Prof. Wingfield is Chair of the Zoology Department at UW and an internationally recognized leader in the field of avian endocrinology.

LITERATURE CITED

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2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002	LONG RANGE FUNDING REQUIREMENTS					
Personnel		$0.0						
Travel		$0.0						
Contractual		$51.4						
Commodities		$0.0						
Equipment		$0.0						
Subtotal	$0.0	$51.4						
General Administration		$3.6						
Project Total	$0.0	$55.0						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

Close out year, costs for Research Work order with University of Washington only.

FY02

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Personnel Costs:		GS/Range/	Months	Monthly		P
Name	Position Description	Step	Budgeted	Costs	Overtime	
NONE						
	Subtotal		0.0	0.0	0.0	
					Personnel Total	

Travel Costs:	Ticket	Round	Total	Daily	P
Description	Price	Trips	Days	Per Diem	
NONE					
				Travel Total	

FY02

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Contractual Costs:	P
Description	
4A Linkage Research Work Order with University of Washington to support Alexander Kitaysky for 12 months to write final report and publications	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	
Commodities Costs:	F
Description	
Commodities Total	

FY02

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

New Equipment Purchases:	Number of Units	Unit Price	P
Description			
NONE			
Those purchases associated with replacement equipment should be indicated by placement of an R. **New Equipment Total**			

Existing Equipment Usage:	Number of Units	I
Description		

FY02

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$0.0						
Travel		$0.0						
Contractual		$0.0						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$0.0						
Indirect								
Project Total	$0.0	$0.0						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY02

Prepared:

Project Number:
Project Title:
Name:

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Personnel Costs:				Months	Monthly		P
	Name	Position Description		Budgeted	Costs	Overtime	
		Subtotal		0.0	0.0	0.0	
						Personnel Total	

Travel Costs:		Ticket	Round	Total	Daily	P
	Description	Price	Trips	Days	Per Diem	
					Travel Total	

FY02

Prepared:

Project Number:
Project Title:
Name:

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Contractual Costs:	P
Description	
Contractual Total	

Commodities Costs:	F
Description	
Commodities Total	

FY02

Prepared:

Project Number:
Project Title:
Name:

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

New Equipment Purchases:	Number of Units	Unit Price	P
Description			
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	

Existing Equipment Usage:	Number of Units
Description	

FY02

Prepared:

Project Number:
Project Title:
Name: