19.07.04 (3 of 8)

APEX: Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska

Project Number:	98163 A-S
Restoration Category:	Research
Proposer:	David Cameron Duffy, Project Leader, University of Alaska Anchorage
Cooperating Agencies:	DOI, ADF&G, NOAA
Alaska SeaLife Center:	yes
Duration:	Third year of five-year project
Cost FY 98:	$ 2,017.0 K
Cost FY 99:	$2,000.0 K
Cost FY 00:	$176.4 K
Geographic Area:	Prince William Sound, Cook Inlet, Northern Gulf of Alaska
Injured Resource/Service:	Common Murre, Harbor Seal, Marbled Murrelet, Pacific Herring, Pigeon Guillemot.

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ABSTRACT

This study uses seabirds as probes of the trophic (foraging) environment of Prince William Sound, comparing their reproductive and foraging biologies, including diet, with similar measurements from Cook Inlet, an area with apparently a more suitable food environment. These measurements are compared with hydroacoustic and net samples of fish to calibrate seabird performance with fish distribution and abundance, to allow us to determine the extent to which food limits the recover of seabirds from the *Exxon Valdez* oil spill. We sample fish to compare diet, energetics and reproductive parameters of the different forage-fish species, to determine whether competitive and predatory interactions or different responses to the environment may be favoring the abundance of one fish species over another.

Combined, these data will allow us also to determine critical habitats for forage fish and seabirds dependent on them, both on land and on sea, so that future developments, many flowing from the initial publicity over the spill, can be routed away from such areas. Identification of prime forage fish habitats may also allow restoration activities to provide or protect suitable nesting habitat within seabird foraging distance of such habitat.

INTRODUCTION

The spill from the oil tanker *Exxon Valdez* resulted in significant mortality of several seabirds and in acute massive damage to Prince William Sound (PWS) and the Gulf of Alaska (GOA) (Piatt *et al.* 1990). Six years following the spill, several species have not recovered. This may be the result of lingering effects of the oil spill (toxicity of prey or sublethal effects of oil exposure to organisms). Other non-oil factors may also be involved, such as predation, climate-driven ecosystem changes, or even 'random' perturbations.

Both to aid in the recovery of injured resources and to safeguard the long-term health of Prince William Sound and the upper Gulf of Alaska, we need to understand the ecological processes that control the ecosystem. This project focuses on the trophic interactions of seabirds and the forage species they feed on. We chose food as the focus because: 1) much of seabird population theory and several empirical field tests have identified food as an important limiting factor (Ashmole 1963; Cairns 1989; Birt *et al.* 1987; Furness and Birkhead 1984); 2) seabird/fish researchers in the PWS/GOA complex have concluded that major changes in food have occurred during the period (Springer 1993; Anderson *et al.* 1994; Piatt and Anderson 1995); 3) other factors such as oil toxicity and climate change might express themselves through the food supply; and 4) knowledge of the forage prey base is critical for other apex predators, such as marine mammals and predatory fish (Pitcher 1980, 1981; Lowry *et al.* 1989), as well as for any larger effort to manage the marine resources of Prince William Sound and the Gulf of Alaska in a sustainable manner.

We propose to continue the study of the distribution and abundance of prey species through acoustic and net sampling in relation to food, environmental conditions and possible competitors, then to examine the physical, behavioral and competitive factors that limit access to these forage species for seabirds. We will examine the reproductive consequences of such limitations for pigeon guillemots *(Cepphus columba),* black-legged kittiwakes (*Rissa tridactyla),* tufted puffins (*Fratercula cirrhata),* common murres (*Uria aalge)* and cormorants (*Phalacrocorax* spp.).

By examining the diet and reproductive consequences for a surface-feeder (kittiwake), a benthic diver (pigeon guillemot), and two pelagic divers (puffin and murre), we should be able to build up a picture of the forage base for the entire seabird community, setting the stage for a long-term, low-cost monitoring program. The study will make between-year comparisons within sites and within-year comparisons between sites in Prince William Sound and Lower Cook Inlet, areas that have different food-availability. The comparisons between years will allow us to assess the degree of variability of different food regimes, while the between-site comparisons will allow us to assess the responses of seabird communities to these same regimes.

In addition, we will be using models to relate oceanographic and spatial features of Prince William Sound and the Gulf of Alaska to changes in seabird diet and population trends.

NEED FOR THE PROJECT

A. Statement of Problem

Numerous seabird species have declined between surveys in the 1970's and the 1990's in Prince William Sound: cormorants (*Phalacrocorax* spp.), kittiwake, glaucous-winged gull (*Larus glaucescens*), Arctic tern (*Sterna paradisaea*), Kittlitz's and marbled murrelets (*Brachyramphus brevirostris* and *B. marmoratus*), tufted and horned (*F. corniculata*) puffins, and pigeon guillemot (Agler *et al.* 1994 a,b; Klosiewski and Laing 1994). Colony trends for kittiwakes in Prince William Sound have been inconsistent, with colonies decreasing in the southern portion and increasing in the north (Irons unpubl. data). The population of pigeon guillemots in PWS has decreased from about 15,000 in the 1970's to about 3,000 in 1993 (Isleib and Kessel 1973; Sanger and Cody 1993). Based on censuses taken around the Naked Island complex, pre-spill counts were roughly twice as high as post-spill counts (Oakley and Kuletz 1993). Pigeon guillemots are listed as "Not recovering" in the 1994 *Exxon Valdez* Oil Spill Restoration Plan.

Common murres were among the species most damaged by the oil spill (Piatt *et al.* 1990), but most of the oiled birds nested outside PWS. Murres were also listed as "Not recovering" in the 1994 *Exxon Valdez* Oil Spill Restoration Plan, but have been upgraded to "recovering" because productivity has been normal since 1993 (Roseneau *et al.* 1995, 1996).

The best evidence for a shift in trophic resources for seabirds within Prince William Sound comes from pigeon guillemots. No long-term diet data sets exist for other species or, like black-legged kittiwakes, diet exhibits great year to year variability. In 1994, sand lance (*Ammodytes hexapterus*) accounted for only about 1% of prey items fed to guillemot chicks at Jackpot Island and about 8% at Naked Island ; in contrast, in 1979 the sand lance component at Naked Island was about 55% (Kuletz 1983; Oakley and Kuletz 1993). Gadids were much more prevalent in the diet of guillemot chicks on Naked Island in 1994 (ca. 30%) than they were in 1979-1981 (< 7%) (Kuletz 1983).

Pre-spill studies of pigeon guillemots breeding at Naked Island suggest that sand lance are preferred prey during chick-rearing (Kuletz 1983). Breeding pairs that specialized on sand lance tended to initiate nesting attempts earlier and produce chicks that grew faster and fledged at higher weights than did breeding pairs that preyed mostly upon blennies and sculpins, at least in years when sand lance were readily available. Consequently, the overall productivity of the guillemot population was higher when sand lance were available.

The decline in the prevalence of sand lance in the diet of guillemots breeding at Naked Island might be a key element in the failure of this species to recover from the oil spill. The schooling behavior of sand lance, coupled with their high lipid content relative to that of gadids and nearshore bottom fish, might make this species a particularly high-quality forage resource for PWS pigeon guillemots. This is consistent with the observation that other seabird species (e.g., puffins, murres, kittiwakes) experience enhanced reproductive success when sand lance are available (Pearson 1968; Harris and Hislop 1978; Vermeer 1979, 1980; Monaghan *et al.* 1993) .

Several other factors may be at work. The major shifts seen in the northern Gulf of Alaska and North Pacific (Springer 1993; Piatt and Anderson 1995) may have favored pollock (*Theragra chalcogramma*), also an important seabird food (Springer and Byrd 1989) which has become one of the most abundant forage fish species currently available to seabirds (Parks and Zenger 1979; Brodeur and Merati 1993; Haldorson unpubl. data). Pollock may be an important competitor or predator of other forage fish species and may have suppressed populations of these species.

Similarly, other species pairs may overlap in diet, such as herring and sand lance (McGurk and Warburton 1992) or pink salmon (*Oncorhynchus gorbuscha*) and sand lance (Sturtevant 1995 and unpubl.), raising the possibility that reductions in the trophic role of one species may 'release' others from competition for food.

B. Rationale/Link to Restoration

Both scientific theory and common sense suggest that ecosystems change over time and that changes to one species or other component of the ecosystem may reverberate through the entire ecosystem (Pimm 1984; Wolfe and Kjerfve 1986). Such changes have occurred in the North Pacific and Gulf of Alaska (Hatch *et al.* 1993; Springer 1993; Piatt and Anderson 1995). Climate variations, fishing, or an oil spill may trigger changes that can take years to become apparent (Duffy 1993). Similarly, restoration efforts following the *Exxon Valdez* oil spill might increase injured species that are predators or competitors of other injured species, preventing their recovery several years after oil was removed as an immediate cause.. By studying only the species level, we may miss such effects. An ecosystem approach, such as the APEX study of the upper-trophic level predators of Prince William Sound, is designed to look for such indirect links and to improve our understanding of the ecological context lacking from single-species work (Wheelwright 1994). In conjunction with the Sound Ecology Assessment Project and the Nearshore Vertebrate Predators Project, ecosystem projects funded by the *Exxon Valdez* Oil Spill Trustee Council, APEX will give us a basic understanding of the ecological processes that may affect future changes in upper trophic levels that may in turn affect restoration efforts and also help us to determine when we have finally restored a sustainable and healthy Prince William Sound.

C. Location

The project will conduct field work in Prince William Sound and Lower Cook Inlet, with historical analyses covering the entire Northern Gulf of Alaska.

COMMUNITY INVOLVEMENT

APEX will continue to work with Council radio and press efforts and directly with the press. P.I.s also will participate in the International Symposium on Changes in Pacific Seabirds in Asilomar, California in 1998.

PROJECT DESIGN

A. Objectives

Each objective number also refers to the hypothesis of the same number below.

1. Summarize and interpret existing historical data on change in forage fish populations.
2. Determine whether differences in diet exist between forage fish species and determine the consequences at the individual and population level.
3. Determine the distribution of forage species in relation to oceanographic processes.
4. Productivity and size of forage species change the energy potentially available for seabirds.

5. Determine if forage fish characteristics (water depth, school density, prey size) and interactions among foraging seabirds (kleptoparasitism, aggression) determine access to prey or prey schools for different seabird species.

6. Determine if seabird foraging group size and species composition correlate with prey patch size.

7. a. Determine the degree of correlation between seabird diet composition and amount and the relative abundance and distribution of forage fish at relevant scales around colonies

   b. Determine the "relevant scales".

8. Determine if forage fish abundance predicts adult seabird foraging trips, chick meal-size and chick provisioning-rates.

9. Determine if differences in forage fish nutritional quality predict seabird reproductive productivity.

10. Determine if seabird species within a community react predictably to the different prey bases identified in Objective 1.

B. Methods

It is important to note that the methods presented here are overviews, details can be found in the individual descriptions of projects in the appendices. Also, APEX planning is extremely dynamic and changes are likely to occur in response to oceanographic or other events such as storms, catastrophic predation at certain colonies, extreme shifts in prey distribution, or the results of the projects themselves.

General Hypothesis

A shift in the Prince William Sound marine trophic structure has prevented recovery of injured resources.

Working Hypotheses

1. The trophic structure of PWS has changed at the decadal scale.

2. Planktivory is the factor determining abundance of the preferred forage species of seabirds.

3. Forage fish species and jellyfish differ in their spatial responses to oceanographic processes.

4. Productivity and size of forage species change the energy potentially available for seabirds.

5. Forage fish characteristics and interactions among seabirds limit availability of seabird prey .

6. Seabird foraging group size and species composition reflect prey patch size.

7. Seabird diet composition and amount reflect changes in the relative abundance and distribution of forage fish at relevant scales around colonies.

8. Changes in seabird productivity reflect differences in forage fish abundance. as measured in adult seabird foraging trips, chick meal-size and chick provisioning-rates.

9. Seabird productivity is determined by differences in forage fish nutritional quality.

10. Seabird species within a community react predictably to different prey bases.

List of Projects

Project	PI	Short Title
a.	Haldorson	Fish population sampling
b.	Ostrand	Seabird foraging
c.	Sturtevant	Fish diets
d.	--	*not active in 1998*
e.	Irons/Suryan	Kittiwake foraging and reproduction
f.	Hayes	Guillemot foraging and reproduction
g.	Roby	Seabird reproduction and energetics
h.	--	*not active in 1998*
i.	Duffy	Project leader
j.	Roseneau	Barrens nesting study
k.	--	*not active in 1998*
l.	Piatt, Anderson & Blackburn	Historical analysis
m.	Piatt	Cook Inlet studies
n	Romano	Captive feeding
o.	McDonald	Statistical support
p.	--	*not active in 1998*
q.	Ainley & Ford	Modeling
r.	Kuletz	Murrelets
s.	Purcell	Jellyfish

Methods by Objective

The lead project with responsibility for coordinating data sharing is given in bold face.

1. *Summarize and interpret existing historical data on change in forage fish populations.*

Major changes in community structure and species abundance over the last several decades. Project **98163 L** will use existing trawl and net sample data from NMFS and ADF&G to further examine changes in forage fish communities over the last t three decades.

2. *Determine whether differences in diet exist between forage fish species and determine the consequences at the individual and population level.*

   Projects **98163 C** and **S** will examine diet differences, using fish and jellyfish samples provided by **98163 A,** which will also examine the condition of fish caught.

3. *Determine the distribution of forage species in relation to oceanographic processes.*

   Project **98163 A** and **S** will use acoustic sampling, net surveys, and oceanographic sampling to determine whether fish, crustaceans, and jelly species respond predictably to environmental conditions, such as depth, water temperature, distance offshore, or salinity. Inshore sampling will coordinate methods and logistics with the SEA and NVP projects.

4. *Productivity and size of forage species change the energy potentially available for seabirds.*

   Body condition of fishes changes with size, species, and date. Projects **98163 A** and **G** will examine this; **A,** using fish caught by sampling and **G**, using fish caught by birds.

5. *Determine if forage fish characteristics (water depth, school density, prey size) and interactions among foraging seabirds (kleptoparasitism, aggression) determine access to prey or prey schools for different seabird species.*

   Depth of prey, distance offshore and presence of other species affect the species' composition of seabird foraging flocks. Project **98163 B** will examine foraging compared to previous years during transects by Project **98163 A** and the **SEA herring** project.

6. *Determine if seabird foraging group size and species composition correlate with prey patch size.*

   Project **98163 B** will continue to examine foraging in relation to the data collected by Project **98163** A and the **SEA herring** project.

7. *a. Determine the degree of correlation between seabird diet composition and amount and the relative abundance and distribution of forage fish at relevant scales around colonies.*

   At a meso-scale level, three Cook Inlet colonies showed a correlation between food availability and seabird reproductive and foraging performance. Further efforts will include a joint project involving fish distribution data from **98163 A,** foraging data from projects **98163 B and M,** and diet data at colonies from projects **98163 E, F,G, J, M.** Data will be examined within Cook Inlet and within PWS, as well as across all study sites.

   b. Determine the "relevant scales".

Spatial scales will be determined from shipboard transects (Projects **98163 B** and **M, R**) and radiotracking (Project **98163 E**) of seabirds and from repeated sampling of fish ((98163 A and M); temporal scales will be determined retrospectively from the times over which diet and growth of seabirds (Projects **98163 E, F,G, J, M**) and distribution and abundance of fish (Projects **98163 A** and **M**) change.

8. *Determine if forage fish abundance predicts adult seabird foraging trips, chick meal-size , chick provisioning-rates, and productivity*

   This will be a joint project involving fish distribution data from **98163 A**, foraging and distribution data from projects **98163 B** and **M, R,** and diet data at colonies from projects **98163 E, F, G, J, M.**

9. *Determine if differences in forage fish nutritional quality predict seabird reproductive productivity.*

   Field data show significant differences in diet quality and growth of seabirds based on differences in forage fish taken. Data on fish-provisioning rates, growth, and diet of wild birds from projects **98163 E, F, J,** and **M** will be provided to Project **98163 G** to test this. In addition, Project **98163 N** will use fish provided by **98163 M** to continue captive rearing of kittiwakes as an independent test of the field results.

10. *Determine if seabird species within a community react predictably to the different prey bases identified in Objective 1.*

    This objective will be examined in Prince William Sound by Project **98163 Q** in conjunction with Projects **B, C, E, F, G, H, I, L, O,** and between three sites in Cook Inlet by Projects **98163 M** and **98163 J** . Within species, **Projects 98163 E, J, and M** will examine kittiwake response, and **98163 F** and M will compare pigeon guillemots, Projects **98163 J** and **M** will compare common murres, and Project **R** will examine Marbled Murrelets. At the foraging level, Project **98163 B** will undertake a similar analysis in conjunction with **98163 O.** Data on fish distributions and status will be provided by projects **98163 A, C, M.**

In addition, Project **98163 O** will assist with design and analysis of all projects. Project **98163 I** will conduct an international symposium on changes in Pacific seabirds, to be held at Monterey, California in January 1998.

C. Cooperating Agencies, Contract, and other Agency Assistance

Details of the responsibility of each agency and contracts with the private sector and with other government agencies can be found in the appendices describing individual subprojects in the FY 98 Detailed Project Descriptions.

SCHEDULE

A. Measurable Project Tasks for FY 98

1999

January	Annual meeting and presentations by all P.I.s
	Symposium on Change in North Pacific Seabirds
April	Annual report

B. Project Milestones and Endpoints

Annual reports and publications from individual subprojects in the literature will constitute the main milestones. A series of synthesis papers will be produced later in the project.

1998	*International Symposium on Changes in Pacific Seabirds*, sponsored by the Pacific Seabird Group at Asilomar, California.
1999	*Symposium on Ten Years of Recovery Following the Exxon Valdez Oil Spill.*
2000	Monitoring Plan for Seabirds an Fish in the Restoration Area
2001	Final Reports completed

C. Completion Date

September 30, 2001

PUBLICATIONS AND REPORTS

These may be found under the individual subprojects.

PROFESSIONAL CONFERENCES

All Principal Investigators (Projects **98163 A-S**) will attend the annual (January 1998) *Exxon Valdez* Restoration Workshop in Anchorage. In 1998, the Project Leader will be convenor and several P.I.'s will be participants in the *International Symposium on Changes in Pacific Seabirds*, sponsored by the Pacific Seabird Group at Monterey, California. Finally, APEX will present one or more sessions of integrated presentations at the 1999 *Symposium on Ten Years of Recovery Following the Exxon Valdez Oil Spill.* Further details will be found under the individual subprojects.

NORMAL AGENCY MANAGEMENT

98163 A
Not applicable

98163 B
see explanation under 98163 E

98163 C
NOAA and NMFS has statutory stewardship for all living marine resources; however, if the oil spill had not occurred NOAA would not be conducting this project. NOAA NMFS proposes to make a significant contribution (as stated in the proposed budget) to the operation of this project, making it truly cooperative.

98163 D
Not applicable

98163 E
The Fish and Wildlife Service is responsible for managing migratory birds. To manage bird populations indices of populations and production of several game bird species and a few non-game bird species are monitored in some parts of Alaska. In Prince William Sound the FWS funded a marine bird survey in 1972 and some seabird colony studies at Hinchinbrook Island in 1976 to 1978 in response to the building of the Alaska pipeline. In 1984-85 the FWS funded their first shoreline sea otter survey, combined with shoreline marine bird survey. Also in 1984 the FWS began annual monitoring black-legged kittiwake populations and productivity in PWS. The only ongoing monitoring of migratory birds in PWS is the kittiwake monitoring. The FWS generally does not fund research studies and when they do the studies are often on game species. The APEX study is only being conducted because there was an oil spill. The need for the APEX study would not exist if the oil spill had not occurred. The FWS is has contributed the past data on migratory birds to the EVOS trustees and is continuing to contribute the data collected on kittiwakes to the EVOS trustees.

98163 F
see explanation under 98163 E

98163 G
Not applicable

98163 H
Not applicable

98163 I
Not applicable

98163 J
The work that will be conducted on seabirds at the Barren Islands by AMNWR for the EVOS APEX project is not something that AMNWR or the FWS is required to do by statute or regulation.

98163 K
Not applicable

98163 L
The U.S. Geological Survey conducts research in support of the land management missions of state and federal agencies. Internal programs and funds do not exist for routine monitoring or research on ecosystems. This project would not exist if the oil spill had not occurred.

98163 M
see L

98163 N
see L

98163 O
Not applicable

98163 P
Not applicable

98163 Q
Not applicable

98163 R
see E

98163 S
Not applicable

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

APEX is in itself a major integrated research effort, spanning 19 principal investigators at 15 institutions, agencies, and private businesses. Details of integration at the individual project level may be found in the appendices for each project.

At the level of coordination between APEX and the other two Trustee-funded ecosystem projects, there are several efforts underway. SEA (Sound Ecology Assessment), NVP (Nearshore Vertebrate Project) and APEX are coordinating acoustic and inshore sampling methodologies. The SEA herring project is sharing data on bird flocks in return for staff assistance during field work. SEA and APEX developed Project S on jellyfish together. SEA and APEX share analysis capabilities for fish stomachs (98163 C). NVP and APEX will be splitting field work and sharing data from the Jackpot and Naked island pigeon guillemot studies. Consultations between the project leaders of the three projects continue on a regular basis.

In coordination with Dr. Kathy Frost of ADF&G, 98163 I has been collating harbor seal foraging data with historical data on distribution and changes in forage fish in Prince William Sound and the northern Gulf of Alaska. In addition, we are documenting Steller's Sea lion data for PWS. This effort will help Projects B and I to build up a "trophic landscape" of PWS, to ask "what are the spatial patterns of prey consumption by upper-level predators?", and to determine whether such predators co-vary in abundance.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

98163 A
No major changes are planned.

98163 B
This project will reduce its field component to continue recording foraging flock characteristics in the three acoustic transect 'boxes', to extend its multiyear data set. It will also, with Projects A and O work to identify physical characteristics of areas of forage fish concentrations, for spatial modelling.

98163 C
Project C will conclude analysis of collected samples.

98163 D
Not applicable

98163 E
This project will continue its expansion into studies of interannual survival and dispersal between colonies.

98163 F
This project will continue

98163 G
No major changes are planned except for the addition of studies of doubly-labeled water, to measure energetic requirements and expenditures in the field.

98163 H
Not applicable.

98163 I
This will continue to explore and expand links with marine mammal projects. We will integrate additional data on Steller's Sea lions in PWS with Harbor Seal and seabird data to look for Sound-wide coherent shifts in upper-level predators.

98163 J
No major changes are planned.

98163 K
This project has been reactivated.

98163 L

98163 M
No major changes are planned.

98163 N
This study will conclude, using the year for analysis and writing up of manuscripts for publication.

98163 O
No major changes are planned.

98163 P
Not active.

98163 Q

98163 R
This is a new project.

98163 S
This is a new project.

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PERSONNEL

Over sixty persons are involved in APEX. These include 18 Principal Investigators. Their qualifications may be found in the individual detailed project descriptions for 98163 A-S.

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A
Forage Fish Assessment

98163 A
Forage Species Studies in Prince William Sound

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INTRODUCTION

Prince William Sound (PWS) is one of the largest areas of protected waters bordering the Gulf of Alaska (GOA). It, and the nearby open waters of the Gulf, provide a foraging area for large populations of apex predators including piscivorous seabirds and marine mammals. These surface-dependent predators were severely impacted by the EXXON VALDEZ oil spill (EVOS); and many - especially common murres, marbled murrelets, pigeon guillemots and harbor seals - suffered population declines that have not recovered to pre-EVOS levels. Piscivorous seabirds and marine mammals in PWS are near the apex of food webs based on pelagic production of small fishes and macroinvertebrates. Recovery of apex predator populations in PWS depends on restoration of important habitats and the availability of a suitable forage base. Since the 1970's there apparently has been a decline in populations of apex predators in the pelagic plankton production system, and it is not clear if failure to recover from EVOS-related reductions is due to long-term changes in forage species abundance or to EVOS effects. In this proposal we describe research that will provide quantitative descriptions of the forage community in PWS .

BACKGROUND

Forage species include planktivorous fishes and invertebrates. Planktivorous fish species that occur in PWS and are known or likely prey of apex predators include Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus*), walleye pollock (*Theragra chalcogramma*), capelin (*Mallotus villosus*) and eulachon (*Thaleichthys pacificus*). Among these, Pacific herring are commercially valuable in PWS and have been studied extensively by Alaska Department of Fish and Game (ADF&G) to facilitate management. Data available for Pacific herring include population size, year-class abundance, and growth. Walleye pollock are commercially valuable in the western GOA and the Bering Sea; consequently there are considerable data describing populations and biology in those areas, but relatively little information on pollock in PWS. The other fish species are not commercially important in Alaska and have received little study, although some scattered information allows a preliminary assessment of their life-history features, distributions and food habits.

Pacific herring populations in PWS are monitored through egg surveys, with subsamples aged to estimate year-class abundances. Through the 1980's herring abundances were relatively high in PWS, with cyclical strong year classes. In 1993 and 1994 herring populations were reduced sharply, adults had relatively high incidences of lesions caused by viral hemorrhagic septicemia (VHS), and the mean size at age was abnormally low. Apparently herring populations in PWS have been seriously stressed in recent years. Although linkage to the EVOS is not clearly demonstrated, herring declines may be due to post-EVOS changes in the pelagic production system of PWS.

In the western GOA and Bering Sea juvenile walleye pollock are planktivorous, and are preyed upon by apex predators. In Shelikof Strait in April walleye pollock comprised about 99% of midwater planktivores (Brodeur and Merati 1993). In PWS walleye pollock are probably important forage species. In a bottom trawl survey of PWS, walleye pollock were the most abundant species (Parks and Zenger 1979). In our acoustic survey of PWS in July and August of 1995, YOY pollock were by far the most abundant small pelagic fishes in PWS. Juvenile walleye pollock are very important constitutents of the diets of piscivorous seabirds (Springer and Byrd 1989, Divoky 1981) and marine mammals (Lowry et al. 1989, Pitcher 1980, 1981).

Pacific sand lance occur throughout the GOA, and are important forage species wherever they occur. They are planktivorous, feeding on euphausiids and copepods, with euphausiids more important in winter months (Craig 1987). Throughout their range, calanoid copepods have generally been reported as their principal prey (Simenstad and Manuwal 1979, Rogers et al 1979, Cross et al. 1978, Craig 1987). Pacific sand lance have been reported as prey for a variety of marine seabirds including common murres (Drury et al. 1981, Springer et al 1984), puffins (Wilson et al. 1984), auklets (Vermeer 1979, Wilson and Manuwal 1984) and murrelets (Sealy 1975). They are also eaten by many marine mammals including harbor seals (Pitcher 1980) and Steller sea lions (Pitcher 1981). There is little information on the abundance and distribution of sand lance in the PWS area, but they are probably an important intermediate link in the food webs that support apex predators.

Two smelt species, capelin and eulachon, are probably important forage species in PWS. In a bottom trawl survey conducted in April, eulachon were the fifth most abundant species collected overall, but was the dominant species in depths over 200 fm. (Parks and Zenger 1979). Those fish were ready to spawn and apparently were intercepted while migrating to their spawning grounds in rivers. Eulachon are important forage species throughout Alaska, and may be the most important forage fish in the southern Bering Sea (Warner and Shafford 1981). Capelin spawn on nearshore sandy substrates. In the northern Gulf of Alaska (Kodiak) they spawn in May and June (Warner and Shafford 1978, Pahlke 1985). They are prey of many piscivorous seabirds (Baird and Gould 1984) and marine mammals (Fiscus et al. 1964).

Macrozooplankton; including euphausiids, shrimp, mysids and amphipods; are a central component in the diets of herring, sand lance, capelin and pollock, as well as young salmon (Clausen 1983, Coyle and Paul 1992, Livingston et al. 1986, Straty 1972). When aggregated in sufficient densities, macrozooplankton are fed on directly by marine birds (Coyle et al. 1992, Hunt et al 1981, Oji 1980). Swarming behavior by breeding euphausiids (Paul et al. 1990b) and physical factors (Coyle et al. 1992, Coyle and Cooney 1993) may concentrate macrozooplankton and micronekton into aggregations of density suitable for efficient foraging by predators. Unfortunately, there is little information on the abundance, distribution and fluctuations of these key invertebrates in the EVOS impact region. In the GOA zooplankton abundance has varied on a decadal time scale (Brodeur and Ware 1992); and, superimposed on longer cycles, are interannual fluctuations as high as 300% (Frost 1983, Coyle et al. 1990, 1992, Paul et al. 1990a, 1990b, 1991, Paul and Coyle 1993). Such variability in abundance may affect populations of apex predators in PWS.

OBJECTIVES

1. Provide an estimate of the distribution and abundance of forage species in three core areas of Prince William Sound, including inshore and offshore areas.

2. Describe the species composition of the forage base and size distributions of the most abundant forage species in the three core areas.

3. Gather basic oceanographic data describing conditions in the study area, and salinity, temperature, and sigma-t profiles of the water column and water depth at all sites of data collection the three core areas.

4. Describe and quantify zooplankton and zooplanktivorous species in two process study sites within Prince William Sound in Spring, Summer and Fall. The two process study sites will be within the North and the South core study areas.

MILESTONES

1. May 1997 - Complete an 8 day survey of two process study sites within PWS.

2. August 1997 - complete a 21 day acoustic/net sampling survey of inshore and offshore zones in the three APEX core study areas, and an 8 day survey of two process study sites within PWS.

3. October 1997 - Complete an 8 day survey of two process study sites within PWS.

4. December 1997 - Complete laboratory analyses of forage species catch compositions and length distributions from 1995 survey sampling.

5. February 1998 - Complete analyses of CTD data collected in 1996.

6. March 1998 - Complete analyses of acoustic data set collected in 1996

ACOUSTIC ASSESSMENTS

A major goal of the forage fish project is the evaluation of the distribution and abundance of forage fish relative to bird distribution and physical features affecting fish distribution. The main tool for measuring the distribution and abundance of forage fishes is hydroacoustics. Bird data will be collected by observers from other sub-projects concurrently with acoustic data to determine the relationship between bird distribution and acoustically measured fish densities. An understanding of the relationship between forage fish species and seabird distributions requires data collection at a variety of spatial and temporal scales. Hydroacoustics can measure horizontal and vertical abundance and biomass at scales not possible by traditional net sampling techniques. Acoustics has been used to map fish (Thorne and Blackburn 1974; Thorne et al. 1977; Thorne 1977; Thorne et al. 1982; Mathisen et al. 1978) and plankton using a variety of deployment techniques (Green et al. 1988; Green and Wiebe 1988; Green et al. 1989; Green et al. 1991). Acoustics have been used to examine fine-scale biological patchiness (Nero et al. 1990), aggregated migration pathways of Atlantic Cod (Rose 1993), forage fish distributional characteristics in Chesapeake Bay (Brandt et al. 1992) and the spatial patterns of a variety of aquatic populations (Gerlotto 1993; Baussant et al. 1993; Simard et al. 1993). In Alaskan waters, acoustics have been used to measure biomass relative to tidally-generated frontal features (Coyle and Cooney 1993) and the relationship between Murre foraging, tidal currents and water masses in the southeast Bering Sea (Coyle et al. 1992).

Hydroacoustics will provide the sampling intensity required to assess the density of highly aggregated forage fish schools distributed over mesoscale dimensions and to document individual interactions between avian predators and prey at very small scales. The broad size range of individual targets from zooplankton to apex predators requires multifrequency sampling and an extremely high dynamic range. The surveys will consist of line transects through areas in Prince William Sound using a BioSonics DT4000 digital system with 120 kHz down-looking transducers to measure the vertical distribution forage fish. Specifications of the DT4000 include high dynamic range, low noise, GPS input, school classification software, target strength measurement, high resolution chirp transmission and complete raw data storage. The system includes visual editing software for efficient data analysis. Transducers will be single-beam for reasons outlined below.

Accurate calibration is critical for both relative and absolute measures of fish abundance. The systems used in this study will be calibrated with U.S. Naval standard hydrophones prior to and after field use. In addition, the calibration parameters will be routinely checked during cruises with standard target spheres developed at the Marine Laboratory, Aberdeen, Scotland, and optimized for each frequency. The calm conditions in Prince William Sound and diagnostic programs developed for the new generation of digital transducers will facilitate field calibration. The diagnostic programs evaluate the echoes from standard targets and compare them with the expected returns based on hydrophone calibrations stored in the digital transducer memory.

Target strength measurements are required to compute absolute abundance and estimate the size of the acoustic targets. However, absolute abundance is not as critical an objective as relative abundance with respect to seabird foraging and reproductive success. Real-time *in situ* target strength information is often not obtainable with schooling fishes because individual targets are difficult to resolve and measure. Nevertheless, we intend to make every effort to estimate absolute abundance as accurately as possible emphasizing accurate calibration since accurate calibration is critical to absolute population estimates. Biomass - target strength relationships for herring, pollock and other fish of interest have been developed during numerous surveys (Thorne 1977; Thorne et al. 1982; Thorne et al. 1983; Thorne 1983; Traynor, NMFS, Northwest and Alaska Fisheries Center, personal communication) and use of these data supplemented with *in situ* data should allow absolute abundance estimation with reasonable accuracy.

While target strength is critical for absolute biomass estimates, estimation of fish length from target strength data is of limited value for the following reasons: 1) Accurate in situ target strength measurements of schooled fishes is not usually possible. 2) The inherent variability in target strength - fish length measurements is so great that the results are of limited value even when such measurements are possible. The small variation in the size of forage fish is swamped by the high variability in the target strength estimate.

Three types of acoustic systems have been used for target strength measurements: split beam, dual beam and single beam. Several comparisons between split-beam and dual-beam capabilities have demonstrated that mean target strength estimates by the two systems are similar but split beam yields the highest precision. However, split beam is limited to lower frequencies and has inherently lower single target resolution, which can seriously bias the results (Barange and Soule 1994). Split-beam would therefore be least suitable for the forage fish study.

While dual-beam would provide a viable alternative for the forage fish objectives, Hedgepeth (1994) has shown that single-beam systems provide very similar measurement capabilities with less complexity. Because *in situ* measurement of fish size provides only a minimal contribution to the objectives of this study, we propose to use single-beam acoustic systems rather than the more complex dual-beam system.

Programs will be written in Quick BASIC for ship board use and a programmer will be on hand to modify programs as required. Acoustic data analysis will be done on UNIX work stations. This should provide the speed and data storage capability necessary for analyses of large data sets generated by the DT4000. However, a 1 G hard drive is necessary to insure sufficient space for any PC computations which may be necessary and a tape interface is needed to store and retrieve the data. Data management will be done on an INGRES data management system. Programs for data recovery and analysis on the UNIX system will be written in FORTRAN. The use of a work station should insure easy comparison between SEA and Forage Fish data bases.

NET AND VIDEO SAMPLING FOR IDENTIFICATION OF ACOUSTIC TARGETS

Hydroacoustic sampling will be the primary method used to quantify the abundance of forage species in Prince William Sound. However, net and video sampling will be needed to identify the species comprising the hydroacoustic signals and to provide biological samples for life history, condition and energetics studies of forage species. For offshore net sampling we will use a research-scale (100 m^2 opening) version of a mid-water commercial trawl and a purse seine. For nearshore net sampling we will use a purse seine, beach seine and cast nets. In both the offshore and nearshore surveys, we will use an underwater video camera to identify acoustic targets. This camera system will operate to depths of 60 meters. The video system has a real-time monitor on the operating vessel, and schools of fish will be recorded with a high resolution video recorder.

Invertebrates.

Macroinvertebrates will be preserved shortly after collection, and sorted by species later. The difficulties of identifying invertebrates to species will preclude working them up in the field. For example, there are likely to be at least five species of euphausiids in PWS. We will fix and preserve macrozooplankton samples from nets and sort and measure them in the laboratory. Large jellyfish will be identified, measured, and returned to the sea. Subsamples of larger zooplankton, particularily eupahusiids, will be frozen in individual containers for later bioenergetic analyses.

Fishes.
Fish larger than about 50 mm will be identified in the field. We will sort samples to species, and measure all fish, unless net hauls contain large numbers of individuals of some species. In the case of large catches we will randomly subsample and measure 100 - 200 individuals of each species. Length stratified subsamples of all forage fish species will be frozen and returned to the laboratory for future life history and energetics studies.

We will provide those samples requested by NMFS for food habits studies, and additional samples for other agencies for stable isotope and lipid analyses. Those agencies for whom we collect fishes and invertebrates must provide us with:

a) written directions as to the number of each species they require, and directions for preserving them.
b) all preservatives, sample and shipping containers
c) arrangements for sample shipping, and payment of all shipping charges.

OCEANOGRAPHIC DATA
We will collect oceanographic data at all of our survey stations and sampling sites. At each transect and collection site we will use a Seabird SEACAT CTD to sample the water column from the surface to 200 m depth, or to within 5 m of the bottom at shallower stations. This instrument has an internal data logger, and will record conductivity, temperature and depth. From this data we will produce vertical profiles of salinity, temperature and sigma-T at all stations. The data will also be available as ASCII files for agency biologists and SEAS researchers. We will compare our data to the more extensive data set compiled by SEAS researchers to determine if the distributions of forage species we observe are related to oceanographic features such as frontal zones, convergences, pycnoclines or major currents.

PROCESS STUDIES.
In the 1997 field season we will begin studies designed to determine if differences observed in forage fish abundance among areas in PWS result from differences in food web dynamics at planktivore trophic levels. We intend to quantify the abundance of the important zooplankton consumers, including forage fishes and major invertebrate planktivores, at two study sites in PWS - one each in the North and South core study areas.

In each of the process study sites we will set up a grid of 8 - 10 areas; within each area we will randomly select a sampling location where hydrographic measurements and zooplankton samples will be collected. A CTD equipped with a fluorometer will measure temperature, salinity and chlorophyll. A CALVET plankton net with 243 micron mesh nets will collect small plankton with a vertical haul, and a 1 M^2 NIO/Tucker trawl with 1 mm mesh will collect large zooplankton and micronectonic species in a double oblique haul. All plankton nets will be equipped with General Oceanics flow meters. The abundance of small planktivorous fishes in the process study sites will be quantified by hydroacoustic transects of the study area. The transects will be sets of parallel lines no more than 1 nautical mile apart. Fish aggregations located by hydroacoustics will be identified by net sampling with a mid-water trawl or a purse seine. In addition, we will use the underwater video system to identify acoustic targets.

FIELD STUDY PLAN
The field work will consist of a nearshore and offshore survey of the three core study areas in July/August 1997, and three surveys of the two process study sites - one each in May, July/August, and October.

We propose to conduct the nearshore and offshore surveys of the core study areas in a research cruise in July/August 1996 when bird species are at an important stage of their reproductive activity. This survey will be a 21 day cruise beginning as soon as possible after 15 July. The survey will sample three areas intensively (Figure 1): 1) North (Valdez Arm, Port Fidalgo, Port Gravina); 2) Central (Naked Island, northern Knight Island); 3) South (Knight Island Passage, Whale Bay). The survey will be conducted by two vessels - an acoustic vessel that will run pre-selected transects and a catcher vessel that will use a purse seine and video equipment to identify acoustic targets. The nearshore survey will be conducted first, and should be completed in about 12 days. The cruise will finish with the offshore survey, which should require about 8 days.

Nearshore survey.
Nearshore sampling will follow procedures developed in the 1996 program. In each of the three areas, a series of 8 - 10 study sites will be pre-selected for detailed acoustic and net survey. Each study site will consist of a section of shoreline 12 km in length, and extending from the approximate mean low tide line out to 1 km. This section of shoreline will be surveyed acoustically by a series of 20 zig-zag transects (10 zigs, 10 zags) about 1.2 km in length. A net/video sampling vessel will acompany the acoustic vessel, and will sample acoustic targets as directed by the acoustic vessel. The net/video vessel will also conduct all CTD sampling during the survey.

Offshore survey.
We will conduct offshore acoustic sampling following procedures developed in the 1995 and 1996 programs. In each of the three areas a series of transects spaced at 2 nautical mile intervals will be sampled acoustically from the acoustic vessel. A net/video sampling vessel will acompany the acoustic vessel, and will sample acoustic targets as directed by the acoustic vessel. The net/video vessel will also conduct all CTD sampling during the survey.

SURVEY COORDINATION
Surveys will be planned cooperatively with biologists from USFWS, NMFS, and SEA project. At least two weeks prior to each survey, a cruise plan will be circulated to all participants, including all University project participants, agency biologists from USFWS and NMFS, and the SEA project, and the COTR.

BUDGET SUMMARY AND JUSTIFICATION
Vessel Charters.
A major budget item in this study is for vessel charters. The type of research we propose requires relatively large vessels with substantial daily charter rates. We will require:

1) Acoustic vessel - we intend to use the F/V MISS KAYLE and either the F/V CAPE ELRINGTON or the M/V PACIFIC STAR for the acoustic vessels. All were chartered by us in the 1996 field season and have contract extension clauses in those contracts.

2) Net and Video sampling vessel - We intend to use the F/V PAGAN for this purpose. That vessel was chartered by us in the 1996 field season and has a contract extension clause in its contract.

3) Process study vessel in March and October - We intend to charter the ADF&G reserach vessel R/V PANDALUS for 8 - 10 days to conduct these two cruises.

4) Mid-water trawl vessel - We intend to use the ADF&G research vessel R/V PANDALUS to conduct mid-water trawling for approximately 3 days in August.

BioSonics, Inc. Subcontract
BioSonics Inc. is budgeted for a subcontract to provide technical and consulting support for this project. In the first two years of the APEX program, BioSonics was subcontracted to provide: acoustic equipment, installation and operation of equipment, and data analyses support. In the research we now propose, we will purchase the acoustic equipment and operate it. However, we will still require some limited technical support from BioSonics to insure that the new equipment is integrated into our project, and that the data produced is comparable to the data collected in the prior two years.

Equipment
The budget also includes a major cost for acoustic equipment purchase from Biosonics Inc. The core of the research program is the acoustic sampling, and Biosonics is an industry leader in developing the new digital technology. In the first two years of this project (1995 - 96) we subcontracted to Biosonics, Inc. to provide the equipment and to assist in its operation in the field. We now have two years experience in using this equipment, and it will now be more economical to purchase our own systems, with a limited subcontract to Biosonics, Inc. to insure that the equipment is properly installed and compatible with the electronics in the acoustic vessel. We are purchasing the Biosonics, Inc. systems because we have used them for two years, and this will insure that the data are compatible and that the data can be used with the analytic software we have developed. In addition, the system we are purchasing are identical to the other system in use by the APEX program in Cook Inlet. Using the same equipment will ensure that the data collected in the two APEX study areas are compatible, and that the same software can be used to analyze data from the two areas. We are purchasing one complete DT4000 digital acoustic system with the necessary backup components.

The budget includes the cost of a backup video camera from Fisheye Inc. We have one video camera from that company, and require the backup camera to be by the same manufacturer in order to be compatible with the deployment equipment. Any other camera would not be useable in our existing equipment.

The budget includes the purchase of a fluorometer from Seabird, Inc. This sensor will be added to our existing Seabird CTD (model SBE-19) instrument. There is no other source for this additional equipment, as only Seabird Inc. has the capability of adding this equipment, and has the software to integrate this piece of equipment into the existing set of sensors (depth, salinity, temperature) in the SBE-19 CTD instrument.

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B
Bird/Fish Interactions

SEABIRD/FORAGE FISH INTERACTIONS

Project Number:	97163 B
Restoration Category:	Research
Proposed By:	DOI
Duration:	5 years
Cost FY 97:	$89,900
Cost FY 98:	$122,300
Cost FY 99:	$126,300
Geographic Area:	Prince William Sound
Injured Resource/Service:	Piscivorous birds

ABSTRACT

The APEX project is investigating the general hypothesis that a shift in the marine trophic structure of spill affected area is preventing the recovery of piscivorous birds. This component contributes to that investigation by examining seabird foraging in relation to schooling forage fish at sea. During 1995 - 1997 we sought to determine if forage fish characteristics and/or interactions among seabirds limit food availability. We also examined the relationship between seabird feeding group size and the characteristics of associated forage fish. Seabird/forage fish interactions were monitored by conducting systematically arranged transects, 21 July - 11 August 1995 and 14 - 28 July 1996 in three study areas in Prince William Sound Alaska, Alaska. The study sites were located in Valdez Arm, Naked and Knight Islands, and Jackpot and Icy bays. In 1996 nearshore survey blocks were added in these three areas. Hydroacoustic and bird-observation data were collected simultaneously during these surveys. We collected additional data on seabird/forage fish interactions at 22 mixed species feeding flocks in both 1995 and 1996. We determined that *Brachyramphus* murrelets selected forage fish schools in shallow water habitats, that are generally associated with high energy forage fish that have declined in abundance. Whereas, tufted puffins (*Fratercula cirrhata*) were generalist forages. We speculated that differences in forage selection and life history of these species may explain their differential response to the *Exxon Valdez* oil spill. We determined that there may be a commensal relationship between black- legged kittiwakes (*Rissa tridactyla*) and marbled murrelets (*Brachyrampus marmoratus*) with kittiwakes the beneficiary and a competitive interaction between kittiwakes and glaucous-winged gulls (*Larus glaucescens*) at mixed-species feeding flocks. The total number of birds in mixed-species feeding flocks was positively related to the chord length of associated fish schools and negatively related to density and depth of water to schools.

INTRODUCTION

This is an ongoing study which began with a pilot effort in 1994 to test field methods. In 1995, the study was expanded to look at seabird foraging in several habitats in 3 study sites within Prince William Sound. Data collected in 1994 and 1995 indicated that seabird activity was concentrated in shallow water near shore. In response to these findings the 1996 study expanded data collection by adding an extensive survey of nearshore habitats.

We sought to determine if forage fish characteristics limited availability of prey. We approached this issue by comparing the characteristics of fish schools selected by tufted puffins and murrelets. Tufted puffins were not severely impacted by the spill (Piatt et al. 1990) and have since been increasing (Agler and Kendall 1997) whereas murrelets were impacted (Piatt et al. 1990) and have not increased following the spill (Agler and Kendall 1997). Our analysis indicated that *Brachyramphus* murrelets foraged in habitats associated with high energy content forage species. We suggest that the generalist foraging and the nesting strategies of tufted puffins has allowed this species to adjust to ecological change and increase its population. Whereas, *Brachyramphus* murrelets' life history suggests a need for high energy foods and a foraging strategy that selects habitats associated with high energy forage species, that have declined in abundance. We suggest that the variations in foraging and life history strategies of these species are linked to their differential response following the spill. We intend to expand this comparative approach to include other seabird species and feeding flocks. Also,we will make comparisons at 3 scales: 1)Fine scale which use fish schools as the sampling unit, as we did in our murrelet/puffin comparisons. 2)intermediate scale which will use the 12x1-km study blocks, that we developed in 1996 to examine nearshore habitats, as the sample unit. 3)Course scale which wil use the 6 large study areas within Prince William Sound and Cook Inlet as the study unit to make comparisons.

To determine if interactions among seabirds limited access to prey we examined behaviors at feeding flocks during 1995 and 1996. Behavior changes from 1995 to 1996 included; reduced presence of kittiwakes and tufted puffins, increased presence of marbled murrelets and glaucous-winged gulls, more tightly aggregated feeding flocks, reduced feeding success of kittiwakes and greater feeding success of gulls, reduced kleptoparasitism of kittiwakes and increased kleptoparasitism of gulls. We suggest that there may be a commensal relationship between black-legged kittiwakes and marbled murrelets with kittiwakes the beneficiary and a competitive interaction between kittiwakes and glaucous-winged gulls at mixed-species feeding flocks. Our 2 years of data suggest that glaucous-winged gulls may be limiting kittiwake access to prey. We intend to collect data on feeding behavior for the duration of this study and expect to be able to resolve the nature of inter- and intra-specific relationships among seabirds.

We examined the relationship between mixed-species seabird feeding group size and the characteristics of associated forage fish, through a multivariate approach. We determined that the total number of birds in feeding flocks was positively related to the chord length of associated fish schools and negatively related to density and depth of water to schools. We will continue to examine these relationships for the extent of this study.

NEED FOR THE PROJECT

A. Statement of Problem

The *Exxon Valdez* oil spill resulted in extensive mortality of seabirds and damage to other resources in Prince William Sound and the Gulf of Alaska (Piatt et al. 1990). Several of these resources had not recovered 5 years after the spill (Agler et al. 1990a&b, Klosiewski and Laing 1994, Agler and Kendal 1997). The APEX project was initiated in 1994 to determine if a shift in the marine trophic structure has prevented the recovery of injured seabirds. Seabirds interact with the marine system principally through foraging; therefore, a study of the seabird/forage fish interactions and foraging behavior is a necessary component of the APEX project.

B. Rationale

A major objective of the *Exxon Valdez* Oil Spill Trustee Council (EVOS TC) is to secure the recovery of injured species. For each of the injured seabirds, a principle component of the restoration strategy is to "conduct research to find out why (the respective species) is not recovering" (EVOS TC 1994). APEX and this study play an essential roll in gaining an understanding of why recovery is not occurring and identifying any management activities that can aid recovery.

We have been successful in modeling the selection of forage fish schools by 2 seabird species and in doing so have gained insight into the factors associated with their population responses following the spill. This approach needs to be expanded to examine the bird/fish relationship for additional species and extended to other scales in order to further understand the ecological processes within the spill affected area. Duffy (1980) has suggested that if piracy is extensive, it may be a critical factor for nesting success. Our results thus far indicate that piracy does occur and that there is a competitive relationship between black-legged kittiwakes and glaucous-winged gulls, however it will take additional years of data to determine trends and effect.

C. Summary of Major Hypotheses and Objectives

The general hypotheses that direct this study are:

1. Forage fish characteristics and interactions among seabirds limit availability of seabird prey.

2. Seabird foraging group size and species composition reflect prey patch size.

In additions to these hypotheses we hope to work with SEA's Herring component (see proposal for project 98320) to examine:

3. The diel movements of forage fish correlate to the behavior of piscivorous birds.

D. Completion Date

We anticipate that 5 years of field data collection (FY 1995-1999) to quantify seabird/forage fish interactions at both temporal and spacial scales followed by 2 additional years of to analyze data and publish the findings of the study in scientific journals.

COMMUNITY INVOLVEMENT

A community involvement and traditional knowledge program will be developed by the APEX chief scientist.

FY 98 BUDGET

Personnel	89.2
Travel	7.1
Contractual	5.7
Commodities	0.7
Equipment	5.9
Subtotal	108.6
Gen. Admin.	13.7
Total	122.3

PROJECT DESIGN

The 1998 field season will be a continuation of on-going research. Based on preliminary results the focus of the study has shifted to nearshore shallow habitats. Techniques will be added to address new questions.

A. Objectives

The Seabird/Forage Fish Interactions study will focus sampling efforts in nearshore habitats, while continuing pelagic data collection. Data collection will be directed to addressing the following objectives which are given in order of their priority:

1. Analyze data on the formation feeding flocks collected in 1996 and prepare scientific publication on results.

2. Examine the relationship between forage fish and seabird distribution at intermediate scales (this analysis will use blocks established for nearshore surveys as the sampling unit).

3. Use resource selection functions to compare foraging strategies of kittiwakes, common murres (*Uria aalge*), tufted puffins, marbled murrelets (*Brachyramphus marmoratus*), and mixed species feeding flocks. This objective will require coordination with component 98163m and will be ongoing for the duration of the project. Achievement of this objective will be dependent upon the development of faster software for the analysis of hydroacoustic data.

4. Coordinate with components 98163a and 98163m to examine relationships between forage fish and seabirds at more course scales. These comparisons will use the 6 established study areas in Prince William Sound and Cook Inlet to compare and examine the interactions of fish abundance; characteristics of fish schools; seabird abundance, productivity, and seabirds species composition; and oceanography. This objective will begin in 1998 and will not be fully achieved until completion of the project.

5. Continue to determine if aggressive behavior among seabirds limits access to prey within feeding flocks. This objective will receive low priority and will be accomplished if time and funding are available.

7. Coordinate with SEA (98054) herring project to use areal flights to examine selection of nearshore forage fish schools by larids and participate in boat surveys to investigate diel relationships between seabirds and herring. Data collection on this objective began in 1996 and will continue at the discretion of the SEA principle investigator. Analysis of this data will receive low priority during 1998.

B. Methods

Data collection: In 1997 we will collect data in association with the APEX forage fish study as well as the SEA herring studies. Sampling designs, field seasons, and observation platforms will be determined by these projects. Data collection will focus on nearshore habitats. Fish sampling techniques will continue to include hydroacoustics and the verification of acoustic targets by net sampling and video. Aerial surveys will be used to locate feeding fish schools and foraging flocks. For descriptions, see the Forage Fish Assessment component (98163a) and SEA's herring (98054) proposals.

We will conduct seabird and marine mammal surveys simultaneously with hydroacoustic surveys during the APEX and SEA herring cruise (hydroacoustic survey methods are described in proposal 98163a). See attached protocol for detailed description of data collection methods.

Data analysis - fish schools: Hydroacoustic data will be obtained from the Forage Fish Assessment component (98163a) and these data will be displayed with contouring and 3 dimensional surface-mapping software (Keckler 1995) or the best hydroacoustic analysis software available. These images will then be used to determine school density, depth to top of schools, depth to bottom of schools, height of school, chord length of schools, and bottom depth each fish school.

A geographic information system (GIS) will be used to examine the spatial relationship between forage-fish schools, depth, distance to shore, and locations of bird colonies. GPS data for fish schools and colony locations will be converted into GIS layers. Digital NOAA coastline data will be used to calculate distance to shore for each forage-fish school. Finally, we will use GIS to calculate the distance to the nearest for each of the respective colonial seabird species (U. S. Fish and Wildl. Serv., Anchorage, Alas., unpublished data) for each school. These data sets will then be combined with acoustic data on fish school characteristics for analysis. We will use custom software to determine which of the forage-fish schools are within 100 m of a seabird location.

We will check variables for independence through correlation analysis. Paired variables with a correlation coefficient (r) > 0.50 will not be used in the analysis. We will use resource selection functions based upon logistic regression to model the selection of fish schools by birds (Manly et al. 1993).

Intermediate scale comparisons: Hyroacoustic data for the nearshore survey will be processed by the Forage Fish Assessment component (97163 A). We will use multivariate least squares regression to relate characteristics of each block (i.e. bottom gradient, distance to the nearest respective seabird colony, dominant forage species within block, and CTD data) and fish density to abundance of seabirds (collectively and individual species).

Course scale comparisons: Course scale comparisons will be a collaborative effort that will require further discussion and integration among projects. Work will begin in 1998 and continue for the duration of the project.

LITERATURE CITED

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C
Fish Diet Overlap

Diet Overlap, Prey Selection, Diel Feeding Periodicity and Potential Food Competition Among Forage Fish Species

Project Number:	98163C
Restoration Category:	Research
Proposer:	Molly V. Sturdevant, NMFS
Lead Trustee Agency:	NOAA
Cooperating Agencies:	JCFOS; USFWS; OSU; ADFG; UAF
Alaska SeaLife Center:	
Duration:	4th year, 5-year project
Cost FY 98:	$39,936
Cost FY 99:	$
Cost FY 00:	$
Geographic Area:	Prince William Sound, Cook Inlet, Barrens Islands
Injured Resource/Service:	Multiple

ABSTRACT

"Diet Overlap, Prey Selection, Diel Feeding Periodicity and Potential Food Competition Among Forage Fish Species," a component of the Alaska Predator Ecosystem Experiment (APEX), will continue to examine the feeding ecology of forage fish species in the Exxon Valdez (EVOS) spill area, focusing on Prince William Sound (PWS). To date (1994-1996), samples have been obtained opportunistically during field seasons of other projects; the diet study is heavily dependent on the Fish Population Sampling component of APEX (96173A) and little directed sampling has been possible given other APEX primary objectives and limited budgets. The FY98 study will focus on 1) processing samples remaining from 1996 collections; 2) analyzing data and submitting a final report/publication for samples collected in 1995; and 3) beginning analysis on 1996 collections, the results of which will be included in the1998 annual report synthesizing all results to date. The APEX hypothesis that "planktivory is the factor determining the abundance of preferred forage species to seabirds" will be tested with the following objectives: 1) to assess the potential for prey resource competition between forage fish species pairs by testing for shifts in the food habits and prey selection of fish when they occur in mixed species schools compared to when they occur in monospecific schools; 2) to determine the principal feeding periods of each species and whether prey resources are partitioned among co-occurring species on a diel basis; 3) to determine if diets differ on temporal or spatial scales that could explain differences in forage fish quality and availability to seabirds; 4) to improve descriptions of food habits and prey selection of

underrepresented, key forage species, particularly sandlance and capelin; and 4) to describe diets of potential forage species, such as demersal nearshore pricklebacks, daubed shanny, sandfish, and prowfish. Analysis of 1996 diet samples will address the above objectives and increase the information available about trophic interactions among intraspecific and interspecific forage species by comparing sample data with temporal and spatial characteristics at several scales. The more than 800 samples already on hand have been reviewed to establish sample processing priorities in the following order: a) multiple species per haul versus single species per haul; b) diel collections of a species at the same station or replicate stations; c) time series samples from the same station (seasonal, weekly, bi-monthly, annual or other time intervals); d) samples allowing intraspecific comparisons between geographic areas (eg., PWS-Cook Inlet); e) samples allowing intraspecific comparisons between regions of a geographic area (ie, northeastern, central and southwestern PWS; Lower Cook Inlet versus Barrens Islands); and f) samples that will allow description of the food habits of miscellaneous, little known species, eg., sandfish, prowfish, and others. The requested funding will provide for microscopic analysis of approximately 720 stomach or prey samples, which will adequately cover the high priority samples remaining from 1996 collections.

INTRODUCTION

The Alaska Predator Ecosystem Experiment (APEX) 98163C project, a study of trophic interactions of forage fish and their prey in the spill area, proposes to focus on processing samples collected in 1996 and summarizing the data obtained in the 1998 annual report. This data will supplement information gained from analysis of 1994-1995 APEX fish diet samples, which have been completely processed and summarized in the 1997 annual report. The current proposal includes a summary of forage fish and prey samples collected in 1996 and how they will be used. Further details about their collection may be found in the 97163A (Fish Population Sampling) and 97163M (Cook Inlet Studies) chapters of the 1997 annual report.

Efforts to restore apex predators injured by the EVOS oilspill, particularly harbor seals, pigeon guillemots, marbled murrelets, and black-legged kittiwakes, could be enhanced through an understanding of the biology and population dynamics of their prey resources, forage fish. Forage fish species include pelagic species in the offshore region as well as demersal nearshore species. Potential prey in offshore assemblages include Pacific herring (*Clupea harengus pallasi*), Pacific sandlance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), northern smoothtongue (*Leuroglossus schmidti*), eulachon (*Thaleichthys pacificus*), walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), tomcod (*Microgadus proximus*), juvenile salmon (*Oncorhynchus* spp.) and prowfish (*Zaprora silenus*); potential prey in nearshore assemblages may include these and other species, such as Pacific snake pricklebacks (*Lumpenus sagitta*), Pacific sandfish (*Trichodon trichodon*) and daubed shanny (*L. maculatus*). In 1998, APEX will enter its fourth year of colony studies of marine birds, conducted simultaneously with population studies on the distribution, abundance and availability of forage fish. Findings to date are summarized in various chapters of the project's 95163-97163 annual reports.

Knowledge about forage fish food habits, prey availability and selection, shifts in prey selection when fish distributions overlap (allopatry vs. sympatry), diel feeding chronology, and other aspects of the feeding ecology, as well as geographic, seasonal and interannual comparisons of such trophic attributes, will provide insight into how the population dynamics of these fish affect predation on them by apex predators, and in turn, the health of the bird populations. The forage fish diet and prey study obtains samples from several APEX projects, primarily the fish population studies in Prince William Sound and Cook Inlet and the food sampling aspects of bird studies. Because of the survey designs and specific objectives and priorities of these projects, samples for diet studies have been collected opportunistically rather than through directed sampling. In particular, little repeated sampling of forage fish schools or particular sites has been possible. Competition between species is principally demonstrated through some kind of behavioral change that results in a negative impact on one species. The samples obtained from APEX 1994-1996 field studies can be examined for this type of shift by comparing diets and prey selection of co-occurring species to those of the same species collected from monospecific net hauls. Secondarily, other kinds of comparisons can provide information about interspecific and intraspecific trophic interactions, for a better understanding of ecosystem dynamics.

NEED FOR THE PROJECT

A. Statement of the Problem

This food study is a sub-project of APEX (98163A-Q), a multi-disciplinary project designed to understand the PWS food web and its effects on species injured by the *Exxon Valdez* Oil Spill (EVOS). The high sea bird mortalities associated with EVOS occurred during a period of decline in several sea bird populations (Piatt and Anderson, 1996). While the environmental conditions which contributed to these declines have not been explained, damage assessment studies since the spill have associated continuing sea bird declines with the availability of forage fish prey. Reproductive failures were documented among black-legged kittiwakes from oiled areas (Irons, 1996) and may be associated with food conditions. Greater declines of pigeon guillemots in oiled areas compared to non-oiled areas were associated with reduced deliveries of sandlance, a high energy prey, to their chicks (Oakley and Kuletz, 1993).

At the same time as the health of marine birds and mammals declined in PWS in the last few decades, unexplained, long-term shifts in the relative population abundances of prominant forage species, such as herring, pollock and sandlance, have occurred (Anderson et al., 1994). Enhancement facilities have simultaneously increased production of juvenile salmonids released into the sound. These population changes could be reflected in trophic interactions if the available food limits the carrying capacity of PWS. Incomplete knowledge of forage fish abundance and distribution, planktonic prey production and how prey resources are partitioned restricts efforts to estimate the carrying capacity of PWS (Cooney 1993). Partitioning of prey resources reflects the degree of habitat and diet overlap among forage species. For many forage fish species, particularly juvenile stages, food habits have not been completely described. This information is needed to characterize trophic niches, which must be determined before niche overlap can be examined and the potential for resource competition between species can be assessed. Understanding the interactions between forage fish species may help to explain changes in the food habits and reproductive biology of injured marine birds dependent on them.

B. Rationale

While the APEX PWS project focuses on the summer nesting period of marine birds, a complete understanding of the influence of the trophic niche of their prey must take into account the fish's entire life history and environment. Ideally, trophic studies should examine seasonal relationships between species over a broad area, include as many stages of the life history as possible, assess the dynamics of prey resources, and investigate diel feeding rhythms, behavior and daily ration of each species. With this kind of background about the biology of the fish, the impact of changes in the oceanographic environment, food resources and densities of potential competitors and predators will be better understood. This information helps to explain the dynamics of how co-occurring species partition resources and each sustain healthy populations. Conversely, competition among species can be inferred from an observed shift in resource use, such as reduced absence from preferred habitat or failure to use a preferred a prey resource (Sogard 1994); the shift is then reflected in some measure of health, such as poorer condition, lower energy reserves, or slower growth. Ultimately, survival may be affected and populations reduced.

Seasonal, ontogenetic, spatial or temporal partitioning of prey resources may occur among forage fish species inhabiting the same area. A species preferred foraging habitat may change with changing hydrographic conditions and will reflect foraging behaviors that could also change ontogenetically. Species caught in the same area also may have foraged in different levels of the water column. This spatial segregation will be reflected in low dietary overlap and complementary selection of the prey available throughout the water column. Niche overlap between age-1 herring and capelin, for example, was highest in the spring when both species foraged in the water column; after the water column stratified, herring switched to a surface foraging mode in response to a newly available prey assemblage (Coyle and Paul 1992). Niche overlap between the two species then decreased as capelin continued to feed in the water column. Such trophic shifts also suggest that species which are not competitors during one season or life history stage may become competitors at another time.

In years or areas where potential competitors are not abundant, a species may exhibit higher growth and survival because it is able to feed on more energetically favorable prey resources than in years or areas where competitors predominate. Along with data on population trends, interannual and geographic shifts in forage species diets would support a competitive mechanism. The 1995 and 1996 diet samples may provide such a temporal comparison, since pollock were abundant in the former year and virtually absent in the latter year (personal communication, L. Haldorsen).

Species sharing the same habitat may also partition resources on a temporaral basis, perhaps by having different diurnal feeding rhythms. For example, APEX and SEA investigators have sometimes observed juvenile herring schooling in shallow water. Potential competitors may include the demersal nearshore residents such as tomcod, sandlance, or other species; prey might include proportionately more epibenthic or brackish water taxa or might depend on tidal influx of pelagic prey. Dietary overlap and competition might be minimized by fish feeding at different tidal stages when the suite of available prey changes, or the fish themselves may migrate between onshore and offshore areas; both of these possibilities could operate through differences in diel feeding rhythms. Conversely, potential competitors of herring located in pelagic waters offshore may include juvenile pollock. In this region, prey partitioning might occur on a vertical scale rather than a horizontal scale, as planktonic prey perform their diel vertical migrations; however, the mechanism might still be a difference in the diel feeding rhythms of forage species.

A complete investigation of all of these factors is outside the scope of the APEX forage fish diet study, yet some aspects can be addressed by examining the samples collected during the 1996 field study and pooling results from diet studies begun in previous years. These samples are stored at Auke Bay

Laboratory, NMFS, where they have been transferred from fixative solution (formalin) to preservative (50% isopropyl alcohol). They have been inventoried against field records, a database of availability has been established, and, as discussed below, the inventory has been reviewed to determine how many of what kind of samples can be used to address the APEX hypothesis that "planktivory is the factor determing abundance of the preferred forage species of seabirds."

C. Location

Samples were collected in northern, central and southern PWS in offshore and nearshore areas, in Cook Inlet offshore and nearshore areas, and in the Barrens Islands. Samples will be analyzed at the National Marine Fisheries Service Auke Bay Laboratory in Juneau.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

No participation by residents of PWS is anticipated for this laboratory project.

PROJECT DESIGN

The principal APEX field season occurs during the birds' summer breeding periods (July-August). It was designed to estimate the abundance and distribution of forage species through hydroacoustic surveys along transects in three broad areas of the sound (northern, central and southwestern). These areas were defined based on the their foraging distance from bird colonies. Birds were counted and their behavior in foraging flocks studied simultaneously with hydroacoustic surveys of fish. Diet samples of forage species were retained from net samples collected to calibrate acoustic targets. When results of 1995 field studies suggested that most birds forage within a mile of shore, the field study design was modified in 1996 to include nearshore surveys while preserving the offshore surveys to allow for interannual comparisons of distribution and abundance. Although the 1996 diet DPD proposed that substantial directed sampling be conducted to address the potential for interspecific and intraspecific competition that was suggested by 1995 results, only a limited amount of directed sampling was possible in PWS last year. Therefore, in addition to the interspecific geographic comparisons made possible, diet samples from the Barrens Islands, Cook Inlet and Naked Island projects were incorporated because their site monitoring aspects allowed an increase in the number of diet samples that could be used to describe temporal feeding.

A. Objectives

This study will address the potential for food competition between forage fish species and will continue to collect basic food habits information through stomach analysis. The objectives for analyzing the existing 1996 samples include both spatial and temporal aspects. The principal objective is: 1) to address the potential for prey resource competition between forage fish species pairs by testing for a difference in food habits and prey selection when fish co-occur in multi-species schools compared to when they occur in monospecific schools; objectives with a temporal component are 2) to determine the principal feeding periods of each species and whether prey resources are partitioned among co-occurring species on a diel basis; 3) to examine patterns in fish diets collected in weekly time series at certain locations; and 4) to make interannual comparisons between species collected in similar environments; objectives with a spatial component are 5) to describe general food habits and diet similarity between forage fish species in the northeastern, central and southwestern areas of PWS and between geographic regions of the spill area (PWS, Cook Inlet, Barrens Islands); and 6) to compare diets of the same species collected in nearshore beach seines versus offshore purse seines and trawls.

B. Methods

Forage fish stomach samples and prey samples (zooplankton/epibenthic invertebrates) will be analyzed at the NMFS Auke Bay Laboratory. Laboratory protocols are the same as in 1994 and 1995 diet studies, and are completely described in the attached protocol.

Summaries of the pertinent 1996 APEX field collections are described in the 97163A (Fish Population Sampling), 97163M (Cook Inlet Studies), 97163J (Barrens Nesting Study), and 97163F (Guillemot Foraging and Reproduction) chapters of the 1997 annual report and in the 1997 DPD. The complete methods of handling and analyzing specimens collected for diet studies are described in "Protocol for Collecting and Processing Samples for APEX Forage Fish Diet Investigations (97163C) (Appendix 1). A brief description of pertinent field sampling by these projects is given below.

Project 96163A conducted offshore hydroacoustic surveys along established parallel transects in each area of the sound (northeast, central, southwest) during approximately three weeks in July-August. Nearshore hydroacoustic surveys were simultaneously conducted for the first time along zig-zag transects in each area. Various nets were fished to verify targets, determine species composition and to collect diet and other project samples. Schools detected hydroacoustically in offshore areas were sampled with purse seines and trawls. Schools detected hydroacoustically in shallow nearshore water or visually sighted at the surface were sampled primarily with purse seines, cast nets and dipnets. In addition, a nearshore survey was conducted blindly by systematically fishing three randomly selected, fishable sections of each beach segment with a beach seine (thebeach segment formed the base of the zig-zag that was hydroacoustically assessed). Diet samples were collected opportunistically during offshore operations whenever fish targets were captured and nearshore whenever beach seines captured fish. Zooplankton samples (20 m vertical hauls, 243-μ mesh) and epibenthic samples (10 m horizontal hauls, 243-μ mesh) were collected at beach seine sites where fish were successfully sampled to assess prey available to fish from epibenthic and pelagic production systems. Few additional plankton samples were collected offshore; however, in some cases, prey samples collected to complement beach seined fish will be used with purse seined fish samples. Project 96163M (Lower Cook Inlet Studies) collected nearshore and offshore forage fish samples in a manner similar to the work done in PWS. Plankton samples were not collected. Diet samples obtained from this investigation include beach seine and trawl samples collected from mid-June to mid-September at approximately 2-week intervals. The best subsets available from these samples is a 7-bimonthly time series of sandlance and 3 sets of Pacific cod to compare to collections from Naked Island (Table 1).

Due to gear and time constraints, it was not possible to conduct directed sampling on specific schools for the proposed investigations of feeding periodicity and comparisions of diets of fish in monospecific and mixed species schools (see objectives in 97163C DPD). However, we attempted to address these objectives at least minimally. First, diel samples were collected during one day of serial beach seining in northeastern PWS at the end of the APEX cruise. Two beach segments (see above) where fish had been successfully seined during surveys just days before were selected (N05, Knowles Bay and N15, Bligh

Island). Two replicate sections on each segment were beach seined at least once during each of four, 6-hour diel intervals (I: 10:01-14:00, II: 14:01-20:00, III: 20:01-04:00, and IV: 04:01-10:00). These sections were N0506 and N0505 in Knowles Bay, and N1503 and N1507 on southern and western Bligh Island. Unfortunately, it was not possible to fish these beach sections during time interval III at either location. The broad, shallow shelf off Knowles Bay required a long trip by small skiff from the supporting vessel (M/V Ms. Barrett) in semi-darkness, which was determined to be unsafe, and there was no time to return to Bligh Island. The best subsets of samples obtained from this diel feeding investigation were for sandlance and herring. Sandlance were collected during three intervals at Knowles Bay; in addition, a "pseudo-diel" sample collected at the same site two days earlier during surveys provides a fourth time data point foro sandlance. Herring are also available from four times at Knowles Bay. Herring samples were collected at both replicate beach segments in Knowles Bay within the designated diel period and at one of the segments two days earlier during surveys. Additionally, co-occurring herring and sandlance were collected in one of the diel samples. No diel series for a single species was available from Bligh Island replicate segments. The diel samples from Knowles Bay in northeastern PWS and Cabin Bay in central PWS (see below) are the only stomach samples analyzed to date from the 1996 APEX collections (approximately 150 fish).

Second, Project 96163F conducted weekly sampling from the end of June to early August at Cabin Bay on western Naked Island (Central PWS) using beach seines. Several sites in the bay were seined approximately weekly to collect guillemot prey samples. These collections provide two subsets of samples that we will use to address temporal aspects of sandlance diets: a 6-week time series spread over five sites in Cabin Bay and a diel series collected at a single station in late July over five diel intervals (four times and one repeat the next day). The time series samples were collected over roughly the same time period that Diel samples in central PWS (at Naked Island) were collected within days of those in northeastern PWS (at Bligh Island and Knowles Bay). A 5-set collection of Pacific cod samples is also available (Table 1).

Third, Project 96163J (Barrens Islands Nesting Study) provided diet samples from weekly beach seine operations conducted from early July to early September. This sampling was also conducted to determine forage species available to marine birds at the colony sites. Subsamples were preserved for fish diet studies. The best subset of samples available from these collections is a 6-bimonthly time series of sandlance.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

The major activities for this project include use of NOAA biological lab space and microscopes for sample analysis and storage, access to agency library materials and literature, and computers for database management and statistical analysis. These activities will be integrated and supported by the normal operations of the Salmon Investigations and Ocean Carrying Capacity Programs which the PI participates in at ABL. NOAA will contribute 3 months of salary for the Principal Investigator, beyond the one month proposed in this study, for coordinating and managing the project and writing manuscripts and reports. NOAA will provide three GS7-1 Fisheries Biological Technician term positions for processing of stomach and prey samples, data entry, and support for the preparation of data tables and graphics. These personnel will be funded by EVOS and supervised by the diet study PI at ABL. Diet study personnel will participate in field research and sample collection for APEX project 98163A as needed and as funding from that project allows.

SCHEDULE

A. Measurable Project Tasks for FY 98 (October 1, 1997-September 30, 1998)

October 1 to December 31:	Complete processing 1996 APEX diet and prey samples collected from projects 96163A, 96163M, 96163F and 96163J;
	Create relational database of 1996 stomach contents and related information;
	Inventory samples collected for diet study in 1997 by other APEX projects;
	Submit publication from 1994 forage fish seasonal diet studies (941613C) co-authored with ADFG and UAF personnel;
November - February 28:	Prepare oral-slide presentation summarizing 1994-96 diet study results for APEX scientific peer review
December - January 31:	Prepare summary for EVOS Annual Meeting poster session;
	Provide graphics and diet information for APEX summary presentation at the EVOS Annual Meeting ;
	Participate in EVOS Annual Meeting
February 1 - March 15:	Prepare FY99 DPD and budget for APEX forage fish diet studies;
	Complete annual report summarizing results from all 1994-96 forage fish diet and prey samples
April 15, 1998:	Deadlines for 1997 Annual Report, FY99 DPD
July, 1998:	Begin FY98 field study to collect APEX forage fish diet and prey samples?

B. Project Milestones and Endpoints

Collecting detailed food habits data from fish and prey samples is a slow, laborious process. Consistent results depend on the availability of adequately trained biological technicians who work as a team and remain on the project throughout its duration. Complete data are generally not completely available for several months after the samples are collected in a given field season. When diet samples are completely analyzed from the APEX project, datasets from all years will be combined to produce a synthesized picture of forage fish feeding ecology and trophic interactions. Milestones will be successful field seasons, completion of sample analyses and basic data summaries for annual reports and presentations. Endpoints will be publication of results.

C. Completion Date

Processing of fish stomach samples and epibenthic and planktonic prey samples collected during 1996 field season began in early winter, 1997 and will be completed by the end of the year. Most of the eighteen person-months of technician time that were funded in FY97 have already taken place; they were spent analyzing samples, managing the diet database and laboratory functions, and in supporting the PI in literature searches, tabulating data summaries, and preparaing graphics for posters, presentations and reports. It is expected that the approximately three months technician time remaining in FY97 and the nine months proposed funding in FY98 will allow for the proposed laboratory and database work to be completed. Preliminary data analysis and results will be reported in the 1998 annual report.

PUBLICATIONS AND REPORTS

Annual reports summarizing results of samples completed to date will be submitted by the April 15 annual deadline. Final reports will lag by at least a year. After the 1997 field season, the diet studies will be current in laboratory processing of samples. It is expected that the 1998 annual report will incorporate all diet data from 1994-1996 APEX field collections, and will include interannual comparisons. Preparation of manuscripts concerned with subsets of the data wo be submitted for journal publication will begin in 1997. Data may be combined with other APEX projects (eg., 163A) for final manuscript publication.

PROFESSIONAL CONFERENCES

The PI will attend the EVOS Annual Meeting in the winter of 1998. A poster summarizing APEX forage fish diet results will be presented.

NORMAL AGENCY MANAGEMENT

NOAA and NMFS have statutory stewardship for all living marine resources; however, if the oil spill had not occurred, NOAA would not be conducting this project. NOAA, NMFS proposes to make a significant contribution (as stated in the proposed budget) to the operation of this project, making it truly cooperative.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The APEX diet studies are highly integrated with other components of the APEX project and with components of the SEA salmon and herring projects. The juvenile herring study component of SEA will collect forage fish samples for APEX stomach analysis outside of the designated 2-week APEX field season. In addition to these supplemental samples, samples will be shared by multiple APEX components when the numbers collected are insufficient to provide each component with its required number of samples.

Trophic web information from the diet study will be used to establish the basic structure of future ecosystem models of PWS. These models will incorporate data on changing oceanographic regimes, primary and secondary productivity, fish distribution, fish diet overlap, prey selection and potential competitive interactions. They are necessary for understanding recovery of predatory species and are useful in guiding recovery activities. Information from the APEX project in PWS and Cook Inlet geographic regions will also be integrated into the Ocean Carrying Capacity (OCC) program at Auke Bay Laboratory. Designed to assess trends in ocean productivity and their effects on salmonids, the OCC ecosystem study has completed its second year of surveys and sample collection in the Gulf of Alaska (GOA) and additional years studying inside and outside waters of Southeast Alaska. The OCC food habits studies of salmonids and non-salmonids, including forage fish, are being conducted under the direction of the APEX diet study PI. Results from these projects will provide an integrated picture of trophic interactions of salmonids and forage species through much of their life history.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

The FY98 budgets of many multi-year, EVOS-funded studies have been reduced from past amounts, as was anticipated. This proposal incorporates the comments and recommendations of the peer reviewers from the February, 1997 APEX review in Anchorage. The principal recommendation was that field sampling be reduced or eliminated in 1997 to allow the PI and technician personnel to focus on processing samples collected in the past. The proposed budget has been reduced by 50% compared to 1996. The amount proposed will essentially provide funding for the three technicians staffing the ABL food habits laboratory for one quarter year (six pay periods) and will provide one month (two pay periods) funding for the PI. Additional, in kind support for the diet project will be provided for the PI's salary from NMFS ABL base funding.

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The Principal Investigator for the APEX diet study has been employed as a Fisheries Research Biologist at Auke Bay Laboratory, NMFS, for 9 years. She holds a Master of Science degree (1987) in Fisheries Science from the University of Alaska, Juneau. The majority of her past work has been in the field of trophic ecology. Past research includes studies of meiofaunal invertebrates, post-metamorphic flatfish feeding behavior and food habits, juvenile salmon diets, and spring zooplankton dynamics. She has worked on forage fish diet studies in PWS since their inception under the EVOS SEA Program in 1994, and is a co-author on reports of that study.

OTHER KEY PERSONNEL

Mary E. Auburn is completing a B.S. degree in Biology from the University of Alaska Fairbanks, and has several years experience in fisheries and marine biology field and laboratory investigations. She has been employed with PI at ABL on the SEA and APEX Forage Fish Diet studies since their inception in early 1994 and the lead technician managing operation of the food habits lab.

Lee B. Hulbert holds a B.S. degree in Environmental Science from Humboldt State University. He has extensive commercial fishing experience in Prince William Sound and two years work experience in fisheries biology at ABL, including approximately one year with APEX.

Audra L. J. Brase holds an M.S. degree in Fisheries Science from the University of Alaska, Fairbanks and has experience in larval fish feeding and plankton dynamics in the Bering Sea. She was previously employed during SEA field cruises as a seasonal Fish and Game technician. She has been employed with the APEX project at ABL since January, 1997.

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Table 1A. Co-occurring forage fish species and associated prey samples collected in PWS in non-diel hauls in 1996.

APEX 96163A

Southwest Region PWS

date	station-haul -gear	species	time
West Latouche Island			
7-15	1-1-beach	tomcod	13:20
7-15	1-1-beach	pink salmon	13:21
7-15	1-2	epibenthic	13:45
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Point Grace (Latouche Is.)			
7-15	2-1-purse	pink salmon	16:28
7-15	2-1-purse	chum salmon	16:28
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Latouche Is.			
7-16	1-1-purse	pink salmon	14:46
7-16	1-1-purse	chum salmon	14:46
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Bainbridge Point			
7-16	10-1-beach	herring	15:30
7-16	10-1-beach	pink salmon	15:30
7-16	10-2	epibenthic	16:05
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Prince of Wales Passage			
7-16	3-2-purse	herring	15:48
7-16	3-2-purse	pink salmon-sml	15:48
7-16	3-2-purse	pink salmon-lrg	15:48
7-16	3-2-purse	chum salmon	15:48
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30

date	station-haul -gear	species	time
Whale Bay			
7-17	12-1-beach	herring	8:30
7-17	12-1-beach	tomcod	8:30
7-17	12-2	epibenthic	8:40
7-17	12-3	plankton	8:55
7-17	12-4	plankton	9:05
West of Point Countess			
7-17	14-1-beach	herring	10:10
7-17	14-1-beach	tomcod	10:10
7-17	14-2	epibenthic	10:35
7-17	14-3	plankton	10:40
7-17	14-4	plankton	10:45
Paddy Bay			
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	tomcod	18:42
7-17	20-1-beach	pink salmon	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00
Italian Bay			
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	tomcod	13:00
7-18	24-1-beach	pink salmon	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35

Number of fish stomachs=220
Number of epibenthic samples=6
Number of plankton samples=10

Table 1A. Co-occurring forage fish species and associated prey samples collected in PWS in non-diel hauls in 1996.

APEX 96163A

Northeast Region PWS

date	station-haul -gear	species	time
Tatitlek Narrows along Black Pt.			
7-23	57-1-beach	tomcod	13:50
7-23	57-1-beach	unid. greenling	13:50
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32
West Bligh Island			
7-24	60-1-beach	herring	9:50
7-24	60-1-beach	sandlance	9:50
7-24	60-1-beach	sandfish	9:50
7-24	60-2	epibenthic	10:10
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15
outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00
Knowles Bay, Redhead			
7-25	71-1-beach	sandlance-lrg	14:30
7-25	71-1-beach	sandlance-sml	14:30
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50
Knowles Bay			
7-27	84-1-beach	herring**	18:00
7-27	84-1-beach	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42

**stomach ID completed

Number of fish stomachs=90
Number of epibenthic samples=4
Number of plankton samples=10

Central Region PWS

date	station-haul -gear	species	time
South side of Pt. Eleanor			
7-20	34-1-beach	lingcod	11:05
7-20	34-1-beach	tomcod	11:05
7-20	34-1-beach	pollock	11:05
7-20	34-2	epibenthic	11:15
7-20	34-3	plankton	11:20
7-20	34-4	plankton	11:25
SE Bass Harbor (Naked Is.)			
7-20	36-1-beach	pink salmon-sml	14:40
7-20	36-1-beach	pink salmon-lrg	14:40
7-20	36-2	epibenthic	14:55
7-20	36-3	plankton	14:50
7-20	36-4	plankton	14:55
S. McPherson Bay			
7-21	42-1-beach	pollock	13:30
7-21	42-1-beach	tomcod	13:30
7-21	42-2	epibenthic	13:50
7-21	42-3	plankton	13:50
7-21	42-4	plankton	13:45
point off of N arm of Cabin Bay			
7-22	48-1-beach	pink salmon	10:50
7-22	48-1-beach	sandlance	10:50
7-22	48-2	epibenthic	11:00
7-22	48-3	plankton	11:05
7-22	48-4	plankton	11:10

Number of fish stomachs=90
Number of epibenthic samples=4
Number of plankton samples=8

Table 1B. Diel series of forage fish diet samples collected in PWS in 1996.

Cabin Bay, Naked Island, 1996			
Beach seines (APEX 96163F)			
no plankton samples available			
date	station-haul	species	time
7-21	F-1	sandlance**	19:55
7-22	F-1	sandlance**	8:00
7-22	F-2	sandlance**	12:10
7-22	F-1	sandlance**	16:05
7-22	F-2	sandlance**	20:15

Northeast Region PWS, 1996

Knowles Bay (replicate 1)
Beach seines (APEX 96163A)

date	station-haul	species	time
7-27	80-1	sandlance**	11:10
7-27	80-2	epibenthic	11:22
7-27	80-3	epibenthic	11:25
7-27	80-4	plankton	11:55
7-27	80-5	plankton	12:00
7-27	84-1	herring**	18:00
7-27	84-1	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42
7-28	88-1	sandlance**	6:35
7-28	88-2	epibenthic	6:38
7-28	88-3	epibenthic	6:40
7-28	88-4	plankton	6:58
7-28	88-5	plankton	7:00

**stomach ID completed

Knowles Bay (replicate2)
Beach seines (APEX 96163A)

date	station-haul	species	time
7-27	79-1	herring	9:55
7-27	79-2	epibenthic	10:08
7-27	79-3	epibenthic	10:12
7-27	79-4	plankton	10:20
7-27	79-5	plankton	10:25
7-28	87-1	herring	4:40
7-28	87-2	epibenthic	5:15
7-28	87-3	epibenthic	5:17
7-28	87-4	plankton	5:30
7-28	87-5	plankton	5:35

"pseudo-diels" at Knowles Bay
collected at diel station two days earlier

7-25	71-1	sandlance-lrg	14:30
7-25	71-1	sandlance-sml	14:30
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

7-25	72-1	herring	15:20
7-25	72-2	epibenthic	15:50

Table 1C. Diel series of forage fish diet samples collected in PWS in 1996.

Cabin Bay, Naked Island, 1996			
Beach seines (APEX 96163F)			
no plankton samples available			
date	station-haul	species	time
7-21	F-1	sandlance**	19:55
7-22	F-1	sandlance**	8:00
7-22	F-2	sandlance**	12:10
7-22	F-1	sandlance**	16:05
7-22	F-2	sandlance**	20:15

Northeast Region PWS, 1996

Knowles Bay (replicate 1)
Beach seines (APEX 96163A)

date	station-haul	species	time
7-27	80-1	sandlance**	11:10
7-27	80-2	epibenthic	11:22
7-27	80-3	epibenthic	11:25
7-27	80-4	plankton	11:55
7-27	80-5	plankton	12:00
7-27	84-1	herring**	18:00
7-27	84-1	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42
7-28	88-1	sandlance**	6:35
7-28	88-2	epibenthic	6:38
7-28	88-3	epibenthic	6:40
7-28	88-4	plankton	6:58
7-28	88-5	plankton	7:00

**stomach ID completed

Knowles Bay (replicate2)
Beach seines (APEX 96163A)

date	station-haul	species	time
7-27	79-1	herring	9:55
7-27	79-2	epibenthic	10:08
7-27	79-3	epibenthic	10:12
7-27	79-4	plankton	10:20
7-27	79-5	plankton	10:25
7-28	87-1	herring	4:40
7-28	87-2	epibenthic	5:15
7-28	87-3	epibenthic	5:17
7-28	87-4	plankton	5:30
7-28	87-5	plankton	5:35

"pseudo-diels" at Knowles Bay
collected at diel station two days earlier

7-25	71-1	sandlance-lrg	14:30
7-25	71-1	sandlance-sml	14:30
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

7-25	72-1	herring	15:20
7-25	72-2	epibenthic	15:50

Table 1D. Miscellaneous forage fish species collected for diet samples from PWS, Cook Inlet and Barrens Islands in 1996, by area, date, station and time. See annual report for station location and other details.

Northeast region PWS
Miscellaneous gear (APEX 96163A)

date	station-haul -gear	species	time
N. Galena Bay			
7-23	53-1-beach	pink salmon	9:00
7-23	53-2	epibenthic	9:05
7-23	53-3	plankton	10:30
7-23	53-4	plankton	10:35
Port Fidalgo			
7-24	66-1-beach	sandlance	18:05
7-24	66-2	epibenthic	18:20
7-24	66-3	plankton	18:20
7-24	66-4	plankton	18:25
Boulder Bay (inside Bidarka Pt.)			
7-24	63-1-beach	sandlance	13:35
7-24	63-2	epibenthic	13:50
7-24	63-3	plankton	13:50
7-24	63-4	plankton	13:55
Irish Cove, Port Fidalgo			
7-24	64-1-beach	sandlance	15:20
7-24	64-2	epibenthic	15:25
7-24	64-3	plankton	15:30
7-24	64-4	plankton	15:35
Galena Bay W. of Narrows			
7-23	54-1-beach	herring	11:10
7-23	54-2	epibenthic	11:20
7-23	54-3	plankton	11:35
7-23	54-4	plankton	11:40

date	station-haul -gear	species	time
Tatitlek Narrows			
7-23	55-1-beach	tomcod	12:35
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32
W. Landlocked Bay, Bidarka Pt.			
7-24	61-1-beach	herring	11:45
7-24	61-2	epibenthic	12:00
7-24	61-3	plankton	12:00
7-24	61-4	plankton	12:05
Port Fidalgo			
7-24	65-2-beach	herring	17:00
7-24	65-3	epibenthic	17:30
7-24	65-4	plankton	17:25
7-24	65-5	plankton	17:20
Inner Port Fidalgo			
7-26	62-2-purse	herring	9:30
		no plankton	
N. Port Gravina			
7-26	76-1-beach	herring	11:20
7-26	76-2	epibenthic	11:35
7-26	76-3	plankton	11:35
7-26	76-4	plankton	11:40
St. Matthews Bay			
7-27	69-1-dipnet	herring	9:00
		no plankton	

Table 1D. Miscellaneous forage fish species collected for diet samples from PWS, Cook Inlet and Barrens Islands in 1996, by area, date, station and time. See annual report for station location and other details.

Central region PWS
Miscellaneous gear (APEX 96163A)

date	station-haul -gear	species	time
South inside of Bay of Isles			
7-19	27-1-beach	tomcod	11:48
7-19	27-2	epibenthic	12:00
7-19	27-3	plankton	12:10
7-19	27-4	plankton	12:15
North side Bay of Isles			
7-19	29-1-beach	tomcod	16:30
7-19	29-2	epibenthic	16:45
7-19	29-3	plankton	16:55
7-19	29-4	plankton	17:00
North side Bay of Isles			
7-19	18-2-purse	herring	12:30
		no plankton	
South Smith Is.			
7-21	65-1-trawl	pollock	15:09
7-21	65-2	plankton	15:35
7-21	65-3	plankton	15:45
South Storey Is.			
7-22	49-1-beach	pink salmon	12:10
7-22	49-2	epibenthic	12:20
7-22	49-3	plankton	12:20
7-22	49-4	plankton	12:25

Southwest region PWS

date	station-haul -gear	species	time
East Chenega Is.			
7-18	22-1-beach	greenling	9:40
		no plankton	

Table 1D. Miscellaneous forage fish species collected for diet samples from PWS, Cook Inlet and Barrens Islands in 1996, by area, date, station and time. Se[illegible]ual report for station location and other details.

Cabin Bay, Naked Island, PWS 1996 (APEX 96163F)			
Beach seines, all species			
date	station-haul	species	time
6-28	F-1	unkn salmon	16:20
6-28	F-1	unkn salmon	16:20
7-14	G-1	sandlance	15:30
7-14	I-1	sandfish	12:00
7-14	I-1	pacific cod	12:00
7-21	F-1	pacific cod	0:00
7-21	F-1	pacific cod	0:00
7-21	F-1	sandlance	19:55
7-21	F-1	sandlance**	19:55
7-22	A-1	sandlance	0:00
7-22	F-1	pacific cod	4:00
7-22	F-1	sandlance**	8:00
7-22	F-1	sandlance**	16:05
7-22	F-2	sandlance**	12:10
7-22	F-2	sandlance**	20:15
7-27	F-1	sandlance	10:35
7-28	I-1	pacific cod	19:20
7-6	F-1	sandlance	15:20
8-1	B-2	herring	16:01
8-1	B-2	herring	16:01
8-1	C-1	herring	13:28
8-13	A-1	sandlance	17:40
8-13	B-1	herring	18:23
8-9	R-1	unk. gadid	17:45

**stomach ID completed

Lower Cook Inlet, 1996 APEX 96163M)			
Miscellaneous gear, all species			
date	station-gear	species	time
6-14	ST-beach	sandlance	15:35
6-16	NF-beach	sandlance	8:30
6-16	NF-beach	sandlance	8:30
6-28	CP1-beach	pink salmon	6:45
6-29	HS-beach	herring	7:45
6-29	HS-beach	eelpout	7:45
6-29	HS-beach	sandlance	8:40
7-1	BF-beach	hagfish	10:20
7-8	CP2-beach	sandlance	15:45
7-16	trawl	pollock	13:43
7-16	trawl	pacific cod	13:43
7-17	trawl	capelin	missing
7-18	trawl	pink salmon	missing
7-18	trawl	sandlance	missing
7-25	trawl	sandfish	missing
8-6	EP-beach	capelin	15:00
8-7	SS-beach	sandlance	9:45
8-7	SS-beach	sandlance	9:30
8-25	missing	herring	missing
8-25	missing	pacific cod	missing
8-27	CP4-beach	sandlance	8:50
8-27	PB-beach	pacific cod	7:27
8-27	PB-beach	pacific cod	7:45
8-27	PC-beach	sandlance	8:10
9-12	ST-beach	smelt	15:20
9-13	PB-beach	sandlance	16:10

Table 1D. Miscellaneous forage fish species collected for diet samples from PWS, Cook Inlet and Barrens Islands in 1996, by area, date, station and time. See annual report for station location and other details.

Sandfish, all areas PWS, 1996			
Beach seines (APEX 96163A)			
date	station-haul	number	time
7-20	34-1	1	11:05
7-20	36-1	4	14:40
7-21	44-1	1	15:45
7-21	42-1	1	13:30
7-21	41-1	3	11:35
7-24	59-1	1	17:50
7-24	60-1	19	9:50
7-27	82-1	1	15:00
7-27	85-1	3	20:40
7-27	86-1	1	21:45

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	set #	species
7-2	1	tomcod
7-2	1	sandlance
7-9	3	surf smelt
7-17	1	pink salmon
7-17	1	sandlance
7-23	1	tomcod
7-23	2	sandlance
7-23	2	sandlance-lrg
7-24	3	sandlance
7-24	3	pink salmon
8-16	3	capelin
8-16	3	sandlance
8-23	1	sandlance
9-8	1	sandlance

Table 1E. Forage fish diet samples and associated prey samples collected in PWS at adjacent sites or with multiple fishing gear types at [illegible] site in 1996.

APEX 96163A

Northeast region PWS
Multiple gear

date	station-haul -gear	species	time
NE Bligh Island			
7-23	47-1-purse	herring	16:15
7-23	47-2-cast	herring	17:30
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15

Central region PWS
Multiple gear

North Eleanor Is.			
7-20	35-1-beach	pink salmon	12:30
7-20	24-2-purse	pink salmon	12:06
7-20	35-2	epibenthic	12:50
7-20	35-3	plankton	13:05
7-20	35-4	plankton	13:10

Northeast region PWS
Adjacent sites

date	station-haul -gear	species	time
Knowles, Redhead			
7-25	71-1-beach	sandlance-lrg	14:30
7-25	71-1-beach	sandlance-sml	14:30
7-25	72-1-beach	herring	15:20
7-25	72-2	epibenthic	15:50
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40

Tatitlek Narrows along Black Pt.			
7-23	56-1-beach	herring	13:15
7-23	57-1-beach	tomcod	13:50
7-23	57-1-beach	unid. greenling	13:50
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Multiple gear and adjacent sites

outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-1-beach	herring	10:40
7-26	68-5-purse	herring	19:00
7-25	68-2	epibenthic	10:55
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00

Table 2A. APEX collections of herring and associated prey samples for diet studies, 1996.

Co-occurring Species

Southwest Region PWS

date	station-haul -gear	species	time
Bainbridge Point			
7-16	10-1-beach	herring	15:30
7-16	10-1-beach	pink salmon	15:30
7-16	10-2	epibenthic	16:05
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Prince of Wales Passage			
7-16	3-2-purse	herring	15:48
7-16	3-2-purse	pink salmon-sml	15:48
7-16	3-2-purse	pink salmon-lrg	15:48
7-16	3-2-purse	chum salmon	15:48
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Whale Bay			
7-17	12-1-beach	herring	8:30
7-17	12-1-beach	tomcod	8:30
7-17	12-2	epibenthic	8:40
7-17	12-3	plankton	8:55
7-17	12-4	plankton	9:05

Southwest Region PWS

date	station-haul -gear	species	time
West of Point Countess			
7-17	14-1-beach	herring	10:10
7-17	14-1-beach	tomcod	10:10
7-17	14-2	epibenthic	10:35
7-17	14-3	plankton	10:40
7-17	14-4	plankton	10:45
Paddy Bay			
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	tomcod	18:42
7-17	20-1-beach	pink salmon	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00
Italian Bay			
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	tomcod	13:00
7-18	24-1-beach	pink salmon	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35

Northeastern PWS

West Bligh Island			
7-24	60-1-beach	herring	9:50
7-24	60-1-beach	sandlance	9:50
7-24	60-1-beach	sandfish	9:50
7-24	60-2	epibenthic	10:10
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15

Table 2B. APEX collections of sandlance and associated prey samples for diet studies, 1996.

Co-occurring Species

Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
West Bligh Island			
7-24	60-1-beach	herring	9:50
7-24	60-1-beach	sandlance	9:50
7-24	60-1-beach	sandfish	9:50
7-24	60-2	epibenthic	10:10
7-24	60-3	plankton	10:10
7-24	60-4	plankton	10:15
Beach seine, Knowles, Redhead			
7-25	71-1-beach*	sandlance-lrg	14:30
7-25	71-1-beach*	sandlance-sml	14:30
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

*also pseudo-diel

Central PWS (APEX 96163A)

date	station-haul -gear	species	time
point off of N arm of Cabin Bay			
7-22	48-1-beach	pink salmon	10:50
7-22	48-1-beach	sandlance	10:50
7-22	48-2	epibenthic	11:00
7-22	48-3	plankton	11:05
7-22	48-4	plankton	11:10

Northeastern PWS (APEX 96163A)
Adjacent sites

Knowles, Redhead			
7-25	71-1-beach*	sandlance-lrg	14:30
7-25	71-1-beach*	sandlance-sml	14:30
7-25	71-1-beach*	herring	15:20
7-25	72-2	epibenthic	15:50
7-25	71-2	epibenthic	15:35
7-25	71-3	plankton	15:40
7-25	71-4	plankton	15:50

Table 2B. APEX collections of sandlance and associated prey samples for diet studies, 1996.

Single Species

Central PWS (APEX 96163A)

date	station-haul -gear	species	time
SW Cabin Bay			
7-22	47-1-beach	sandlance	9:55
7-22	47-2	epibenthic	10:08
7-22	47-3	plankton	10:10
7-22	47-4	plankton	10:15

Southwestern PWS (APEX 96163A)

inside Bainbridge Pt.			
7-16	11-2-beach	sandlance	17:40
7-16	11-3	epibenthic	17:55
7-16	11-4	plankton	18:15
7-16	11-5	plankton	18:25

Miscellaneous

Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
Port Fidalgo			
7-24	66-1-beach	sandlance	18:05
7-24	66-2	epibenthic	18:20
7-24	66-3	plankton	18:20
7-24	66-4	plankton	18:25
Boulder Bay (inside Bidarka Pt.)			
7-24	63-1-beach	sandlance	13:35
7-24	63-2	epibenthic	13:50
7-24	63-3	plankton	13:50
7-24	63-4	plankton	13:55
Irish Cove, Port Fidalgo			
7-24	64-1-beach	sandlance	15:20
7-24	64-2	epibenthic	15:25
7-24	64-3	plankton	15:30
7-24	64-4	plankton	15:35

Table 2B. APEX collections of sandlance and associated prey samples for diet studies, 1996.

Cabin Bay, Naked Island, PWS, 1996			
Beach seines (APEX 96163F)			
date	station-haul	species	time
7-6	F-1	sandlance	15:20
7-14	G-1	sandlance	15:30
7-21	F-1	sandlance	19:55
7-21	F-1	sandlance**	19:55
7-22	A-1	sandlance	0:00
7-22	F-1	sandlance**	8:00
7-22	F-1	sandlance**	16:05
7-22	F-2	sandlance**	12:10
7-22	F-2	sandlance**	20:15
7-27	F-1	sandlance	10:35
8-13	A-1	sandlance	17:40

**stomach ID completed

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	set #	species
7-2	1	sandlance
7-17	1	sandlance
7-23	2	sandlance
7-23	2	sandlance-lrg
7-24	3	sandlance
8-16	3	sandlance
8-23	1	sandlance
9-8	1	sandlance

Lower Cook Inlet 1996			
Miscellaneous gear (APEX 96163M)			
date	station-gear	species	time
6-14	ST-beach	sandlance	15:35
6-16	NF-beach	sandlance	8:30
6-16	NF-beach	sandlance	8:30
6-29	HS-beach	sandlance	8:40
7-8	CP2-beach	sandlance	15:45
7-18	trawl	sandlance	missing
8-7	SS-beach	sandlance	9:45
8-7	SS-beach	sandlance	9:30
8-27	CP4-beach	sandlance	8:50
8-27	PC-beach	sandlance	8:10
9-13	PB-beach	sandlance	16:10

Table 2B. APEX collections of sandlance and associated prey samples for diet studies, 1996.

Diel Samples (APEX 96163A)
Northeastern PWS
Knowles Bay (replicate 1)
Beach seines

date	station-haul	species	time
7-27	80-1	sandlance**	11:10
7-27	80-2	epibenthic	11:22
7-27	80-3	epibenthic	11:25
7-27	80-4	plankton	11:55
7-27	80-5	plankton	12:00
7-27	84-1	herring**	18:00
7-27	84-1	sandlance**	18:00
7-27	84-2	epibenthic	18:10
7-27	84-3	epibenthic	18:12
7-27	84-4	plankton	18:38
7-27	84-5	plankton	18:42
7-28	88-1	sandlance**	6:35
7-28	88-2	epibenthic	6:38
7-28	88-3	epibenthic	6:40
7-28	88-4	plankton	6:58
7-28	88-5	plankton	7:00

**stomach ID completed

Knowles Bay (replicate2)
Beach seines

date	station-haul	species	time
7-27	79-1	herring	9:55
7-27	79-2	epibenthic	10:08
7-27	79-3	epibenthic	10:12
7-27	79-4	plankton	10:20
7-27	79-5	plankton	10:25
7-28	87-1	herring	4:40
7-28	87-2	epibenthic	5:15
7-28	87-3	epibenthic	5:17
7-28	87-4	plankton	5:30
7-28	87-5	plankton	5:35

West Bligh Island
Beach seines

date	station-haul	species	time
7-27	82-1	sandlance	15:00
7-27	82-2	epibenthic	15:30
7-27	82-3	epibenthic	15:32
7-27	82-4	plankton	15:15
7-27	82-5	plankton	15:20

Table 20. APEX collections of pollock and associated prey samples for diet studies, 1996.

Central Region PWS (APEX 96163A)

Co-occurring Species

date	station-haul -gear	species	time
South side of Pt. Eleanor			
7-20	34-1-beach	pollock	11:05
7-20	34-1-beach	lingcod	11:05
7-20	34-1-beach	tomcod	11:05
7-20	34-2	epibenthic	11:15
7-20	34-3	plankton	11:20
7-20	34-4	plankton	11:25

S. McPherson Bay			
7-21	42-1-beach	pollock	13:30
7-21	42-1-beach	tomcod	13:30
7-21	42-2	epibenthic	13:50
7-21	42-3	plankton	13:50
7-21	42-4	plankton	13:45

Miscellaneous (APEX 96163A)

date	station-haul -gear	species	time
South Smith Is.			
7-21	65-1-trawl	pollock	15:09
7-21	65-2	plankton	15:35
7-21	65-3	plankton	15:45

Lower Cook Inlet, 1996 (APEX 96163M)			
date	station-gear	species	time
7-16	trawl	pollock	13:43
		no plankton	

Table 2D. APEX collections of tomcod and associated prey samples for diet studies, 1996.

Co-occurring Species

Southwestern PWS (APEX 96163A)

date	station-haul -gear	species	time
West Latouche Island			
7-15	1-1-beach	tomcod	13:20
7-15	1-1-beach	pink salmon	13:21
7-15	1-2	epibenthic	13:45
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Whale Bay			
7-17	12-1-beach	tomcod	8:30
7-17	12-1-beach	herring	8:30
7-17	12-2	epibenthic	8:40
7-17	12-3	plankton	8:55
7-17	12-4	plankton	9:05
West of Point Countess			
7-17	14-1-beach	tomcod	10:10
7-17	14-1-beach	herring	10:10
7-17	14-2	epibenthic	10:35
7-17	14-3	plankton	10:40
7-17	14-4	plankton	10:45
Paddy Bay			
7-17	20-1-beach	tomcod	18:42
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	pink salmon	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00

Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
Italian Bay			
7-18	24-1-beach	tomcod	13:00
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	pink salmon	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35
Tatitlek Narrows along Black Pt.			
7-23	57-1-beach	tomcod	13:50
7-23	57-1-beach	unid. greenling	13:50
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Central PWS (APEX 96163A)

South side of Pt. Eleanor			
7-20	34-1-beach	tomcod	11:05
7-20	34-1-beach	lingcod	11:05
7-20	34-1-beach	pollock	11:05
7-20	34-2	epibenthic	11:15
7-20	34-3	plankton	11:20
7-20	34-4	plankton	11:25
S. McPherson Bay			
7-21	42-1-beach	tomcod	13:30
7-21	42-1-beach	pollock	13:30
7-21	42-2	epibenthic	13:50
7-21	42-3	plankton	13:50
7-21	42-4	plankton	13:45

Table 2D. APEX collections of tomcod and associated prey samples f[illegible]t studies, 1996.

Single Species

Central PWS (APEX 96163A)

date	station-haul -gear	species	time
large bay on SE Eleanor Is.			
7-20	33-1-beach	tomcod	9:30
7-20	33-2	epibenthic	9:40
7-20	33-3	plankton	9:45
7-20	33-4	plankton	9:50

Southwestern PWS (APEX 96163A)

Paddy Bay			
7-17	18-1-beach	tomcod	16:30
7-17	18-2	epibenthic	16:40
7-17	18-3	plankton	16:45
7-17	18-4	plankton	16:50

Northeastern PWS (APEX 96163A)
Diel Station

South Bligh Is.			
7-27	86-1-beach	tomcod	21:45
7-27	86-2	epibenthic	22:00
7-27	8603	epibenthic	22:02
7-27	8604	plankton	22:25
7-27	86-5	plankton	22:28

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	set #	species
7-2	1	tomcod
7-23	1	tomcod
		no plankton

Miscellaneous

Northeastern PWS (APEX 96163A)

date	station-haul -gear	species	time
Tatitlek Narrows			
7-23	55-1-beach	tomcod	12:35
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Central PWS (APEX 96163A)

South Inside of Bay of Isles			
7-19	27-1-beach	tomcod	11:48
7-19	27-2	epibenthic	12:00
7-19	27-3	plankton	12:10
7-19	27-4	plankton	12:15
North side Bay of Isles			
7-19	29-1-beach	tomcod	16:30
7-19	29-2	epibenthic	16:45
7-19	29-3	plankton	16:55
7-19	29-4	plankton	17:00

Northeastern PWS (APEX 96163A)
Adjacent sites

Tatitlek Narrows along Black Pt.			
7-23	57-1-beach	tomcod	13:50
7-23	56-1-beach	herring	13:15
7-23	57-1-beach	unid. greenling	13:50
7-23	56-2	epibenthic	13:20
7-23	56-3	plankton	13:28
7-23	56-4	plankton	13:32

Table 2E. APEX collections of juvenile pink salmon and associated prey samples for diet studies, 1996.

Co-occurring species (APEX 96163A)
Southwestern PWS

date	station-haul -gear	species	time
West Latouche Island			
7-15	1-1-beach	pink salmon	13:21
7-15	1-1-beach	tomcod	13:20
7-15	1-2	epibenthic	13:45
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Point Grace (Latouche Is.)			
7-15	2-1-purse	pink salmon	16:28
7-15	2-1-purse	chum salmon	16:28
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Latouche Is.			
7-16	1-1-purse	pink salmon	14:46
7-16	1-1-purse	chum salmon	14:46
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Bainbridge Point			
7-16	10-1-beach	pink salmon	15:30
7-16	10-1-beach	herring	15:30
7-16	10-2	epibenthic	16:05
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30

date	station-haul -gear	species	time
Prince of Wales Passage			
7-16	3-2-purse	pink salmon-sml	15:48
7-16	3-2-purse	pink salmon-lrg	15:48
7-16	3-2-purse	herring	15:48
7-16	3-2-purse	chum salmon	15:48
7-16	10-3	plankton	16:20
7-16	10-4	plankton	16:30
Paddy Bay			
7-17	20-1-beach	pink salmon	18:42
7-17	20-1-beach	herring	18:42
7-17	20-1-beach	tomcod	18:42
7-17	20-2	epibenthic	18:55
7-17	20-3	plankton	18:55
7-17	20-4	plankton	19:00
Italian Bay			
7-18	24-1-beach	pink salmon	13:00
7-18	24-1-beach	herring	13:00
7-18	24-1-beach	tomcod	13:00
7-18	24-2	epibenthic	13:30
7-18	24-3	plankton	13:30
7-18	24-4	plankton	13:35

Table 2E. APEX collections of juvenile pink salmon and associated prey samples for diet studies, 1996.

Co-occurring Species (APEX 96163A)
Northeastern PWS

date	station-haul -gear	species	time
outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00

Central PWS

date	station-haul -gear	species	time
SE Bass Harbor (Naked Is.)			
7-20	36-1-beach	pink salmon-sml	14:40
7-20	36-1-beach	pink salmon-lrg	14:40
7-20	36-2	epibenthic	14:55
7-20	36-3	plankton	14:50
7-20	36-4	plankton	14:55
point off of N arm of Cabin Bay			
7-22	48-1-beach	pink salmon	10:50
7-22	48-1-beach	sandlance	10:50
7-22	48-2	epibenthic	11:00
7-22	48-3	plankton	11:05
7-22	48-4	plankton	11:10

Single Species (APEX 96163A)
Central PWS

date	station-haul -gear	species	time
SW arm of Naked Island			
7-21	39-2-beach	pink salmon	9:00
7-21	39-3	epibenthic	9:10
7-21	39-4	plankton	9:25
7-21	39-5	plankton	9:30
SW Naked Island			
7-21	40-1-beach	pink salmon	10:30
7-21	40-2	epibenthic	10:45
7-21	40-3	plankton	10:55
7-21	40-4	plankton	11:00
Bass Harbor (Naked Is.)			
7-21	41-1-beach	pink salmon	11:35
7-21	41-2	epibenthic	11:50
7-21	40-3	plankton	10:55
7-21	40-4	plankton	11:00
Ingot Is.			
7-20	24-2-purse	pink salmon	12:06
		no plankton	
N. Eleanor Is.			
7-20	35-1-beach	pink salmon	12:30
7-20	35-2	epibenthic	12:50
7-20	35-3	plankton	13:05
7-20	35-4	plankton	13:10

Table 2E. APEX collections of juvenile pink salmon and associated prey samples for diet studies, 1996.

Dual gear
Central PWS

date	station-haul -gear	species	time
North Eleanor Is.			
7-20	35-1-beach	pink salmon	12:30
7-20	24-2-purse	pink salmon	12:06
7-20	35-2	epibenthic	12:50
7-20	35-3	plankton	13:05
7-20	35-4	plankton	13:10

Dual gear and adjacent sites
Northeastern PWS

date	station-haul -gear	species	time
outer Port Fidalgo			
7-25	58-2-purse	pink salmon	13:30
7-25	58-2-purse	stickleback	13:30
7-25	68-1-beach	herring	10:40
7-26	68-5-purse	herring	19:00
7-25	68-2	epibenthic	10:55
7-25	68-3	plankton	10:55
7-25	68-4	plankton	10:00

Miscellaneous hauls (APEX 96163A)
Northeastern PWS

date	station-haul -gear	species	time
N. Galena Bay			
7-23	53-1-beach	pink salmon	9:00
7-23	53-2	epibenthic	9:05
7-23	53-3	plankton	10:30
7-23	53-4	plankton	10:35

Central PWS

South Storey Is.			
7-22	49-1-beach	pink salmon	12:10
7-22	49-2	epibenthic	12:20
7-22	49-3	plankton	12:20
7-22	49-4	plankton	12:25

Miscellaneous hauls

Lower Cook Inlet 1996 (APEX 96163M)			
date	station-gear	species	time
6-28	CP1-beach	pink salmon	6:45
7-18	trawl	pink salmon	missing
		no plankton	

Amatouli Cove, Barren Islands, 1996		
Beach seines (APEX 96163J)		
date	set #	species
7-17	1	pink salmon
7-24	3	pink salmon

E
Kittiwake Studies

KITTIWAKES AS INDICATORS OF CHANGE IN FORAGE FISH

Project Number: 98163E

Restoration Category: Research

Proposed By: DOI

Duration: 4 years

Cost FY 98: $181.6

Geographic Area: Prince William Sound

Injured Resource: Piscivorous birds

INTRODUCTION

Seabirds have been recognized as potentially useful indicators of marine resources by many authors (Ashmole 1971, Boersma 1978, Crawford and Shelton 1978, Anderson and Gress 1984, Ricklefs et al. 1984, Cairns 1987, Croxall et al. 1988, Monaghan et al. 1989, Harris and Wanless 1990, Furness and Barrett 1991, Furness and Nettleship 1991, Hamer et al. 1991, Hunt et al. 1991). Availability of food resources affect foraging success, which in turn affects reproductive output. Several reproductive parameters have been proposed as useful indicators: breeding phenology, clutch size, breeding success, chick diets, chick growth rates, adult colony attendance, adult activity budgets, foraging trip duration, and adult mass (Cairns 1987, Croxall et al. 1988).

Although foraging behavior partially determines reproductive output, the nature of this relationship may be complex. Optimal foraging models predict precise behaviors that are assumed to maximize fitness (Schoener 1971, 1987, Pyke 1984, Stephens and Krebs 1986). In contrast to the idea of optimality, evidence indicates there is a range of foraging effort over which reproductive output is not affected (Costa and Gentry 1986, Burger and Piatt 1990, Irons 1992). For example, Cairns (1987) suggested that adult survivorship changes only when food is in very short supply while activity budgets change only during medium and high levels of food availability. The phenomenon responsible for this uncoupling of foraging effort and reproductive output above threshold levels of food abundance has been termed a "buffer" (Cairns 1987, Burger and Piatt 1990). A buffer can be defined as the surplus capacity to forage. Buffers can be used to compensate for periods of low food availability so that reproductive output is maintained even though food is less available. Cairns (1987) also pointed out that activity budgets may be better than reproductive parameters as indicators of changes in food supply; the effects of food supply changes on reproductive output may be reduced by parents altering their foraging behavior to compensate for shortages. Burger and Piatt (1990) and Irons (1992) found evidence of this in common murres (*Uria aalge*) and black-legged kittiwakes (*Rissa tridactyla)*, respectively.

In addition to understanding how food shortages affect productivity of seabirds, it is important to understand how seabirds find their food in order to identify which processes break down during a food shortage. Many species of seabirds, including black-legged kittiwakes and marbled murrelets (*Brachyramphus marmoratus*), forage in flocks (Sealy 1973, Hoffman et al. 1981, Duffy 1983, Harrison et al. 1991) which apparently increases their foraging efficiency (Lack 1968, Morse 1970, Sealy 1973, Hoffman et al. 1981, Wittenburger and Hunt 1985, Gotmark et al. 1986, Harrison et al. 1991). The formation of seabird feeding flocks is enhanced by a form of information transfer termed "network foraging" (Wittenburger and Hunt 1985), which results in seabirds learning of and joining feeding flocks by observing the flight of other seabirds as they fly toward a feeding flock (Gould 1971, Sealy 1973, Hoffman et al. 1981). However, the importance of flock foraging has been questioned by Irons (1992), who found that much foraging by breeding kittiwakes occurred outside of foraging flocks.

Seabirds seek areas to feed where prey are concentrated by oceanographic features such as fronts, eddies, and upwellings (Murphy 1936, Ashmole 1971, Hunt and Schneider 1987), some of which are caused by current flow over underwater topographic features such as continental shelves, banks, and sills (Brown et al. 1979, Vermeer et al. 1987, Brown and Gaskin 1988, Cairns and Schneider 1990, Schneider et al. 1990a, b). In Prince William Sound, the irregular bathymetry and large tidal variation are likely to affect the distribution of forage fish and their availability to kittiwakes.

We propose to investigate the relationship between kittiwake foraging effort and reproductive parameters in different foraging environments and document the habitats and behaviors used by foraging kittiwakes. These results will aid in understanding the processes by which seabirds find food and how these processes are affected by changes in availability of forage fishes.

NEED FOR THE PROJECT

A. Statement of problem

Marbled murrelets, pigeon guillemots, common murres, and black-legged kittiwakes were impacted by the oil spill and have not recovered. In Prince William Sound there is evidence that recovery is not occurring because of a lack of food. We address the question, is food limiting the productivity of kittiwakes in Prince William Sound? Productivity of kittiwakes may be affected by prey in three ways: prey abundance may be inadequate, prey may be present but unavailable to birds, or prey may be of poor energetic value.

B. Rationale

By studying the reproductive performance and foraging behavior of black-legged kittiwakes, we can learn if they are food stressed, and if so, if it is because of lack of available food or lack of high quality food. By studying adult survival, recruitment and dispersal rates we can determine if the population is productive enough to maintain itself. Because kittiwakes are piscivorous like other impacted birds, it is likely that they would be affected by a lack of food in a similar manner as the other species. Kittiwakes are easier and less expensive to study than other impacted species. By studying kittiwakes, we are hopefully learning about factors that are limiting the recovery of other species too.

After it is determined how food is limiting, we can then begin to answer questions about why food is limiting and what can be done about it.

C. Summary of Major Hypotheses and Objectives

1. Kittiwake activity budgets reflect relative abundance of available forage fishes.

2. Kittiwake productivity reflects the relative abundance and quality of available forage fishes.

3. Kittiwake diet reflects the relative composition of forage fishes.

4. Kittiwakes select foraging areas based on specific habitat characteristics. (this objective will be done in cooperation with the seabird/forage fish component).

D. Completion Date

The completion date coincides with the completion date of the APEX project.

COMMUNITY INVOLVEMENT

FY 96 BUDGET

PROJECT DESIGN

A. Objectives

1. Determine relative amount and quality of food available to nesting kittiwakes by the following:

a. Monitoring reproductive parameters such as egg laying date, nesting success, clutch size, hatching success, brood size at hatching, growth rates, fledging success, brood size at fledging, adult attendance, and overall productivity.

b. Monitoring diets and foraging parameters such as foraging trip length, foraging trip distance, foraging areas, chick provisioning rates, and species and size of prey consumed.

2. Determine if populations are productive enough to maintain themselves by:

Monitoring survival rates of adults and recruitment and dispersal rates of young.

3. Identify habitat characteristics of foraging areas used by kittiwakes (this objective will be done in cooperation with the APEX seabird/forage fish component B.).

B. Methods

Egg laying dates, clutch size, hatching success, fledging success and overall productivity data will be collected from the Shoup Bay and Eleanor Island colonies by setting up a series of representative plots throughout the colonies that can be monitored to address these parameters. Plots will be checked every three to five days throughout the nesting season. Clutch size will be recorded at 10 colonies in Prince William Sound (PWS) for which there are historical data. Hatching success and brood size at hatching will be recorded at four colonies in PWS: Shoup Bay, Eleanor Island, Naked Island and North Icy Bay. Overall productivity and brood size at fledging will be recorded for all 26 colonies in PWS.

Hatching success is calculated as the number of eggs hatched divided by the number of eggs laid. Fledging success is calculated as the number of chicks fledged divided by the number of chicks hatched. Overall productivity is calculated as the number of chicks in nests just before fledging divided by the number of nests built.

To determine growth rates, chicks of birds without radios will be weighed to the nearest gram with 300 g and 500 g Pesola scales every five days from hatching to just before fledging. However, chick growth rates of some radio-tagged birds will be recorded to determine if they are different from chick growth rates of birds without radios. Chicks will be selected from accessible nests in several areas at Shoup Bay and all accessible chicks will be weighed at Eleanor Island. All accessible chicks will also be weighed at the North Icy Bay colony and the Naked Island colony. Growth rates will be calculated for the near-linear portion of the growth curve (i.e., 60 - 300 g) by dividing the weight gain by the number of days. For kittiwakes, this method produces results that are virtually identical to Ricklefs' (1967) maximum instantaneous growth rates (Galbraith 1983).

We will collect diet samples from adults at Shoup Bay, Eleanor Island, Naked Island and North Icy Bay colonies from July through August. Ten samples a week will be collected at Shoup Bay, five samples a week will be collected from Eleanor Island and five to ten samples will be collected once a month at Naked Island and North Icy Bay colonies. Diet samples will be taken from chicks by collecting food they regurgitate after we approach or handle them. We will take only one food sample from the chicks in a nest and we will sample each chick once during the nesting season if possible. All samples will be preserved in 70% ethyl alcohol for later analysis. Otoliths will be used to determine fish species and lengths (Messieh 1975, Springer et al. 1986). Fish ages will be determined from their lengths (pers. comm. E. Biggs, Alaska Department of Fish and Game).

Data on foraging behavior and adult attendance will be obtained for radio-tagged birds. Breeding birds will be radio-tagged after capturing them at their nests with a noose-pole. Transmitters in 164-168 MHz range will be attached to 30 adult birds at each Shoup Bay and Eleanor Island. The radio packages weigh about 11 grams, which is about 2.5% of a kittiwake's body mass and will be attached under the base of the tail (Anderson and Ricklefs 1987, Irons 1992). To aid in visual observations of the birds, each bird will be banded with a unique combination of color bands and head, breast, and tail feathers will be dyed unique color combinations.

Data on the foraging trip length, trip distance and foraging area of radio-tagged birds will be collected by following individual birds with a 8m Boston Whaler during foraging trips. To select a bird to follow, we will wait near the colony until we detect a radio-tagged bird leaving the area; then we will follow it. We will follow only birds with chicks.

Following birds involves two people: a boat driver and an observer. We record the location and duration of flying, feeding, and resting behaviors for birds during entire foraging trips. Flying is recorded as either traveling or searching behavior; birds flying in one direction are considered traveling, and birds flying in circles or back and forth are considered searching. The number of feeding attempts is recorded for each bird; a feeding attempt is defined as a surface plunge or surface seize (Ashmole 1971). The number and locations of feeding sites are recorded using GPS, a bird is considered to be feeding in a different site if it moves more than one km between feeding attempts. Birds are considered resting when they are on the water and not feeding or when they are on land or flotsam. If we lose sight of a bird while following it, it will be recorded as lost.

Data on the foraging trip length and foraging areas of radio-tagged birds will also be collected by using remote receiving stations (RRSs). RRSs are composed of a 164 to 168 MHz Advanced Telemetry Systems receiver connected to an Advanced Telemetry Systems data collection computer. The receiver and computer are powered by an 80 amp/hour lead-acid battery, which is charged by a three amp solar panel. The receiver and computer are housed in a waterproof, plastic "Pelican" case. The type of antenna used depends on the range desired; for the RRS set up at colonies a two element "H" antenna will be used, for all other locations a more powerful five-element Yagi antenna will be used. Antennae at all sites except at the colonies will be attached to

10 meter extension poles; at the colony the RRS antenna will be mounted on a two meter pole. The RRSs monitor the frequency of each radio-tagged bird every 10 minutes. RRSs will be placed at the Shoup Bay and Eleanor Island colonies, and at potential foraging areas to record the presence of radio-tagged birds. The ranges of the RRSs will be tested using a boat equipped with four radio transmitters attached to a kite and elevated to 3, 15, and 30 meters above the water. The range boundaries of the RRSs will be approximate because of variation in the strength of the transmitters and the height that birds fly.

Locations of feeding flocks and feeding behavior of radio-tagged birds will be recorded while following radio-tagged birds. A feeding flock will be defined as two or more surface-feeding birds feeding by surface plunging or surface seizing within 10 meters of each other (i.e., presumed to be feeding on the same school of fish) within a period of one minute.

Chick provisioning rates will be obtained from chicks at Shoup Bay and Eleanor Island colonies. Data will be collected by observing chicks at 20 nests for several hours and recording each time a chick is fed by an adult.

Habitat characteristics of foraging areas will be collected while following birds on foraging trips. Data on distance from colony, distance from shore, number and species of foraging birds and mammals, number of foraging flocks, water depth, temperature, salinity, tidal stage, and current flow will be collected.

Adult survival rates will be determined from marked birds at Shoup Bay. Approximately 600 birds were individually colored banded in 1991. To determine survival rates, birds will be observed for a two to three week period in May until all birds are sighted. These data will be compared to data collected in 1994 to determine how many birds did not return to the colony.

Analyses

One-way ANOVAs will be used to compare all behavioral data and growth rates of chicks from four colonies (SAS 1988). Tukey multiple comparison tests will be used to determine significant differences between the locations and years (SAS 1988). The chi-square 2x2 test for differences in probabilities (Zar 1984) will be used to compare clutch sizes, hatching success, fledging success, nest attendance, brood sizes, brood reduction, and overall productivity. Student's t-test (Zar 1984) will be used to compare growth rates of chicks that are reared by radio-tagged birds and chicks that are reared by birds without radios, and to compare chick provisioning rates. Distances that birds fly, which will be recorded while following the birds, will be measured using Atlas GIS. The maximum distance that radio-tagged birds fly to feed is defined as the distance from the colony to the farthest feeding site. The total cumulative distance that radio-tagged birds fly on foraging trips is defined as the total length of its path during a trip. The pursuit and handling time will be combined with search time to analyze time budgets of radio-tagged birds because both are insignificant compared to time spent searching (Irons 1992). Frequency of occurrence of prey in the diet samples will be used to determine the relative importance of each species. Means are reported $\pm$ one standard error. Results will be considered significantly different at $\alpha = 0.10$.

C. Contracts and Other Agency Assistance

This project will require a contract for analysis of diet samples and safety training of field personnel.

D. Location

We propose to study of black-legged kittiwakes at 24 colonies in Prince William Sound, Alaska (61° 09' N, 146° 35' W). PWS is a 10,000 km^2 body of protected water located along the north coast of the Gulf of Alaska. Two colonies will be studied intensively, Shoup Bay and Eleanor Island. In 1993, the Shoup Bay colony was the largest in the Sound, with 4200 breeding pairs and Eleanor Island supported 190 breeding pairs. Both colonies have a sufficient number of accessible nests to permit obtaining both adults for radio-tagging and chicks for recording growth rates.

SCHEDULE

A. Measurable Project Tasks of FY 96

B. Project Milestones and Endpoints

This component provides annual information on the relative availability of forage fish to birds. This information is needed for all years of the APEX project, therefore, the endpoint is the same as the APEX project.

C. Project Reports

Annual reports will be submitted by March of every year. The final report will be submitted as part of the final report of the APEX project. Papers will be published as appropriate throughout the duration of the study.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The coordination of this component is largely with other components of the APEX project, although we have been coordinating with Evelyn Brown, (SEA project 96320T) in respect to her data on the distribution, movements, and behavior of young herring in Prince William Sound. We have also coordinated with Mark Willette, of the SEA project, concerning the consumption of herring by birds. We have discussed collaborating with Ted Cooney on a publication combining his data on the river/lake phenomenon and our historical data on kittiwake productivity. We routinely share equipment and personnel with the Nearshore Vertebrate Predator Project whenever it enhances the overall efficiency of EVOS projects.

The Fish and Wildlife Service, as part of their normal agency management of seabirds, has monitored the kittiwake colonies in PWS and has had an intensive monitoring site at Shoup Bay. The Service is donating all the data collected as part of its normal agency management to the EVOS funded APEX project. In addition, the Service is collecting specific information requested by the APEX project (the Service is providing about $80K worth of services and data). In the future, the role of the Service in the APEX project may diminish as funds are cut. The Service is experiencing unprecedented declines in funding and the trend may continue into the future.

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PERSONNEL

Project Leader: David Irons received his Ph. D. from the U. of CA, Irvine in 1992. His dissertation was on the foraging ecology and breeding biology of the black-legged kittiwake. The field work for this study was conducted in Prince William Sound. Irons received his M. S. from Oregon State University in 1982 where he studied foraging behavior of glaucous-winged gulls in relation to the presence of sea otters. Irons conducted marine bird and sea otter surveys in PWS in 1984 and 1985. He has been studying kittiwakes in PWS for 12 years and completed the EVOS kittiwake damage assessment study. Irons has overseen several seabird studies in the past few years including marine bird and sea otter surveys in PWS, Cook Inlet, and SE Alaska, a seabird monitoring study on Little Diomede Island, a cost of reproduction study on kittiwakes, a seabird/forage fish interactions study, and various population and reproductive studies on pigeon guillemots and marbled murrelets. Irons has authored and co-authored several reports and publications on seabirds and has made several presentations at scientific conferences on seabirds.

Selected Publications:

Irons, D.B. In press. Size and productivity of black-legged kittiwake colonies in Prince William Sound, Alaska before and after the T/V *Exxon Valdez* oil spill. American Fisheries Society Symposium 18:000-000.

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Irons, D.B. In preparation. Foraging site fidelity and tidal rhythms in individual Black-legged Kittiwakes.

Irons, D.B. In preparation. Flexible foraging behavior in seabirds: short-term buffer and long-term tradeoff?

Irons, D.B. In preparation. The role of food availability in sibling aggression and brood reduction of the Black-legged Kittiwake.

Assistant Project Leader: Rob Suryan received a B.S. degree in wildlife management at Humboldt State University (1989), a M.S. degree in marine science at Moss Landing Marine Laboratories (1995), and has nine years of experience in field biology. He has conducted studies of terrestrial and marine birds and mammals, involving population estimates, habitat use, foraging ecology, diving behavior, and effects of human disturbance. His seabird studies have involved at-sea surveys to assess the potential impact of dumping dredged materials in relation to the distribution and behavior of seabirds and marine mammals off the Farallon Islands, California, and seabird surveys during ship shock trials of the U.S.S. John Paul Jones. Rob has been studying the reproductive biology and foraging ecology of Black-legged Kittiwakes in Prince William Sound, Alaska, since May 1995.

Reports and Publications

Suryan, R.M. and J.T. Harvey. In prep. The effect of disturbance on recovery, vigilance, and distance of harassment of the harbor seal (*Phoca vitulina richardsi*) off the northern San Juan Islands, Washington.

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Suryan, R.M. 1995. Pupping phenology, disturbance, movements, and dive patterns of the harbor seal off the northern San Juan Islands, Washington. M.S. Thesis, Moss Landing Marine Laboratories. 75 pp.

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F
Guillemot Studies

CONSEQUENCES OF PREY DISTRIBUTION AND ABUNDANCE IN PIGEON GUILLEMOTS IN PRINCE WILLIAM SOUND

Project Number:	98163F
Restoration Category:	Research
Proposed By:	DOI
Leading Trustee Agency:	DOI
Cooperating Agencies:	NOAA and ADFG
Duration:	5 years
Cost FY 98:	$113.2
Cost FY 99:	$156K
Geographic Area:	Prince William Sound
Injured Resource:	Pigeon Guillemot

ABSTRACT

This project will compare the diet and productivity of pigeon guillemots at two locations in Prince William Sound and one location in Kachemak Bay to determine if the abundance and distribution of schooling forage fish such as sand lance and herring limit the population size and productivity of pigeon guillemots.

CONSEQUENCES OF PREY DISTRIBUTION AND ABUNDANCE IN PIGEON GUILLEMOTS IN PRINCE WILLIAM SOUND

INTRODUCTION

A great deal of attention has been given to the relationship between numbers of seabirds and the temporal and spatial aspects of their prey (e.g., foraging range of birds, predictability vs. patchiness of prey, abundance of prey during and outside the breeding season). Lack (1967) believed that populations of marine birds are regulated by density-dependant factors such as food supply outside the breeding season, whereas Ashmole (1963) argued that it is availability of food during the breeding season that is limiting, because at this time the adults feeding young are constrained to foraging within a certain distance of their colony. Lack (1967) noted that pelagic feeders tend to nest in large colonies and inshore feeders in smaller, less dense colonies. Likewise, Diamond (1978) showed that migrant species tended to be more numerous than resident species. Both related these observations to the relative sizes of the available foraging areas. Pelagic feeders would obviously have a larger foraging area than inshore feeders; also, migration to an alternate feeding area during the nonbreeding season would be equivalent to using a larger area during the breeding season.

Birt et al. (1987) found evidence of prey depletion within the normal foraging depths of double-crested cormorants around Prince Edward Island. Furness and Birkhead (1984) also tested the idea of prey depletion by considering the size of seabird colonies relative to their spatial distribution; they generally found a negative correlation between the size of a colony and the number of conspecific colonies within the foraging range of the species for northern gannets, shags, black-legged kittiwakes, and Atlantic puffins. The results of both studies provide support for Ashmole's hypothesis that seabird populations are limited by intraspecific competition for food during the breeding season.

Cairns (1989) proposed a hinterland model of population regulation of seabird colonies that was based on the idea that colony size is related to the amount of foraging habitat used by a colony. This model suggests that seabirds from neighboring colonies use nonoverlapping foraging zones and that the population of a colony is a function of the size of these zones. In her study of Galapagos penguins, Boersma (1976) found that chicks raised on an island grew faster than those on the nearby mainland and related this to the fact that adults nesting on a small island can forage over twice as much area as those along a coast.

Pigeon guillemots forage in the nearshore environment within a few kilometers of the colony, but feed on both demersal and schooling fish. Still, differences in the diet of guillemot chicks probably reflect local differences in the availability or abundance of prey. Schooling fish such as sand lance, herring, and capelin may be subject to temporal and spatial fluctuations in abundance. Nearshore demersal fish probably constitute a more predictable food source. At Naked Island the proportion of sand lance in the diet of guillemot chicks has declined dramatically since 1979, and gadids, which were generally not present in the diet before the *Exxon Valdez* oil spill, now make up a much larger component of the diet (Oakley and Kuletz 1994, Hayes 1995).

At numerous colonies around Naked Island, the number of breeding birds has decreased considerably since 1979. In the absence of schooling fish, guillemots must rely more heavily on demersal fish. Competition for these demersal fish over the limited shallow-water foraging area surrounding Naked Island may be preventing some adults from breeding or successfully raising their young. However, at Jackpot Island, where a large portion of the chick diet is schooling fish (herring and sand lance), the percent of breeding birds in the population appears to be much higher. Nest sites, not food, may be limiting the number of guillemots at this small island.

The post-spill decline in sand lance in the diet of guillemots breeding at Naked Island might be a key element in the failure of this species to recover from the oil spill. Pre-spill studies of pigeon guillemots breeding at Naked Island suggest that sand lance are a preferred prey during chick-rearing. In 1979-1981 some breeding guillemots at Naked Island specialized on sand lance; today there are no such specialists, probably because this resource is too scarce and patchy. Breeding pairs that specialized on sand lance tended to initiate nesting attempts earlier and produce chicks that grew faster and fledged at higher weights than breeding pairs that preyed mostly upon blennies and sculpins in years when sand lance were readily available (Kuletz 1983). Consequently, the overall productivity of the guillemot population was higher when sand lance were available. The high lipid content of sand lance relative to that of gadids and nearshore demersal fish (D. Roby, personal communication), might make this species a particularly high-quality forage resource for PWS pigeon guillemots. This is consistent with the observation that other seabird species (e.g., puffins, murres, kittiwakes) experience enhanced reproductive success when sand lance are available (Pearson 1968; Harris and Hislop 1978; Hunt et al. 1980; Vermeer 1979, 1980). This component, in conjunction with the Seabird Energetics component (96163 G), will help assess the relative importance of sand lance and other forage fish resources in maintaining productive colonies of guillemots in south central Alaska.

NEED FOR THE PROJECT

A. Statement of problem

The population of pigeon guillemots in Prince William Sound (PWS) has decreased from about 15,000 in the 1970's (Isleib and Kessel 1973) to about 5,000 in 1994 (Agler et al. 1994). There is some evidence (Oakley and Kuletz 1993) suggesting that this population was in decline before the *Exxon Valdez* oil spill in March of 1989. An estimated 2,000 to 3,000 pigeon guillemots were killed throughout the spill zone immediately after the spill (Piatt et al. 1990). Based on censuses taken around the Naked Island complex (Naked, Peak, Storey, Smith, and Little Smith Islands), pre-spill counts (ca. 2,000 guillemots) were roughly twice as high as post-spill counts (ca. 1,000 guillemots); also, relative declines in the numbers of guillemots were greater along oiled shorelines than along unoiled shorelines (Oakley and Kuletz 1994). The population has not recovered since the oil spill.

B. Rationale

Considerable baseline data on pigeon guillemot populations in PWS and their reproductive and foraging ecology have been collected both before and after the *Exxon Valdez* oil spill. Continuation of these efforts is essential for monitoring any trends in the PWS populations.

There is a critical need for this information to understand the constraints that currently limit the recovery of pigeon guillemots populations affected by the oil spill.

PROJECT DESIGN

A. OBJECTIVES

To determine if a lack of schooling forage fish limits the population size and productivity of pigeon guillemots by testing the following hypotheses:

1) Guillemot colonies are larger in areas where forage fish are readily available to feed to their young than in areas where forage fish are less available.

2) Guillemots are limited by nesting habitat in areas where forage fish are readily available but are limited by food in areas where forage fish are not available in large schools.

3) Productivity of individual pairs feeding primarily on forage fish is higher than that of pairs feeding primarily on demersal fish.

4) Based on adult survival rates and recruitment rates the Naked Island guillemot colony can maintain the present population size.

B. METHODS

Pigeon guillemots will be censused in early June (in the early morning at or around high tide) at the principal study sites. The Naked Island census will include the other islands (Peak, Storey, Smith, and Little Smith) in the Naked Island Complex.

All accessible guillemot nests on Naked and Jackpot Islands will be used for collecting growth rate and productivity data. Nests that are observable from blinds or boats will be used for determining provisioning rates and diet. All guillemot adults and chicks that are handled will be banded (one USFWS metal band and three color plastic bands). Any breeding adults that are handled will be marked with dyes or permanent markers to make these birds more visible on the foraging grounds.

Nest checks will be made at five-day intervals from just before hatching through fledging. Nest status will be determined and morphometric data acquired from all accessible chicks during each visit. Blood samples for biomarker analyses will be collected using standard protocols developed by Dan Roby for the pigeon guillemot component of the Nearshore Vertebrate Predators Project. Blood samples will be taken from chicks on three successive visits, the first one from any given chick being taken when it is approximately 20 days of age. Blood samples and morphometrics will be obtained from any adults that are handled.

Throughout the nestling period, feeding observations will be made at selected nests or groups of nests during eight-hour observation periods beginning at 0600 or 1400. These observations will be made from strategically located blinds or from boats anchored offshore. Opportunistic feeding observations will be made at other sites and at other times of the day, whenever possible. Observers will record the following information when known: type of fish to lowest possible taxon; size of fish to nearest one-half bill length; time of adult's arrival at and departure from the colony; time of delivery; direction of adult's approach and departure.

Samples of chick meals will be obtained whenever they are found in or near the nests and by intercepting adults with mist nets in front of the nest entrances. These samples will be used for positive identification of fish types delivered to guillemot chicks and for analyses of energy content in Dan Roby's lab. The weight and standard length will be obtained from each fish.

Foraging areas will be determined by following guillemots returning to forage after making a delivery at the colony. This can be done during the feeding observations by using VHF radio communications between observers in blinds and others in boats stationed offshore, or during dedicated watches made specifically for this purpose. Observations of flight directions of guillemots (with and without fish) will be made from strategic locations around Naked Island (and possibly Peak and Storey) to locate and assess the importance of other foraging areas to the guillemots. Observations of guillemots on their foraging grounds will be made to look for any evidence of aggressive interactions or possible defense of "feeding territories," which would suggest competition for food.

Fish traps will be set and checked regularly at several locations, including those where guillemots are known to forage. Beach seine sets will be made regularly at the same locations used for fish traps. Samples of fish from each seine will be taken. The weight and standard length will be obtained from all fish caught in the traps and those sampled from the beach seine hauls.

In conjunction with Steve Jewett of the Nearshore Vertebrate Project, we will obtain data on the abundance and distribution of benthic fish along portions of the shoreline of Naked Island and in the vicinity of Jackpot Island. This data will be collected by SCUBA divers swimming along randomly selected transects.

In conjunction with Evelyn Brown's work of spotting fish schools and plotting their locations, we will attempt to coordinate our efforts with hers. With advance notice of her schedule, and via radio communications between boat and plane, she may be able to tell us the locations of fish schools, which we can ground-truth for species composition.

Prototype nest boxes will be placed at various locations around the periphery of Jackpot and Naked Islands before, or very early in, the breeding season.

C. CONTRACTS AND OTHER AGENCY ASSISTANCE

The transport of equipment, supplies, and fuel to and from the field camps will be contracted to a local business operating within PWS.

The energy content analyses will be done through Dr. Roby's lab as part of his BAA.

D. LOCATION

The two primary study sites in PWS will be at Naked and Jackpot Islands. Similar work will also be conducted at several guillemot colonies along the southern shore of Kachemak Bay.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The Forage Fish Assessment component (96163A) will provide the Pigeon Guillemot component with data on the distribution, abundance, and species composition of schooling fish in the nearshore environment, while the Seabird/Forage Fish Interactions component (96163B) will provide pertinent data on the foraging behavior of guillemots in relation to these schools. The Pigeon Guillemot and Seabird Energetics (Dr. Roby, PI) components are closely tied; virtually all the data collected during each nest visit will be used by both projects. Dr. Roby is also one of the principal investigators of the pigeon guillemot component of the Nearshore Vertebrate Project, and in support of that project, we will collect blood samples from guillemots during our routine nest checks. All logistics for field camps at Naked, Eleanor (kittiwakes), and Jackpot Islands will be coordinated (i.e., same barge for transport of equipment, supplies, and fuel) and all transport expenses shared.

PERSONNEL

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G
Energetics

APEX: Diet Composition, Reproductive Energetics, and Productivity of Seabirds in the *Exxon Valdez* Oil Spill Area (Submitted Under the BAA)

Project Number:	98163 G (formerly 95118-BAA)
Restoration Category:	Research (continuing)
Proposed By:	Oregon State University (PI - Daniel D. Roby)
Lead Trustee Agency:	NOAA
Duration:	4th year, 6-year project
Cost FY 98:	$221,300
Cost FY 99:	$70,000
Cost FY 00:	$35,000
Geographic Area:	Prince William Sound (Naked Island, Jackpot Island, Eleanor Island, Shoup Bay, Icy Bay) and Lower Cook Inlet (Kachemak Bay, Barren Islands, Gull Island, Chisik Island)
Injured Resource/Service:	Multiple resources

ABSTRACT

Reproduction in seabirds is frequently limited by parents' ability to allocate energy to the breeding effort. This study is designed to examine potential energetic factors (diet composition, diet quality, meal size, meal delivery rate, adult energy expenditure rates) that constrain the productivity of seabirds in the *Exxon Valdez* Oil Spill area, with special emphasis on those species that are failing to recover to pre-spill population levels. The results will help identify those forage fish resources that limit seabird numbers and require enhancement for full recovery of injured populations of piscivorous seabirds and marine mammals.

STUDY HISTORY

This project is similar to the research described in the original proposal submitted under the BAA (95118-BAA), for which funding was first approved by the Trustee Council in April 1995, the Detailed Project Description (DPD) for FY 96 that was submitted in April 1995, and the DPD for FY 97 submitted in March 1996. Parts of this FY 98 DPD that have been modified from the FY 97 DPD have been printed in bold face below for the convenience of peer reviewers.

Research in 1995 for Alaska Predator Ecosystem Experiment (APEX) Project 95118-BAA provided the first account of the effects of diet composition on the reproductive energetics and productivity of piscivorous seabirds in the northern Gulf of Alaska. Black-legged kittiwakes, pigeon guillemots, and tufted puffins were studied as bioindicators of the distribution and abundance of forage fishes to further understand the recovery of injured seabird resources. Study sites were at Shoup Bay, and Eleanor, Naked, Jackpot, and Seal islands in Prince William Sound and at Kachemak Bay, Gull, Chisik, and the Barren islands in Lower Cook Inlet. In 1996, this research continued without the tufted puffin component and with the shift from Seal Island to North Icy Bay for research on black-legged kittiwakes. To date, this project has produced new information advancing our knowledge of the comparative biochemical composition and physiological condition of forage fishes available to seabird, marine mammal, and fish predators; the influence of location, age, gender, and reproductive status on the nutritional quality of forage fishes; effects of diet quality and provisioning rates on energy intake rates by broods; and the consequences of energy provisioning rates for seabird growth and productivity.

In 1997, the project will continue to investigate the relationship between diet quality and nesting productivity at the black-legged kittiwake and pigeon guillemot colonies that were studied in 1996. Results from 1995 and 1996 suggest that sand lance, herring, and capelin are key forage fish resources for piscisorous seabirds nesting in the oil spill area. Based on apparent trends in availability of these high energy forage fishes, we predict that guillemot productivity will increase at Naked Island and decline at Kachemak Bay. We predict that kittiwake productivity will increase at the Barren and Chisik islands, Icy Bay and Eleanor Island, while productivity at Shoup Bay and Gull Island will remain the same or decline. Results from the 1997 breeding season will allow us to better understand the adaptive compensation of breeding seabirds to decadal shifts in forage fish populations.

A pilot study will be initiated to measure the free-ranging metabolic rates of parents during the chick-rearing period as an index of reproductive effort. The doubly-labeled water method will ultimately allow us to compare the energetic costs of reproduction across colonies for further insight into the consequences of foraging strategy, and diet on reproductive success and adult survivorship. In 1998, the last full field season of research will be completed and the pilot study of adult field metabolic rates will be expanded to assess intercolony differences in parental investment. In FY 99 and FY 00, the data will be fully analyzed and compiled into several manuscripts for inclusion in Jill Anthony's Ph.D. dissertation and other publications.

As an integrative component of APEX, this project is linked, directly or indirectly, to all components of this collaborative ecosystem-wide program. Within APEX, this project interacts most closely with components E, F, J, M, and N. Among the other restoration projects, this project is linked to Pacific Herring, Sound Ecosystem Assessment (SEA), Marine Mammals, Nearshore Vertebrate Predators (NVP), Ecosystem Synthesis, Sand Lance Ecology and Natural History, Marbled Murrelet Productivity, Prince William Sound Marine Bird Surveys, and Status and Ecology of Kittlitz's Murrelet.

INTRODUCTION

Reproductive success in seabirds is largely dependent on foraging constraints experienced by breeding adults. Previous studies on the reproductive energetics of seabirds have indicated that productivity is energy-limited, particularly during brood-rearing (Roby 1991). Also, the young of most seabird species accumulate substantial fat stores prior to fledging, an energy reserve that can be crucial for post-fledging survival in those species without post-fledging parental care (Perrins et al. 1973; but see Schreiber 1994). Data on foraging habitats, prey availability, and diet composition are critical for understanding the effects of changes in the distribution and abundance of forage fish resources on the productivity and dynamics of seabird populations.

The composition of forage fish is particularly relevant to reproductive success because it is the primary determinant of the energy density of meals delivered to nestlings. Parent seabirds that transport chick meals in their stomachs (e.g., kittiwakes) normally transport meals that are close to the maximum load. Seabirds that transport chick meals as single prey items held in the bill (e.g., guillemots, murres, murrelets) experience additional constraints on meal size if optimal-sized prey are not readily available. Consequently, seabird parents that provision their young with fish high in lipids are able to support faster growing chicks that fledge earlier and with larger fat reserves. This is because the energy density of lipid is approximately twice that of protein and carbohydrate. Also, forage fish are generally very low in carbohydrate, and metabolism of protein as an energy source requires the energetically expensive process of excreting the resultant nitrogenous waste. While breeding adults can afford to consume prey that are low quality (i.e., low-lipid) but abundant, reproductive success may be largely dependent on provisioning young with high quality (i.e., high-lipid) food items. If prey of adequate quality to support normal nestling growth and development are not available, nestlings either starve in the nest or prolong the nestling period and fledge with low fat reserves.

Forage fish vary considerably in lipid content, lipid:protein ratio, energy density, and nutritional quality. In some seabird prey, such as lanternfishes (Myctophidae) and eulachon (*Thaleichthys pacificus*), lipids may constitute over 50% of dry mass (A.R. Place, unpubl. data; J. Piatt, unpubl. data; S. Payne, unpubl. data); while in other prey, such as juvenile walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*), lipids are frequently less than 5% of dry mass (J. Wejak, unpubl. data; J. Piatt, unpubl. data). This means that a given fresh mass of lanternfish or eulachon may have 3-4 times the energy content of the same mass of juvenile pollock or Pacific cod. By increasing the proportion of high-lipid fish in chick diets, parents can increase the energy density of chick meals in order to compensate for the low frequency of chick feeding (Ricklefs 1984, Ricklefs et al. 1985).

Lipid content (% dry mass) and energy density (kJ/g wet mass) of forage fishes collected in Prince William Sound and Lower Cook Inlet during the 1995 and 1996 breeding seasons have been measured in my laboratory. **Lipid content varied from as much as 52% in some eulachon to as low as 3% in some juvenile walleye pollock.** Average energy density (kJ/g wet mass) of age 1+ herring was 2.5 times greater than that of age 1+ pollock. Consequently, a parent seabird could potentially increase its rate of energy provisioning to its brood by a factor of as much as 2.5 by selecting prey based on quality, given similar availability (Roby et al. 1996).

Among the schooling forage fishes observed in seabird diets, herring (*Clupea harengus pallasii*), capelin (*Mallotus villosus*), and sand lance (*Ammodytes hexapterus*) had the highest average energy densities. Juvenile gadids (pollock, Pacific cod [*Gadus macrocephalus*], Pacific tomcod [*Microgadus proximus*]) **and prowfish** (*Zaprora silenus*) were generally low in lipids and had the lowest energy densities of the sampled forage fishes. Nearshore demersal fishes (e.g., gunnels, pricklebacks, eelblennies, shannies), important prey of pigeon guillemots, were intermediate between herring and gadids in lipid content and energy density. The lipid content and energy density of herring, sand lance, and capelin, though generally high, were variable depending on age, sex, and reproductive status (pre- or post-spawning; Roby et al. 1996).

NEED FOR THE PROJECT

A. Statement of Problem

Three seabird species that were damaged by the *Exxon Valdez* oil spill (EVOS) are failing to recover at an acceptable rate: pigeon guillemot (*Cepphus columba*), common murre (*Uria aalge*), and marbled murrelet (*Brachyramphus marmoratus*). Damage from the spill to a fourth species of seabird, black-legged kittiwake (*Rissa tridactyla*), is equivocal, but recent reproductive failures of kittiwakes within the spill area may be due to longer term ecosystem perturbation related to the spill (D. Irons, pers. comm.). The status of pigeon guillemots and marbled murrelets in Prince William Sound (PWS) and the Northern Gulf of Alaska has been of concern for nearly a decade due to declines in numbers of adults observed on survey routes (Laing and Klosiewski 1993). All of these damaged or potentially damaged seabird species are piscivorous and rely to a greater or lesser extent on pelagic schooling fishes during the breeding season.

One prevalent hypothesis for the failure of these seabirds to recover is that changes in the abundance and species composition of forage fish resources within the spill area has resulted in reduced availability and quality of food for breeding seabirds. Concurrent population declines in some marine mammals, particularly harbor seals and Stellar sea lions, have also been blamed on food limitation. Seabirds, unlike marine mammals, offer the possibility of directly measuring diet composition and feeding rates, and their relation to productivity. Thus the piscivorous seabirds breeding in PWS and Lower Cook Inlet (LCI) present an opportunity to assess the relationship between the relative availability of various forage fishes and the productivity of apex predators. Whether these changes in forage fish availability are related to or have been exacerbated by EVOS is unknown.

This study is a component of the APEX Project (Project 98163A-P) and is relevant to EVOS Restoration Work because it is designed to develop a better understanding of how shifts in the diet of seabirds breeding in EVOS area affect reproductive success. By monitoring the composition and provisioning rates of seabird nestling diets, prey preferences can be assessed. Measuring provisioning rates is crucial because even very poor quality prey may constitute an acceptable diet if it can be supplied at a high rate. Understanding the diet composition, foraging niche, and energetic constraints on seabirds breeding within the spill area will be crucial for designing management initiatives to enhance productivity in species that are failing to recover from EVOS. If forage fish that are high in lipids are an essential resource for successful reproduction, then efforts can be focused on assessing stocks of preferred forage fish and the factors that impinge on the availability of these resources within foraging distance of breeding colonies in the EVOS area. As long as the significance of diet composition is not understood, it will be difficult to interpret shifts in the utilization of forage fishes and develop a management plan for effective recovery of damaged species.

B. Rationale/Link to Restoration

There is a definite need for information on the relationship between diet and reproductive success for pigeon guillemots, common murres, and marbled murrelets, all seabird species that are failing to recover from EVOS at an acceptable rate (1994 *Exxon Valdez* Oil Spill Restoration Plan). However, the latter two species pose serious problems for studies of diet composition in the spill area. For common murres, it is difficult to collect quantitative data on diet composition, feeding rate, meal size, and chick growth rates without seriously reducing productivity because this species nests in dense colonies on narrow ledges where human activity can cause high losses of eggs and chicks. Murre chicks also leave the nest site to go to sea at only c. 21 days post-hatch, when they are only 20% of adult mass. Marbled murrelet nests are usually located high in mature conifers and are very difficult to locate. Most nest visits by parents provisioning young occur at night, so monitoring chick diets is highly problematic.

Guillemots are the most neritic members of the marine bird family Alcidae (i.e., murres, puffins, and auks), and like the other members of the family, capture prey during pursuit-dives. Pigeon guillemots are a well-suited species for monitoring forage fish availability for several reasons: (1) they are a common and widespread seabird species breeding in the EVOS area (Sowls et al. 1978); (2) they primarily forage within 5 km of the nest site (Drent 1965); (3) they raise their young almost entirely on fish; (4) they prey on a wide variety of fishes, including schooling forage fish (e.g., sand lance, herring, pollock) and subtidal/nearshore demersal fish (e.g., blennies, sculpins; Drent 1965, Kuletz 1983); and (5) the one- or two-chick broods are fed in the nest until the young reach adult body size. Guillemots carry whole fish in their bills to the nest-site crevice to feed their young. Thus, individual prey items can be identified, weighed, measured, and collected for composition analyses. In addition, there is strong evidence of a major shift in diet composition of guillemot pairs breeding at Naked Island. Sand lance were the predominant prey fed to young in the late 1970s (Kuletz 1983), but currently sand lance is a minor component of the diet (D. L. Hayes, unpubl. data). In contrast, guillemots breeding in Kachemak Bay continue to provision their young predominately with sand lance, and sand lance is particularly prevalent in the diet at sites that support high densities of breeding pairs (A. Prichard, unpubl. data). Jackpot Island in southwestern Prince William Sound supports the highest nesting densities of guillemots anywhere in the Sound. The high availability of juvenile herring to guillemots nesting at Jackpot Island may be responsible for this breeding aggregation. Thus availability of high quality schooling forage fishes (herring, sand lance) may be crucial for maintaining high nesting densities of guillemots.

Black-legged kittiwakes also breed abundantly in the spill area and rely largely on forage fish during reproduction. Unlike guillemots, kittiwakes are efficient fliers, forage at considerable distances from the nest, and capture prey at or near the surface. Although kittiwakes are highly colonial, cliff-nesting seabirds, they construct nests and can be readily studied at the breeding colony without causing substantial egg loss and chick mortality. Like guillemots, kittiwakes can raise one- or two-chick broods, and chicks remain in the nest until nearly adult size. Kittiwake breeding colonies at Shoup Bay, Eleanor Island, and Icy Bay in PWS are accessible so that chicks can be weighed regularly. Kittiwake colonies in Lower Cook Inlet (Gull Island, Chisik Island, and the Barren Islands) are not as accessible as the PWS colonies, but acquiring sufficient data on reproductive performance for comparison with PWS colonies is feasible. Most data on kittiwake diets and productivity from Lower Cook Inlet will be collected at Gull Island in Kachemak Bay. Diets fed to kittiwake chicks in PWS and Lower Cook Inlet consist primarily of high-quality schooling forage fish (i.e., sand lance, herring, capelin), although low-quality forage fishes (e.g., juvenile walleye pollock) are also taken.

C. Location

Field work will be focused in PWS (Naked, Jackpot, and Eleanor islands, Icy Bay, and Shoup Bay) and LCI (south shore of Kachemak Bay, Gull Island, Chisik Island, and the Barren Islands) during FY 98. The PWS study sites that were used in 1997 will again serve as study sites in 1998. These sites are identical to those seabird breeding sites that are being used by other components of APEX.

Field work on pigeon guillemots will be conducted at breeding colonies on Naked Island, Jackpot Island (both in PWS), and in Kachemak Bay. Approximately 500 guillemots nest along the shores of Naked Island (Sanger and Cody 1993). The Naked Island field camp in Cabin Bay is an excellent base for field studies on guillemots, and Naked Island supports a high proportion of the total breeding population of guillemots in PWS (Sanger and Cody 1993). In addition, Naked Island has been the site of long term studies of guillemot reproductive ecology since 1979 by the Fish and Wildlife Service (Kuletz 1983). Jackpot Island supports about 42 breeding pairs of guillemots nesting at the highest densities known in PWS (G. Sanger, D. L. Hayes, pers. comm.). Both Naked Island and Jackpot Island were the site of intensive studies of guillemot nesting success during the 1994-97 field seasons and have been selected for continued studies (APEX Component 98163 F). Kachemak Bay will serve as a third study site for guillemots. The breeding population of guillemots on the south shore of Kachemak Bay between Mallard Bay and Seldovia has been the site of intensive studies by Alex Prichard, a UAF graduate student, of guillemot breeding biology and productivity for the last two years. Results to date indicate that the guillemot prey base in Kachemak Bay is largely sand lance, and is perhaps similar to the prey base at Naked Island 15 to 20 years ago. Consequently, the Kachemak Bay guillemot study site provides an excellent reference site for guillemot studies in PWS.

Field work on kittiwakes in PWS will be conducted at three breeding colonies, one at Shoup Bay (off Valdez Arm) that supports approximately 1600 breeding pairs of black-legged kittiwakes, another at Eleanor Island (adjacent to Naked Island) that supports about 180 breeding pairs, and the last in Icy Bay that supports about 500 breeding pairs. The Shoup Bay colony is the site of continuing long-term studies of kittiwake nesting ecology in PWS by the Fish and Wildlife Service and Eleanor Island was selected as a breeding colony within the oiled area of PWS for intensive study for comparison purposes (APEX Component 98163 E). The colony at North Icy Bay was added as a study colony in 1996 because of its proximity to the Jackpot Island guillemot colony and areas where forage fish abundance is being assessed. All colonies include adequate numbers of readily accessible nests. In Lower Cook Inlet, kittiwake breeding colonies at the Barren Islands (high productivity), Gull Island (moderate productivity), and Chisik Island (low productivity) will be monitored for diet and reproductive success.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The study species for the proposed research are not subject to subsistence use by local residents, so the traditional knowledge base on their reproductive ecology and population demography is limited. Nevertheless, every effort will be made to identify qualified local residents who can be hired as field assistants and technicians. Residents of Chenega have expressed an interest in participating in studies of river otters in the Jackpot Island area, and this may present an opportunity to inform local residents of research on guillemots at Jackpot Island and on kittiwakes at nearby Icy Bay. In addition, this component of APEX remains committed to taking advantage of whatever opportunities present themselves to inform local residents of our activities and the rationale behind our research.

PROJECT DESIGN

A. Objectives

1. To determine the nutritional quality of various forage fish species consumed by seabirds in the EVOS area as a function of size, sex, age class, and reproductive status, including:
   a) lipid content
   b) water content
   c) ash-free lean dry matter (protein) content
   d) energy density (kJ/g fresh mass)

2. To determine dietary parameters of nestling pigeon guillemots and black-legged kittiwakes (and other seabird species as conditions permit) breeding in the EVOS area, including:
   a) provisioning rate (meal size X delivery rate)
   b) taxonomic composition of diets
   c) biochemical composition of diets
   d) energy density of diets

3. To determine the relationship between diet and the growth, development, and survival of seabird nestlings. Variables measured will include:
   a) growth rates of total body mass and body size (wing length)
   b) fledgling body mass and fat reserves
   c) fledging age
   e) daily survival rates of nestlings from hatching to fledging

4. To determine the relationship between diet and parental investment during the brood-rearing period. Daily energy expenditure rates (kJ/day) will be measured as an index to parental investment and compared among colonies of the same species.

5. To use bioenergetics approaches to quantify the contribution of specific forage fish resources to the overall productivity of seabird breeding pairs and populations, as well as the level of prey exploitation by piscivorous seabirds in the EVOS area. Parameters to be measured include:
   a) relative contribution of each forage fish species to overall energy intake of nestlings
   b) gross foraging efficiency of parents
   c) conversion efficiency of food to biomass in chicks
   d) net production efficiency of the parent/offspring unit
   e) estimates of population-level requirements for forage fish resources during brood-rearing

B. Methods

The general hypothesis for the APEX Project (EVOS Projects 98163 A-P) is that a shift in the marine trophic structure of the EVOS area has prevented recovery of injured resources. APEX addresses 10 more specific hypotheses, and **three** of those specific hypotheses are the focus of this study:

1. **Productivity and size of forage species change the energy potentially available for seabirds (APEX Hypothesis 4).**

2. Changes in seabird reproductive productivity reflect differences in forage fish abundance as measured in adult seabird foraging trips, chick-meal size, and chick-provisioning rates (APEX Hypothesis 8).

3. Seabird reproductive productivity is determined in part by differences in forage fish nutritional quality (APEX Hypothesis 9).

These **three** hypotheses address three primary determinants of energy provisioning rates to nestling seabirds, namely food delivery rates, diet quality, **and meal size**. These factors in turn have a direct bearing on the fitness of adults through variation in reproductive output. Another important component of adult fitness, parental investment, may vary among breeding sites and years. Parental investment is defined as the reduction in future reproductive output as a result of the effort made by parents in their current reproductive attempt. This effort can be expressed in terms of the rate of energy expenditure of parents provisioning their brood. Changes in forage fish availability and quality may be reflected in changes in parental investment.

The overall objective of this research is to determine the energy content and nutritional value of various forage fishes used by seabirds breeding in the EVOS area, and to relate differences in prey quality and availability to nestling growth performance, parental investment, and productivity of breeding adults. The research in 1998 will emphasize pigeon guillemots and black-legged kittiwakes for practical reasons, but prey composition and quality will be evaluated for common murres and marbled murrelets as data and samples permit. The primary study sites will be in Prince William Sound: Naked Island (guillemots), Jackpot Island (guillemots), Eleanor Island (kittiwakes), Shoup Bay (kittiwakes), and Icy Bay (kittiwakes) and in Lower

Cook Inlet: Kachemak Bay (guillemots), Gull Island (kittiwakes), Chisik Island (kittiwakes) and the Barren Islands (kittiwakes).

The proposed research approach utilizes a combination of sample/data collection in the field (in conjunction with other APEX components in PWS) and laboratory analyses. Sample collection and field data collection will be conducted concurrently during the 1998 breeding season at three sites where pigeon guillemots breed and at 4 to 6 kittiwake breeding colonies, all within the EVOS area. A minimum of 40 active and accessible nests of each species will be located and marked prior to hatching at each of the study colonies. These nests will be closely-monitored until the young fledge or the nesting attempt fails.

Fresh samples of forage fishes used by guillemots will be collected for determination of species composition and proximate analysis using the following three techniques, in order of importance: (1) capturing adults carrying forage fish as they approach or enter the nest and retrieving samples from adults, (2) opportunistically collecting uneaten meal samples found in nest crevices, and (3) retrieving samples from chicks shortly after being fed by parents. Supplemental samples of guillemot forage fishes will be collected using beach seines and minnow traps deployed in guillemot foraging areas and by netting specimens at low tide during spring tide series.

Kittiwakes transport chick meals in the stomach and esophagus, so chick diet samples will consist of semi-digested food. Kittiwake meal samples are normally collected when chicks regurgitate during routine weighing and measuring. Additional diet samples will be collected by capturing adult kittiwakes as they return to feed their young and inducing them to regurgitate the contents of their esophagus. Fresh specimens of forage fishes used by kittiwakes will be provided from net sampling (APEX Component 98163 A).

Fresh fish samples and kittiwake regurgitations will be weighed ($\pm$ 0.1 g) in the field on battery-powered, top-loading balances, placed in whirl-paks, and immediately frozen in small, propane-powered freezers that will be maintained at each of the study sites. Samples will be shipped frozen to Dr. Alan Springer's laboratory at the Institute of Marine Science, where they will be sorted, identified, sexed, aged, and measured in preparation for proximate analysis. Samples will then be shipped frozen to my laboratory at Oregon State University, where proximate analyses will be conducted. Forage fish specimens will be dried to constant mass in a convection oven at 60°C to determine water content. Lipid content of a subsample of dried forage fish will be determined by solvent extraction using a soxhlet apparatus and hexane/isopropyl alcohol 7:2 (v:v) as the solvent system. Lean dry fish samples will then be ashed in a muffle furnace at 550°C in order to calculate ash-free lean dry mass by subtraction. Energy content of chick diets will be calculated from the composition (water, lipid, ash-free lean dry matter, and ash) of forage fish, along with published energy equivalents of these fractions (Roby 1991).

Chick provisioning rates for pigeon guillemots and black-legged kittiwakes in PWS and Lower Cook Inlet will be determined by monitoring active nests to determine meal delivery rates throughout the 24 hour period. Average meal mass will be determined for guillemots by collecting individual prey items from adults as they arrive at the nest site to feed their young. Average meal mass for black-legged kittiwakes will be determined by weighing chicks at 2-hour intervals during watches to determine meal delivery rates. Average meal size, taxonomic and biochemical composition of the diet, and average energy density of chick meals will be determined as part of analyses of diet samples collected from guillemots and kittiwakes.

Active kittiwake nests will be checked daily or every other day during the hatching period in order to determine hatching date. Disturbance of active guillemot nests during the incubation period will be minimized because of the risk of nest abandonment. Consequently, hatching dates will not be known precisely and wing length will serve as a surrogate for age. In the case of two-chick kittiwake or guillemot broods, siblings will be marked as soon after hatching as possible so that individual growth rates can be monitored throughout the nestling period. Nestlings will be weighed and measured regularly (minimum of every five days) to determine individual growth rates throughout the nestling period. During the fledging period, nestlings will be weighed every other day in order to more precisely measure fledging mass and age. Body mass, wing length, culmen length, tarsus length, and primary feather length will be used to develop a condition index for each chick at 30 days post-hatch.

Parental investment of adults raising broods will be assessed by measuring field metabolic rates (FMR) of breeding adults during the chick-rearing period. FMRs will be determined by measuring CO_2 production using the doubly-labeled water (DLW) technique (Lifson and McClintock 1966, Nagy 1980, Roby and Ricklefs 1986). Adult kittiwakes will be measured at Shoup Bay, Eleanor Island, Gull Island, and Chisik Island to represent different environmental conditions (e.g., oiled vs. non-oiled), foraging strategies (e.g., long vs. short foraging distance), and food availability (e.g., low vs. high). If possible, adult guillemots will be measured at Naked Island, Jackpot Island, and Kachemak Bay. A sample of 25 breeding adults per colony will be selected, with a preference for adults raising two chick broods to normalize for the effect of brood size on parental investment. Measurements will be taken between day 10 and 30 of the nestling-rearing period.

Parents will be captured at the nest site with a noose pole and/or foot noose, identified by previous bands or newly banded, dye-marked, measured for wing chord, headbill, and tarsus, and weighed to the nearest gram with a Pesola spring scale. A blood sample will be collected from 5 uninjected adults per colony to determine background levels of $H_2{}^{18}O$ and ^2H_2O for each location. All blood samples will obtained by puncturing the brachial vein, and blood will be collected in 6 to 8 microcapillary tubes (ca. 10 ul each), which will subsequently be flame-sealed. Each adult used in the DLW experiments will be injected intraperitoneally with a 0.75 g dose containing a mixture of 0.5 g $H_2{}^{18}O$ (90 atom %) and 0.25 g ^2H_2O (99.8 atom % deuterium). As both oxygen-18 and deuterium are stable isotopes, they are not radioactive and require no special use permits. Initial blood samples will be collected from each injected adult after a one-hour equilibration period. Injected adults will then be released at their nest site. Injected adults will be recaptured at the nest site after approximately 24 or 48 hours. Once recaptured, injected adults will be reweighed and a final blood sample collected. Isotopic enrichments of blood samples will be determined by mass spectrometry in the laboratory of Dr. Henk Visser (Center of Isotope Research, University of Groningen, The Netherlands). Carbon dioxide production by each adult during each measurement interval will be calculated using the equations of Lifson and McClintock (1966). FMR will be calculated from CO_2 production using an assumed RQ of 0.72 and an energetic equivalent of respired CO_2 of 27.3 kJ per liter (Gessamen and Nagy 1988).

Data on nestling body mass and wing chord length will be separated by colony for each species, and fit to logistic growth models. Growth constants (K), inflection points (I), and asymptotes (A) of fitted curves will be statistically analyzed for significant differences among years and colonies. Gross foraging efficiency of adults will be calculated from daily energy expenditure by the following equation:

$$([M \cdot F \cdot D] + DEE) / DEE = GFE,$$

where M is average chick meal mass in grams, F is average frequency of meal delivery in meals day^{-1} $parent^{-1}$, D is energy density of chick meals in kJ/g wet mass, DEE is adult daily energy expenditure in kJ/day, and GFE is adult gross foraging efficiency in kJ consumed/kJ expended. DEE will be calculated from field metabolic rates of kittiwakes that will be measured at study sites in PWS and Lower Cook Inlet using the doubly-labeled water technique. This will test the hypothesis that daily energy expenditure (parental investment) of adults raising young varies among sites and years, depending on species composition, availability, and quality of forage fish resources. Other measurements of daily energy expenditure rates for kittiwakes breeding in other locales are available for comparison in the published literature (Birt-Friesen et al. 1989).

Comparison of food conversion efficiency of chicks from different colonies fed different diets will provide an estimate of the relative energetic efficiency of diets composed of various forage fishes. The net production efficiency of the parent/offspring unit will be calculated for each diet and each year for both species using the equation:

$$CFCE / ([DEE \cdot 2] + [M \cdot F \cdot D]) = TNPE,$$

where CFCE is chick food conversion efficiency in grams of body mass gained per gram food ingested, TNPE is the total net production efficiency of the parent/offspring unit in grams gained by chicks per kJ of energy expended by both parents, and other variables are as described above.

Approval of the field protocols for work with live birds described in this DPD have been approved by the Institutional Animal Care and Use Committee at Oregon State University. No permits are required for use of deuterium and oxygen-18 for research on wild birds. Any incidental or unintentional take of eggs, nestlings, or adults of either kittiwakes or guillemots will be covered by relevant Federal and State Scientific Collecting permits.

C. Contracts and Other Agency Assistance

Laboratory analyses of the biochemical composition and energy content of forage fishes will be conducted in the laboratory of the PI at Oregon State University. Some new laboratory equipment will need to be purchased for the proposed research with funds provided by the grant because not all equipment that was in the PI's laboratory at University of Alaska Fairbanks is currently available at OSU. A part-time laboratory technician will be hired to help the PI and graduate research assistant with performing of routine laboratory analyses.

Species identification, aging, sexing, and other preliminary analyses of forage fishes will be subcontracted to the Institute of Marine Science at the University of Alaska Fairbanks, where the expertise is available to perform this task.

Isotopic enrichments of blood samples for the doubly-labeled water technique will be determined in the laboratory of Dr. Henk Visser (Center of Isotope Research, University of Groningen, The Netherlands) by means of mass spectrometry. Dr. Visser's lab has extensive experience in proper handling and analysis of deuterium and oxygen-18 in blood.

SCHEDULE

A. Measurable Project Tasks for FY 98 (October 1, 1997 - September 1998)

October 1 - December 31:	**Analyze laboratory samples from FY 97**
January 1 - 14:	**Prepare for Annual Restoration Workshop**
January 15 - 24 (3 days):	**Attend Annual Restoration Workshop**
March 15:	**Submit annual report (FY 97 findings)** **Submit FY 99 DPD to Dr. Duffy**
March 16 - April 30:	**Arrange logistics for FY 98 field season**
May 1 - August 31:	**Field data collection**
August 31 - September 30:	**Enter field data, begin laboratory analyses**

B. Project Milestones and Endpoints

FY 98	
April 15:	**Completion of Objective 1**
FY 99	
April 15:	**Completion of Objectives 2 and 3**
December 31:	**Completion of Objectives 4 and 5**
FY 00	
December 31:	**Completion of Ph.D. dissertation** **Completion of final project report**

C. Completion Date

The anticipated completion of this project will be early in FY 01, at the end of calendar year 2000. This will allow adequate time to complete data analysis, Jill Anthony's dissertation, and manuscript preparation following the last field season in 1998 and completion of laboratory analysis in 1999.

PUBLICATIONS AND PROJECT REPORTS

The following publications are projected for this research project (this is a rough projection and by no means complete):

a) "Lipid content and energy density of forage fishes used by breeding seabirds in the Northern Gulf of Alaska," J. Anthony and D. D. Roby; Comp. Biochem. Physiol., target submission in 1997.

b) "Diet and reproduction in pigeon guillemots from Prince William Sound and Kachemak Bay, Alaska," J. Anthony, D. L. Hayes, D. D. Roby, and A, Prichard; Condor, target submission in 1998.

c) "Diet and reproduction in black-legged kittiwakes from Prince William Sound, Alaska," J. Anthony, D. B. Irons, R. Suryan, & D. D. Roby; Auk, target submission in 1998.

d) "Effects of prey type and quality on postnatal growth and development of piscivorous seabirds: a captive feeding experiment," M. Romano, D. D. Roby, and J. Piatt; Physiol. Zool., target submission in 1998.

e) "Parental energy expenditure of black-legged kittiwakes and pigeon guillemots in relation to diet," J. Anthony, D. D. Roby, D. B. Irons, R. Suryan, others?; J. Anim. Ecol., target submission in 1999.

f) "Effects of diet quality on reproductive success of piscivorous seabirds in Alaska," J. Anthony, D. D. Roby, J. Piatt, & D. C. Duffy; Ecology, target submission in 1999.

g) "Prey exploitation by piscivorous seabirds in Prince William Sound, Alaska: A bioenergetics approach," J. Anthony, D. D. Roby, D. B. Irons, & D. C. Duffy; Can. J. Zool., target submission in 1999.

h) "Food as a constraint on seabird reproduction: Relative importance of quantity and quality," J. Anthony, D. D. Roby, J. Piatt, D. C. Duffy; Amer. Zool., target submission in 2000.

A draft annual report for this component of APEX will be submitted by 15 March 1999 for incorporation into a synthesis Annual Report for the APEX Project by 15 April 1999. The final report for this component of APEX will be submitted 15 December 2000. The bulk of the final report will be excerpted from the doctoral dissertation of the Ph.D. student (Jill Anthony) on this project. This student will be strongly encouraged and directly assisted by the PI to submit for publication in the peer-reviewed scientific literature the results from this research.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The research described in this proposal is a component of the APEX Project (98163 A-P) and dove-tails nicely with new and continuing research to assess factors limiting recovery of seabird populations damaged by EVOS. It is also relevant to efforts toward developing seabird models as upper trophic level sentinels of changes in the availability of forage fishes, such as sand lance, juvenile pollock, herring, and capelin. The proposed research approach utilizes prey composition, reproduction rates, and energetics models to help identify and quantify the present level of forage fish availability within the PWS and Lower Cook Inlet ecosystems. This approach is necessary because evaluation of the stocks of various forage fishes is extremely complex due to temporal and spatial variability and unpredictability in the distribution of forage fishes in PWS.

Studies of foraging, reproduction, and population recovery following the EVOS are on-going for pigeon guillemots, common murres, and marbled murrelets. Black-legged kittiwakes are currently being used as indicators of ecosystem function and health within PWS (APEX Component 98163 E), and are the subjects of a similar study on the Barren Islands (APEX Component 98163 J). This proposal complements and enhances other proposed studies on pigeon guillemots and black-legged kittiwakes, without duplication of effort. The PI on the present proposal has been and will continue to work closely with David Irons and Robert Suryan (PIs on APEX Component 98163 E "Kittiwakes as Indicators of Forage Fish Availability), the replacement for D. Lindsey Hayes (PI on APEX Component 98163 F "Factors Affecting Recovery of PWS Pigeon Guillemot Populations"), David Roseneau, (PI on APEX Component 98163 J "Reproductive Success by Murres and Kittiwakes on the Barren Islands"), and John Piatt (PI on APEX Components 98163 M "Lower Cook Inlet Forage Fish Studies" and 98163 N "Black-legged Kittiwake Feeding Experiment") in developing protocols for collecting field data so as to minimize project cost and maximize data acquisition. Irons is affiliated with the Migratory Bird Branch, U.S. Fish and Wildlife Service and Piatt is with the Alaska Science Center, Biological Resources Division, U.S.G.S. Irons has had extensive experience working in the field with kittiwakes nesting in PWS, and is project leader for on-going studies of the reproductive success and status of kittiwakes and guillemots in PWS. Piatt and Roseneau have had extensive experience with seabird research in Alaska. Close coordination with the research teams of Irons, Roseneau, and Piatt will be essential for the success of the proposed research.

APEX Components E, F, J, M, N, and the present component (G) all require information on chick feeding rates, brood meal size, and taxonomic composition of nestling diets in order to meet their objectives. Collecting these data is extremely labor intensive and the cooperation of these six components in collecting these data will greatly enhance sample sizes. The six components also require data on chick growth performance (body mass in relation to wing and flight feather development), nestling survival, mass and condition of fledglings, and fledging age. Again, cooperation and coordination between these components will greatly enhance sample sizes and the power of statistical tests and inferences. The field crews for the six components will work together to insure that data collection methods and procedures are consistent.

In order to understand dietary factors responsible for poor reproductive performance of seabirds in the EVOS area, it is essential to conduct simultaneous shipboard work (hydroacoustic surveys in conjunction with net sampling) to assess the distribution, abundance, and species composition of forage fishes in seabird foraging areas. That research was funded by the Trustees Council beginning in 1994 (Project 94163) and the continuation of this project (APEX Component 98163 A) will be invaluable for interpretation of data on diets collected as part of the present proposal. In addition, the integrated studies that comprise the SEA Program (98320A-Y) will provide an important foundation for understanding ecosystem function in PWS as it relates to seabird/forage fish interactions.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

The project continues to collect information to examine potential energetic factors (diet composition, diet quality, meal size, provisioning rates) that constrain the productivity of seabirds in the *Exxon Valdez* oil spill area. In 1998, we will expand the investigation of adult energy expenditure rates using the doubly-labeled water technique, as suggested by the APEX peer reviewers and the EVOS chief scientist. This will enable us to compare parental investment in reproduction among seabird colonies that experience different foraging conditions. By directly measuring adult energy expenditure during the chick-rearing period, we will further elucidate the "is it food?" question of APEX. Colonies with different environmental conditions (e.g., oiled vs. non-oiled), foraging strategies (e.g., long- vs. short-distance), and food availability (e.g., low vs. high) will be compared to relate parental energy expenditure to seabird productivity and population recovery. Additonal funds were included in FY 98 to support this expanded research effort.

PRINCIPAL INVESTIGATOR

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The PI (Daniel D. Roby) has extensive experience with studies of the reproductive energetics of high latitude seabirds and the relationship between diet composition and productivity.

OTHER KEY PERSONNEL

The proposed research will be implemented by the Oregon Cooperative Wildlife Research Unit, closely coordinated with and in cooperation with U.S. Fish and Wildlife Service and National Biological Service biologists with expertise on the proposed study species in the proposed study areas. The PI is assembling the analytical equipment necessary to accomplish the proposed laboratory analyses and is familiar with the relevant analytical procedures. To the PI's knowledge, the expertise and equipment necessary for the proposed research are not available within the federal and state agencies that comprise the Trustees Council. The PI will be assisted by a Graduate Research Assistant (Ph.D. candidate Jill Anthony), Field Technicians, Lab Technicians, and undergraduate field assistants who will be carefully selected from the applicant pool as qualified to participate in the proposed research.

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I
Project Leader

APEX: PROJECT LEADER SUBMITTED UNDER THE BAA

Project Number:	98163 I
Restoration Category:	Research
Proposed By:	NOAA: BAA
Duration:	5 years
Cost FY 98:	$150,000
Cost FY 99:	$140,000
Cost FY 00:	$140,000
Geographic Area:	Prince William Sound, Cook Inlet
Injured Resource/Service:	Pigeon Guillemot, Pacific Herring, Marbled Murrelet, Harbor Seal, Common Murre, Subtidal Communities, Commercial Fishing

ABSTRACT
This subproject provides scientific direction and management for the APEX project, develops new subprojects and coordinates research with other EVOS ecosystem projects and other research efforts.

INTRODUCTION

This component of the APEX project provides scientific oversight and coordination between the subprojects of the project.

NEED FOR THE PROJECT

A. Statement of Problem

Several resources injured in the *Exxon Valdez* oil spill have not recovered. While continuing damage is a possibility, there is evidence that a shift in the food available for several injured species may now be restricting their recovery. This project provides scientific direction for the ecosystem project APEX: Alaska Predator Ecosystem Experiment.

B. Rationale/Link to Restoration

The APEX Project evolved from a varied group of projects that all focused on availability of forage fish as a factor in the non-recovery of resources injured in the *Exxon Valdez* oil spill. The EVOS Trustee Council felt that an integrated ecosystem approach would achieve greater research efficiency by exploring the topic across several levels of the food chain. In late 1994, Dr. Duffy was hired to serve as the half-time Project Leader to achieve this coordination.

C. Location

Most activity takes place in Anchorage, with limited field work and visits to Juneau, Fairbanks and Cordova.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

This subproject does not directly involve traditional ecological knowledge. It does provide outreach to the community through interactions with the press, such as National Geographic, Scientific American, National Public Radio, commercial radio and television, and local newspapers.

PROJECT DESIGN

A. Objectives

1. Ensure the selection, development and funding of projects which will allow tests of the main hypotheses of the APEX Project.
2. Ensure publication of APEX project results.
3. Develop tentative methodology for future monitoring
4. Coordinate with other EVOS Trustee Council projects and other research efforts.

B. Methods

1. Selection, development and funding of projects which will allow tests of the main hypotheses of the APEX Project.

As APEX has developed, the underlying hypotheses need top be continually evaluated as some are addressed and others appear intractable. This requires working with the P.I.s of each subproject to evaluate their work in relation to hypotheses and when needed to develop new hypotheses and goals.

2. Ensure publication of APEX project results.

The list of papers and manuscripts may be found under each of the subprojects.

3. Develop tentative methodology for future monitoring

We will continue to examine existing APEX projects for methodology that is inexpensive and correlates well with other, more expensive or intensive sampling methods or that can be incorporated into models that examine environmental variability. We are also reviewing existing sources of long-term environmental data outside of APEX to determine its usefulness for inclusion in a future monitoring program.

4. Coordinate with other EVOS Trustee Council projects and other research efforts.

Please see the section: Coordination and Integration of Restoration Effort, below

Cooperating Agencies, Contracts, and Other Agency Assistance

Performance of this subproject requires cooperating with all the other institutions and agencies active in APEX, as well as with the NVP and SEA projects of the Exxon Valdez Oil Spill Trustee Council.

SCHEDULE

A. Measurable Project Tasks for FY 98

1998

January .	EVOS Restoration Annual Workshop
	Annual APEX Project Report
April	Annual Report

B. Project Milestones and Endpoints

1998	International Symposium on Changes in Pacific Seabirds, Pacific Seabird Group, Monterey, CA.
1999	*Symposium on Ten Years of Recovery Following the Exxon Valdez Oil Spill.*
2000	Monitoring Plan for Seabirds an Fish in the Restoration Area
2001	Final Reports completed

C. Completion Date

PUBLICATIONS AND REPORTS

Two annual report were presented in April 1996 and 1997. Subsequent reports will appear yearly.

PROFESSIONAL CONFERENCES

The main 1998 effort will involve the International Symposium on Changes in Pacific Seabirds, Pacific Seabird Group, Monterey, CA.in January 1998. we are also involved in some of the initial planning for the *Symposium on Ten Years of Recovery Following the Exxon Valdez Oil Spill.*

COORDINATION AND INTEGRATION OF RESTORATION EFFORT-

APEX is in itself a major integrated research effort, spanning 15 principal investigators at 16 institutions, agencie, or private businesses. Details of integration at the individual project level may be found in the appendices for each project.

We will also work with SEA to coordinate sampling toward the development of long-term monitoring for the spill area and we will work with NMFS and Cornell University on a project exploring the cellular consequences of low-lipid diets.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

The initial work with ADF&G on spatial analysis of the relationship between harbor seals and food supplies in PWS will be expanded to Steller's Sealions to see if further work is merited. A separate dpd testing a hypothesis about the seal and bird response to poor food quality will be submitted outside the APEX project.

PRINCIPAL INVESTIGATOR

David Cameron Duffy Ph.D.
Associate Professor
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Dr. Duffy has worked extensively on seabirds and their interactions with prey resources and environmental variability in Peru, Africa, Costa Rica, Galapagos, and New York. he has extensive management and project development experience from managing large seabird projects in Galapagos and South Africa, directing the Darwin Station in Galapagos, establishing a regional wildlife library in Costa Rica, and directing a public health research project on Lyme Disease in New York State.

PERSONNEL

Project Leader	David Cameron Duffy
Data and GIS Manager	Julie Michaelson
Student Assistant	Tracy Gotthardt

J
Barren Islands Study

BARREN ISLANDS SEABIRD STUDIES (PROJECT 98163J)

Project Number:	98163J
Restoration Category:	Research and Restoration This study is part of the APEX forage fish - seabird ecological processes project; it also includes restoration monitoring of common murres
Proposer:	DOI-FWS
Lead Trustee Agency:	USFWS
Cooperating Agencies:	USGS (BRD) and NMFS
Duration:	3 years (FY 98 - FY 00)
Cost FY 98:	$113.3K
Cost FY 99:	$116.7K
Cost FY 00	$ 84.0K
Geographic Area:	Cook Inlet (specifically the Barren Islands)
Injured Resource/Service:	Common Murre, Recreation Tourism

ABSTRACT

As part of the APEX seabird - forage fish study (Project 98163), we have collected information on common murres (*Uria aalge*), black-legged kittiwakes (*Rissa tridactyla*), and tufted puffins (*Fratercula cirrhata*) at the East Amatuli Island - Light Rock colony in the Barren Islands first as a pilot study during mid-June - early September 1995, and then during the same period each summer 1996-1997. The presence near the Barren Islands of large stocks of capelin (*Mallotus villosus*) and a variety of other fishes (e.g., Pacific sand lance, *Ammodytes hexapterus* and walleye pollock, *Theragra chalcogramma*) frequently utilized by seabirds provided an opportunity to study seabird - forage fish relationships and natural ecological processes that might help explain why populations of some seabirds have not increased during the 6-year

interval following the T/V Exxon Valdez oil spill. Data collected during FY 96-97 included information on nesting chronology, productivity, growth and feeding rates of chicks, time budgets of adults, and types and amounts of food fed to chicks. Data obtained during the FY 96 - FY 98 work will be used to test 3 important APEX project hypotheses: (a) composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near the nesting colonies; (b) changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks; and (c) seabird productivity is determined by differences in forage fish nutritional quality.

INTRODUCTION

The APEX Barren Islands seabird studies (Project 98163J) are designed to collect data on 3 key species of fish-eating seabirds: common murres (*Uria aalge*), black-legged kittiwakes (*Rissa tridactyla*), and tufted puffins (*Fratercula cirrhata*) at the Barren Islands colonies during the FY 96 - FY 98 field seasons. Results of the work will be used in a multi year, multi species analysis of seabird productivity and energetics that is designed to help identify and define ecological processes that may be influencing seabird recovery within the T/V Exxon Valdez oil spill area. These data will also be used to test 3 APEX project hypotheses: (a) composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near the nesting colonies; (b) changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks; and (c) seabird productivity is determined by differences in forage fish nutritional quality. As in past years, field work will be conducted at the East Amatuli Island - Light Rock colony during about 10 June - 10 September in 1998. Types of information collected will include data on nesting chronology, productivity, feeding and growth rates of chicks, time budgets of adults, and types and amounts of food fed to chicks (data types will vary slightly between species-see below). Fish and invertebrates brought to chicks will also be collected for stable isotope and nutrient analyses.

The Barren Islands seabird studies were integrated into the APEX seabird - forage fish ecological processes project because capelin (*Mallotus villosus*), an important forage fish species scarce in the northern Gulf of Alaska since the late 1970's (see Piatt and Anderson 1995; P. Anderson, unpubl. data), were abundant in Barren Islands waters during FY 93 - FY 94 (Roseneau et al. 1995, 1996). The presence of large concentrations of capelin near the islands during these years, and their reoccurrence in FY 95 (D.G. Roseneau, unpubl. data) suggest that stocks of these important forage fish are beginning to rebound in the northwestern Gulf of Alaska. The current abundance of capelin at the Barren Islands, combined with the presence of other fishes utilized by seabirds (e.g., Pacific sand lance, *Ammodytes hexapterus* and walleye pollock, *Theragra chalcogramma*; D.G. Roseneau and A. B. Kettle, unpubl. data), continues to provide an opportunity to collect information on seabird - forage fish relationships needed for a multi year, multi species analysis of seabird productivity and energetics that will increase understanding of ecological processes and help test 3 APEX hypotheses (hypotheses 7, 8, and 9 in the FY 95 APEX proposal; also, see below).

We conducted a pilot study at the Barren Islands in FY 95 to determine whether the kinds and amounts of data needed for an analysis of productivity and energetics of several species of seabirds could be collected at the East Amatuli Island - Light Rock colony (95163K). The pilot project successfully met all study objectives; sufficient amounts of data were collected on all targeted variables. Furthermore, we have actively shared data and logistical costs with other studies. An on-going Minerals Management Service - National Biological Service (MMS-NBS) and APEX seabird ecosystem study, lead by J. Piatt, NBS, has collected information on seabirds, fisheries resources, and oceanographic conditions in the Barren Islands and lower Cook Inlet regions during FY 96 - FY 97. We have coordinated sampling protocols, synchronized observation days, and integrated studies in every way we can. A National Marine Fisheries Service - Alaska Dept. of Fish and Game (NMFS-ADFG) sea lion study that collected fisheries data in the Barren Islands during FY 96 will provide additional opportunities to coordinate efforts and share data that will compliment and benefit the work.

NEED FOR THE PROJECT

A. Statement of Problem

Many seabirds were killed during the T/V Exxon Valdez oil spill (e.g., Piatt et al. 1990, ECI 1991), and populations of several species have still not recovered (e.g., Agler et al. 1994a,b; Klosiewski and Laing 1994) or have only partially recovered from the event (e.g., although common murre productivity is now within normal limits at the Barren Islands, population numbers have remained little changed at these injured colonies since the spill-Roseneau et al. 1995, 1996; D.G. Roseneau and A.B. Kettle, unpubl. data). Therefore, there is a need to understand seabird - forage fish relationships and ecological processes that may be influencing seabird recovery within the spill area.

B. Rationale

The study is one of several coordinated components of the APEX seabird - forage fish project (98163). The work was integrated into the APEX study because data on common murre, black-legged kittiwake, and tufted puffin productivity, nesting chronology, feeding and growth rates of chicks, time budgets of adults, and types and amounts of fish fed to chicks are needed from the Barren Islands colonies for use in a multi species productivity and energetics analysis that will help identify and define ecological processes within the Prince William Sound (PWS) and lower Cook Inlet (LCI) sections of the spill area.

C. Summary of Major Hypotheses and Objectives

The study addresses 3 APEX project hypotheses: (a) composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near the nesting colonies; (b) changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks; and © seabird productivity is determined by differences in forage fish nutritional quality. Project objectives are to collect and analyze the kinds and types of data needed to help test these hypotheses.

D. Completion Date

Annual reports for the FY97 field season will be submitted to the APEX project leader (D. Duffy) by 15 March 1998 and for the FY98 field season by 15 March 1999. Field work will be completed in FY 99, and a final report summarizing the FY 95- FY 99 findings will be submitted to the APEX project leader in FY 2000.

COMMUNITY INVOLVEMENT

Large format, computer-generated color posters summarizing annual results will be prepared and submitted to the Trustee Council for public display each year after data have been analyzed The posters are easy to transport and can be used by Trustee Council staff for a variety of purposes, including public displays at oil spill community meetings and schools. Abstracts of annual findings and the posters will also be available on-disk for inclusion in any on-line products that the Trustee Council may develop for public use. Field activities will be photographed and a file of 35 mm color slides will be compiled for Trustee Council use at community meetings and in public newsletters, displays, and on-line information services. Copies of annual and final reports will be available to the public in Homer and Anchorage. Study results will also be presented at public Trustee Council-sponsored meetings and workshops, and published in scientific journals.

FY98-FY2000 BUDGETS

Costs estimates for the FY 98 - FY 2000 Barren Islands seabird studies are summarized below. Funds for attending APEX meetings and EVOS workshops are included in travel estimates. Projected costs for FY 98 - FY 2000 include small anticipated increases in prices of some items (e.g., travel, contracts, personnel; calculations were based on average increases of about 4.5% per year) and costs of analyzing data and writing annual reports.

FY 98 Costs ($K) (1 Oct 1997 - 30 Sep 1998)		Projected FY 99 Costs ($K) (1 Oct 1998 - 30 Sep 1999)	Projected FY 2000 Costs ($K) (1 Oct 1999 - 30 Sep 2000)
Personnel	73.8	76.1	70.0
Travel	7.6	7.6	3.5
Contractual	7.8	7.8	
Commodities	9.5	10.3	
Equipment	2.9	2.9	
Subtotal	101.6	104.7	73.5
Gen. Admin.	11.7	12.0	10.5
Total	113.3	116.7	84.0

PROJECT DESIGN

A. Objectives

The project objective is to collect data on the same murre, kittiwake, and puffin variables targeted in FY 96-97 (nesting chronology, productivity, growth and feeding rates of chicks, time budgets of adults, and types and amounts of prey fed to chicks) at the East Amatuli Island - Light Rock colony for use in a multi species, multi year analysis of seabird productivity and energetics that will help identify and define ecological processes within the PWS and LCI sections of the spill zone.

B. Methods

The study will be conducted at the East Amatuli Island - Light Rock colony (see Fig. 1). As demonstrated during the FY 95 Barren Islands pilot project (95163K), limiting work to this location conserves funds and maximizes data collection opportunities (i.e., compared to study designs that include working at Nord Island). Methods for collecting and analyzing data will follow approved protocols with slight modifications where necessary based on site characteristics.

Data Collection

Data will be collected by 4 personnel stationed at the FWS Amatuli Cove camp during about 10 June - 10 September (the camp leader has 7 years experience working at the East Amatuli Island - Light Rock colony). Personnel will commute to study plots by hiking and boating. Murre and kittiwake productivity and nesting chronology data will be collected from the same sets of plots used to obtain this information during the FY 93 - FY 94 restoration monitoring studies (93049 and 94039; see Roseneau et al. 1995), the FY 95 pilot project (95163K) (Roseneau et al. 1996), and subsequent FY96 (96163K) and FY97 (97163K) annual projects. These plots contain about

340 murre and 370 kittiwake nest sites and sample a wide range of nesting habitats. Ten murre plots (COMU/LPP1-10) and 11 kittiwake plots (BLKI/LPP1-11) will be checked about every 2-3 days, weather permitting.

Information on any factors that might adversely affect the reproductive success of murres and kittiwakes will also be collected during the productivity-chronology work (e.g., avian predation events, disturbance by humans, adverse weather conditions). During predation events or other episodes causing adults to flush from the nesting cliffs, efforts will be made to record losses of eggs or chicks.

Data will be collected on feeding rates of murre and kittiwake chicks and time budgets of adults. by monitoring 10 murre and 10 kittiwake nest sites in plots established for these purposes. During day-long nest site watches, times will be recorded for all adult arrivals, exchanges, and departures, and food deliveries to chicks. Data will be used to calculate seasonal chick feeding rates and time budget indices for adults of both species.

Fish brought to murre chicks will be identified as often as possible during the study to obtain basic information on availability of prey. Blocks of time averaging about 8-10 hrs wk-1 will be set aside to specifically watch for birds returning to nest sites with fish in their bills. Fish will be observed with the aid of spotting scopes and binoculars and identified to species or basic prey groups (e.g., capelin, sand lance, herring, gadids, flatfishes, pricklebacks, other fishes, unidentified fishes) using field characteristics (e.g., colors, tail and fin shapes; observers conducting this part of the study have experience identifying fish hanging from murre bills). Because kittiwakes do not carry fish in their bills, chicks will be gently captured and encouraged to regurgitate food (kittiwake chicks readily regurgitate prey when they are handled and the procedure does not harm the nestlings). About 10-15 regurgitated meals will be collected each week during the nestling period, providing a total of 50-70 samples, which will be sufficient to quantify prey types fed to chicks and detect seasonal changes in diets. Regurgitated food will be weighed to provide information on meal sizes. Samples will be analyzed by A.M. Springer, Institute of Marine Sciences, UAF, using previously published techniques (e.g., see Springer et al. 1984, 1986).

Data collected on tufted puffins will include information on nesting chronology, burrow densities, numbers of active burrows, numbers of occupied burrows producing chicks, chick growth and feeding rates, and types of prey fed to chicks. These data will be obtained from 5 previously established study plots on East Amatuli Island in August after chicks are about 1 week old (disturbing burrows earlier in the nesting season often results in abandonment). Hatch dates will be initially estimated by observing percentages of adults returning to the island during 1000-1300 hrs that have prey in their bills (in previous years, chicks were about 1 week old on these plots when about 20% of the adults were returning with bill-loads of food). To supplement this information, small samples of 5-10 burrows will be checked each week in other sections of the colony to help refine hatch dates. Active burrows will be marked with survey flags and 30 chicks will be carefully removed and weighed and measured about every 5 days until they reach fledging age (wing chord will be the primary measurement). An additional 20 chicks on 2 other plots will be weighed and measured 3 times during the chick-rearing period to test effects of disturbance at the more frequently visited plots. A separate plot of about 25 nests will be used to evaluate hatching success. Just before fledging begins, data on burrow densities, occupancy rates, and numbers and sizes of chicks will be collected from four 3-m wide transects totaling 270 m^2 that have been monitored every year since 1986. Information on feeding rates will be collected by setting up a blind and recording the number of times adults deliver food to nestlings in about 10 active burrows during three day-long watches. Prey items brought to chicks will be obtained from about 150 active burrows outside of the study plots about twice per week during the nestling period by temporarily blocking burrow entrances for 3-hr periods with wire-mesh screens (adults usually drop their bill-loads in front of blocked burrow entrances; e.g., Hatch and Sanger 1992). Fish and invertebrates collected in this manner will be weighed and measured and either returned to the chick or, if requested by other project, collected and frozen. Some frozen specimens will be sent to D. Roby (95163G) and J. Piatt (NBS) for nutrient and stable isotope analyses.

Some information will also be collected on glaucous-winged gulls (*Larus glaucescens*) and cormorants (*Phalacrocorax* spp.) during the project. Data will include counts of birds, nests and their contents, and timing of nesting events. This information will be shared with J. Piatt, NBS.

Because water temperatures are an important factor influencing both seabirds and their prey (see Springer et al. 1984), water temperature data will be collected near the East Amatuli Island - Light Rock colony at regular intervals throughout the study. A data logger will be moored near the colony to provide hourly and daily records of sea surface temperatures (SST). SST will also be measured with calibrated hand-held thermometers in order to compare between this method and the data logger, so that previous hand-recorded measurements from 1993-1995 may be used.

Data Analysis

Standard methods specified in approved protocols will be used to analyze murre, kittiwake, and puffin productivity-chronology data. Nest sites with incomplete observation records (e.g., data gaps of more than 7 days between pre- and post-event observation dates; insufficient data to indicate chicks fledged) will be eliminated from the database. The remaining data will then be analyzed to obtain chronology and productivity information.

Because productivity is an important measurement being used to help assess the recovery status of common murres (see Proceedings of the Science for the Restoration Process Workshop, April 13-15, 1994), murre productivity data will be compared with FY 95 information and data from FY 89 - FY 94 damage assessment and restoration monitoring studies (see Roseneau et al. 1995, 1996). ANOVA and Tukey HSD multiple comparisons tests will used to check for significant differences among years, and Kendall's Tau test will be run to check for trends.

Data on murre, kittiwake, and puffin chick-feeding rates and amounts of time adults spend away from nests foraging for food will be analyzed in a manner that will provide chick-feeding frequency and time budget indices for these species (see approved protocols for detailed methods).

Identifiable fish fed to murre chicks will be reported as percentages of numbers in several basic prey categories (e.g., capelin, sand lance, herring, gadids, flatfishes, pricklebacks, other species). Calculations will be made for the entire chick-rearing period and weekly intervals of time.

Information on food delivered to kittiwake and puffin chicks will be treated in a similar manner. However, in addition to calculating percentages of numbers in various fish and invertebrate prey categories (e.g., capelin, sand lance, gadids, squid, euphasiids), these data will also be reported by weight (in some cases, weights will be estimated from average weights of subsamples of prey).

The primary measure of puffin chick growth rate will be average daily change in mass, reported as g/day (see the protocol). Actual hatch dates will not be known, because burrows will not checked until chicks are about 1 week old (see above). Chick ages will be estimated by using the first wing measurement and a growth equation reported by Amaral (1977). Growth rates of individual chicks will be determined by linear regression of wing measurements obtained when chicks are 10-40 days old; growth is nearly linear during this period (A.B. Kettle and P.D. Boersma, unpubl. data). [Note: Data may be manipulated in slightly different ways to fit the needs of other APEX investigators (e.g., D. Roby, 96163G;J. Piatt, NBS; D. Irons, 96163E).] The median hatch date, derived from chick growth information, will be used to measure nesting chronology.

Growth rate data and other information obtained on puffins during FY 98 (e.g., timing of nesting events, proportion of active vs. inactive burrows, number of chicks per occupied burrow) will be compared with information collected on the same plots in 1995-1997, than in previous years, as it becomes available (e.g., mid-1970's - early 1980's and 1990-1993; these data are being prepared for publication by A.B. Kettle and P.D. Boersma).

Water temperature data will be reported in degrees C by location, date, and time, and summarized in tabular form. The information will also be divided into seasonal time blocks (e.g., weeks and months).

C. Contracts and other Agency Assistance

1. Contracts: A contract with the Student Conservation Association is needed to obtain the services of 2 SCA volunteers to help field crews collect data. Collecting data on seabirds in the Barren Islands is a labor intensive effort and the SCA program is a cost-effective source of volunteers. These positions also provide important training opportunities for high school and college students seeking jobs in resource-related fields).

2. Existing Agency Programs: The Alaska Maritime National Wildlife Refuge will furnish all office and warehouse space, computers, and radio communications services needed for the project. The refuge will also donate up to 2 months of the project manager's time (G.V. Byrd, AMNWR supervising biologist). In addition, the refuge will provide several pieces of field equipment (e.g., back-up outboard motors, hand-held and base radios, survival suits) and miscellaneous camping supplies for the work, and emergency medical consultation services for field personnel under its refuge-wide remote emergency medical services contract.

D. Location

The FY 98 studies will be conducted at the East Amatuli Island - Light Rock colony in the Barren Islands, about 100 km south of Homer in the northwestern Gulf of Alaska. No communities will be affected by the study.

SCHEDULE

A. Measurable Project Tasks for FY 98-FY 2000

1 Feb - 30 Apr 1998:	Review study plan, coordinate protocols with other APEX investigators, arrange hiring of temporary employees, contract for SCA volunteers and transportation, begin purchasing equipment/supplies.
1 May - 9 Jun 1998:	Finalize logistical needs, purchase/pack equipment/supplies, train volunteers.
10-11 Jun 1998:	Load vessel, depart Homer, travel to study area.
12-15 Jun 1998:	Set up camp at East Amatuli Island.
16 Jun - 10 Sep 1998:	Collect data.
11-13 Sep 1998:	Pack equipment/supplies, load vessel, return to Homer.
14-15 Sep 1998:	Unload vessel.
16-20 Sep 1998:	Unpack equipment/supplies, clean equipment, store gear.
21 Sep - 31 Dec 1998:	Compile and analyze data.
1 Jan - 15 Feb 1999:	Complete analyses, prepare draft report of combined FY 98 results.

16 Feb 1999:	Submit draft report to APEX Project Leader (D. Duffy) for review.
15 Mar 1999:	Submit final report to APEX Project Leader (D. Duffy).
16-30 Mar 1999:	Respond to comments, submit final version of report to APEX Project Leader (D. Duffy).
1 Feb - 30 Apr 1999:	Review study plan, coordinate protocols with other APEX investigators, arrange hiring of temporary employees, contract for SCA volunteers and transportation, begin purchasing equipment/supplies.
1 May - 9 Jun 1999:	Finalize logistical needs, purchase/pack equipment/supplies, train volunteers.
10-11 Jun 1999:	Load vessel, depart Homer, travel to study area.
12-15 Jun 1999:	Set up camp at East Amatuli Island.
16 Jun - 10 Sep 1999:	Collect data.
11-13 Sep 1999:	Pack equipment/supplies, load vessel, return to Homer.
14-15 Sep 1999:	Unload vessel.
16-20 Sep 1999:	Unpack equipment/supplies, clean equipment, store gear.
21 Sep - 31 Dec 1999:	Compile and analyze data, present results at EVOS workshop
1 Jan - 15 May 2000:	Complete analyses, prepare draft report of combined FY 95 - 99 results.
16 May - July 2000	Revise report and prepare manuscripts for publication
1 Aug - 30 Sep	Complete final APEX report

B. Project Milestones and Endpoints

March 1998	Final draft of FY 97 results submitted to APEX Project Leader (D. Duffy).

September 1998	FY 98 Field work completed at East Amatuli Island.
March 1999	Final draft of FY 98 results submitted to APEX Project Leader(D. Duffy).
May 2000	First draft of Final Report FY95-99 to APEX Project Leader (D. Duffy).

C. **Project Reports**

See above Milestones

COORDINATION OF INTEGRATED RESEARCH EFFORT

The FY 98 Barren Islands seabird studies are fully coordinated and integrated with other components of the APEX seabird - forage fish project. Information on murre, kittiwake, and puffin productivity; feeding and growth rates of chicks; amounts of food fed to chicks; and time budgets of adults will be transmitted to D. Roby for use in his energetics study (98163G). Roby will also receive data on prey species fed to chicks and specimens of prey for nutrient analysis. D. Irons (98163E) will be sent a variety of information on kittiwakes, including timing of nesting events, and several measurements of productivity (e.g., fledglings nest-1, fledglings single and double chick nests-1) and growth rates of chicks (e.g., all chicks combined, and "a" and "b" nestlings). During the field work, J. Piatt, NBS, will be given information on observations of feeding concentrations of birds and whales to help him locate schools of forage fish during his hydroacoustic and trawl surveys. Data obtained on all of the murre, kittiwake, puffin, gull, and cormorant variables will also be shared with and analyzed in cooperation with Piatt. Piatt will also be sent specimens of fish for stable isotope analysis.

The Barren Islands seabird project is also closely coordinated with a recently approved Trustee Council-sponsored murre restoration monitoring study that were conducted at the Barren Islands in FY 96 - FY 97 (Project 96144).

An on-going joint NMFS-ADFG sea lion study being conducted in the Barren Islands is also coordinated with the Barren Islands seabird project. D. Merrick, NMFS, will be making additional hydroacoustic-trawl surveys within a 16 km radius of the Sugarloaf Island sea lion rookery in late June - mid-July. He will share information with the seabird studies.

ENVIRONMENTAL COMPLIANCE

No permits are required for the study, and based on review of CEQ regulation 40 CFR 1500-1508, this project has been determined to be categorically exempt from the requirements of

NEPA, in accordance with 40 CFR 1508.4.

PERSONNEL

A. Project Manager - G. Vernon Byrd

Vernon Byrd received a B.S. degree in wildlife management from the University of Georgia in 1968, did post-graduate studies in wildlife biology at the University of Alaska-Fairbanks in 1975, and completed a M.S. degree in wildlife resources management at the University of Idaho in 1989. His thesis, entitled "Seabirds in the Pribilof Islands, Alaska: Trends and monitoring methods", explored statistical procedures for analyzing kittiwake (Rissa spp.) and murre (Uria spp.) population data. Mr. Byrd has worked for the U.S. Fish and Wildlife Service for over 20 years, focusing on studies of marine birds in Alaska and Hawaii. His major interests center around monitoring long-term trends in seabird populations, including numbers of birds and reproductive performance at colonies. He has worked at murre colonies in the Aleutian Islands, the Bering and Chukchi seas, and western Gulf of Alaska. Mr. Byrd was a co-author of the final T/V Exxon Valdez oil spill damage assessment report for murres. Also, he was project manager of the 1993 and 1994 common murre restoration monitoring studies (Projects 93049 and 94039, respectively), and projects to remove predators from islands containing seabird colonies (Projects 94041 and 95041, in 1994 and 1995, respectively). Mr. Byrd has authored over 45 scientific papers and 50 U.S. Fish and Wildlife Service reports on field studies, and has made about 20 presentations on seabirds at scientific meetings. Mr. Byrd is the supervisory wildlife biologist at the Alaska Maritime National Wildlife Refuge, the premier seabird nesting area in the national public land system.

Selected Seabird Publications

Byrd, G.V., E.C. Murphy, G.W. Kaiser, A.J. Kondratyev, and Y.V. Shibaev. 1993. Status and ecology of offshore fish-feeding alcids (murres and puffins) in the North Pacific Ocean. Proceedings of "Symposium on the Status , Ecology, and Conservation of Marine Birds of the Temperate North Pacific". Canadian Wildlife Service, Ottawa.

Byrd, G.V., and J.C. Williams. Whiskered Auklet. 1993. A chapter describing the biology of the species in The birds of North America, No. 76 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia PA, and the American Ornithologists' Union, Washington, D.C. 12 pp.

Byrd, G.V., and J.C. Williams. Red-legged Kittiwake. 1993. A chapter describing the biology of the species in The birds of North America No. 60 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia PA, and the American Ornithologists' Union, Washington, D.C. 12 pp.

Springer, A.M. and G.V. Byrd. 1989. Seabird dependence on walleye pollock in the southeastern Bering Sea. Pages 667-677 in Proceedings of the International Symposium on the Biology and Management of Walleye Pollock. Alaska Sea Grant Rep. No. 89-1, Univ. of Alaska-Fairbanks.

B. Project Leader - David G. Roseneau

David Roseneau received his B.S. degree in wildlife management and M.S. degree in biology from the University of Alaska - Fairbanks in 1967 and 1972, respectively. His thesis research was on the numbers and distribution of gyrfalcons, Falco rusticolus on the Seward Peninsula, Alaska. He joined the U.S. Fish and Wildlife Service in January 1993 and was project leader of common murre restoration monitoring Projects No. 93049 and 94039 in the Barren Islands during 1993 and 1994. Mr. Roseneau was also principal investigator of the APEX seabird studies pilot program in the Barren Islands in 1995 (Project 95163K). Prior to 1993, he was a consulting biologist for 20 years, and he has conducted and managed marine bird, raptor, and large mammal projects in Alaska and Canada for government agencies and private-sector clients. Mr. Roseneau has been involved in several large-scale murre (Uria spp.) population monitoring projects. During 1976-1983, as co-principal investigator of NOAA/OCSEAP Research Unit 460, he conducted monitoring studies of murres and black-legged kittiwakes (Rissa tridactyla) at capes Lisburne, Lewis, and Thompson in the Chukchi Sea, and St. Lawrence, St. Matthew, and Hall islands in the Bering Sea. He also studied auklets (Aethia spp.) at St. Lawrence and St. Matthew islands, and participated in murre and kittiwake projects at Bluff in Norton Sound. In 1984-1986, he participated in follow-up studies of murres and kittiwakes in the northeastern Chukchi Sea, and during 1987-1988, 1991-1992, and 1995 he helped conduct additional murre and kittiwake work at capes Lisburne and Thompson, and at Chamisso and Puffin islands. Mr. Roseneau is experienced in collecting and analyzing data on numbers, productivity, and food habits of seabirds; relating trends in numbers and productivity to changes in food webs and environmental parameters (e.g., air and sea temperatures, current patterns); and assessing potential impacts of petroleum exploration and development on nesting and foraging marine birds. He has broad knowledge of rock climbing techniques and has operated inflatable rafts and other outboard-powered boats in the Bering, Chukchi, and Beaufort seas and on various Alaskan rivers in excess of 2,800 hrs. Mr. Roseneau has also accrued several hundred additional hours operating time in small boats and larger, more powerful vessels (e.g. 25 ft, 300-400 hp HydroSports and Boston Whalers) in Kachemak Bay, Prince William Sound, and Kenai Peninsula and Barren Island waters. During his career, Mr. Roseneau has authored and co-authored over 70 reports and publications, including 23 on Alaskan seabirds.

Selected Seabird Publications

Murphy, E.C., A.M. Springer, and D.G. Roseneau. 1991. High annual variability in reproductive success of kittiwakes (Rissa tridactyla L.) at a colony in western Alaska. J. Anim. Ecol. 60: 515-534.

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Murphy, E.C., D.G. Roseneau, and P.J. Bente. 1984. An inland nest record for the Kittlitz's murrelet. Condor 86: 218.

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B. Field Team Leader - Arthur B. Kettle

Arthur Kettle received his B.A. degree in Human Ecology from the College of the Atlantic in 1984. Since that time, he has participated in several large-scale seabird projects at remote locations. He joined the U.S. Fish and Wildlife Service in May 1993, and was the field team leader for the 1995 APEX Barren Islands seabird studies pilot project (Project 95163K). In that capacity, Mr. Kettle was responsible for logistics at Amatuli Cove camp. He was also responsible for ensuring that data were collected according to study design. Mr. Kettle was in charge of the East Amatuli Island field work during previous common murre restoration monitoring projects (Project 93049 and 94039 in 1993 and 1994, respectively). During these studies, his broad knowledge of boat-mooring systems and technical rock climbing techniques allowed him to safely collect productivity and chronology data from a series of study plots he established on East Amatuli Island (a difficult technical task not accomplished during any previous pre- or postspill study). He also censused birds at East Amatuli Island and East Amatuli Light Rock in 1993 and 1994. Mr. Kettle counted these murre colonies and collected productivity data on Light Rock during Exxon-sponsored University of Washington studies in 1990-1992. In addition to this work, he also participated in large-scale University of Washington studies of magellanic penguins (Spheniscus magellanicus) in Argentina during 1987-1991, and tufted puffins (Fratercula cirrhata) and fork-tailed storm-petrels (Oceanodroma furcata) at the Barren Islands colonies in 1990-1992. Mr. Kettle has over 16 years experience safely operating small boats in the north Atlantic and Pacific oceans (e.g., Maine and Alaska), including 6 consecutive field seasons running outboard-powered craft at the Barren Islands.

Selected Seabird Publications

Boersma, P.D., J.K. Parrish, and A.B. Kettle. 1993. Common murre abundance, phenology, and productivity on the Barren Islands, Alaska: The Exxon Valdez oil spill and long-term environmental change. In BOOK TITLE, ASTM STP 1219._. (eds.); American Society for Testing and Materials, Philadelphia 1993.

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Hunt, G.L., Z. Eppley, B. Burgeson, and R. Squibb. 1981. Reproductive ecology, food, and foraging areas of seabirds nesting on the Pribilof Islands, 1975-1979. Pp. 1-258 in Environ. Assess. Alaska Contin. Shelf, Final Repts. Princ. Invest., Vol. 12. NOAA Environ. Res. Lab, Boulder, CO.

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Piatt, J.F. and P. Anderson. 1995. Response of common murres to the Exxon Valdez oil spill and long-term changes in the Gulf of Alaska marine ecosystem. In Press: in Rice, S.D., R.B. Spies, D.A. Wolfe, and B.A. Wright (eds.). Exxon Valdez Oil Spill Symposium Proceedings. Amer. Fisheries Soc. Symposium No. 18.

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Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 1995. Common murre restoration monitoring in the Barren Islands, 1993. Restoration Project No. 93049. Unpubl. final rept., U.S. Fish Wildl. Serv., Homer, AK.

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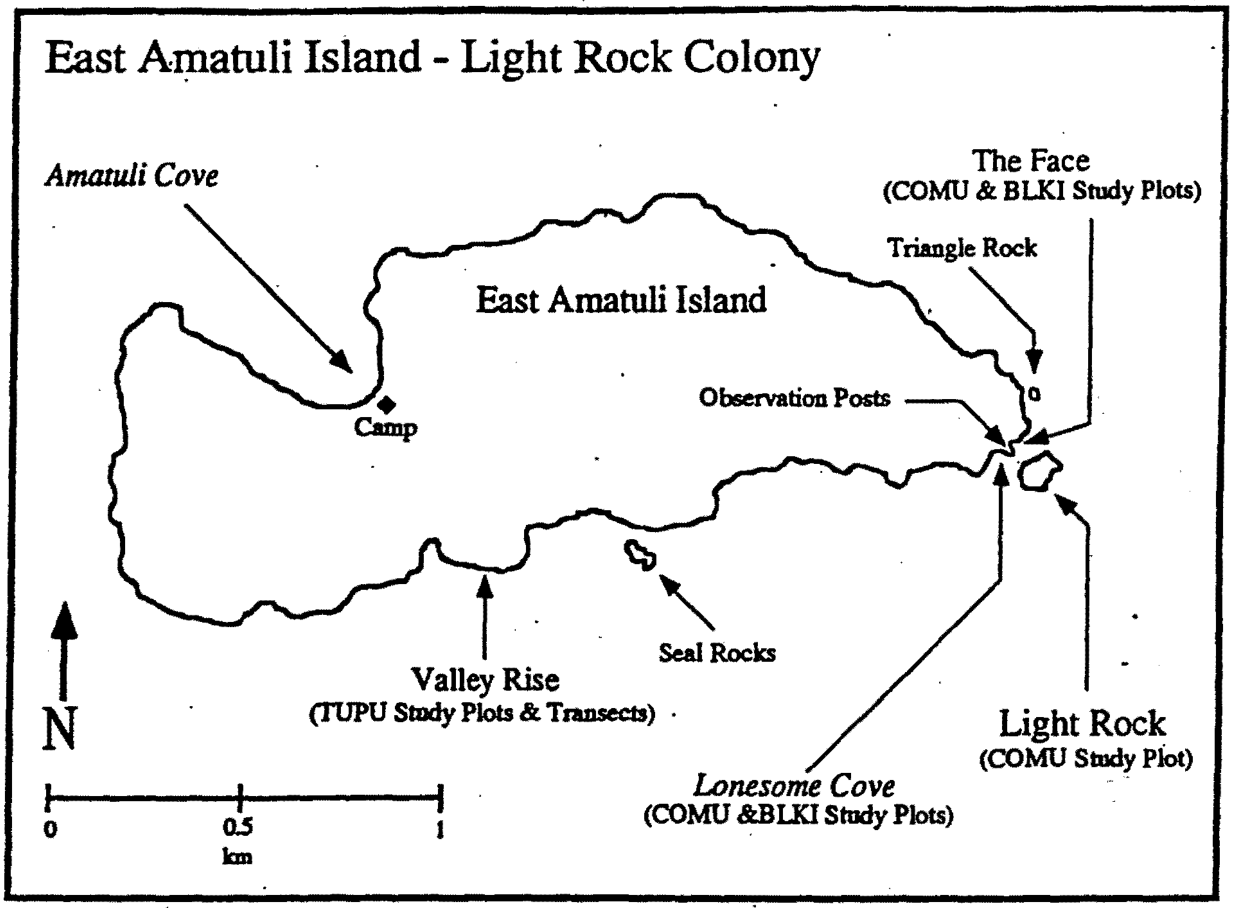

Figure 1. Barren Islands study area showing locations of common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study plots.

K
Fish as Samplers Study

USING PREDATORY FISH (PACIFIC HALIBUT) TO SAMPLE FORAGE FISH (PROJECT 98163K)

Project Number:	98163K
Restoration Category:	This study is part of the APEX forage fish - seabird ecological processes project
Proposer:	DOI-FWS
Lead Trustee Agency:	USFWS
Cooperating Agencies:	Monetarily none; however, the study will share data with NBS and NMFS
Duration:	3 years (FY 98 - FY 00)
Cost FY 98:	$9.6 K
Cost FY 99:	$10.1 K
Cost FY 00	$10.1 K
Geographic Area:	Field work will be conducted in Lower Cook Inlet in the vicinity of Homer, Alaska.
Injured Resource/Service:	This study is a component of the APEX seabird - forage fish ecological processes project. It will benefit common murres and other seabird species injured by the Exxon Valdez oil spill

ABSTRACT

As part of the APEX seabird - forage fish study (Project 98163), we have been using sport-caught Pacific halibut (*Hippoglossus stenolepis*) to obtain spatial and temporal information on capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus)* and other prey important to piscivorous seabirds. Evaluating the influence of fluctuating prey populations is critical to understanding the recovery of seabirds injured by the T/V *Exxon Valdez* oil spill. In 1995 and 1996 we examined over 500 halibut stomachs annually collected from cooperating vessels in a 150-200 charter boat fleet fishing throughout Cook Inlet waters during late May-early September. Plans are to sample a similar number in 1997. Catch locations and dates provided information on geographic and seasonal variation in the incidence of capelin and sand lance in seven eastern inlet subunits between Anchor Point and Shuyak Island. We also obtained information on prey brought to black-legged kittiwake (*Rissa tridactyla*), common murre (*Uria aalge*), and tufted

puffin (*Fratercula cirrhata*) chicks at Cook Inlet colonies to help evaluate the sampling techniques. It appears halibut diets reflect availability of common forage fish, because seabird diets reflected similar among-year patterns as halibut. Halibut provide a low-cost method for sampling forage fish abundance in Lower Cook Inlet.

INTRODUCTION

This study was developed and integrated into the APEX project because there was need for a cheap, cost-effective means of assessing relative abundance of important prey species, particularly forage fishes, near seabird nesting colonies. Evaluating the influence of fluctuating prey populations (e.g., forage fishes) is a crucial element in understanding annual variations in the productivity of several fish-eating marine birds, including both divers (e.g., common and thick-billed murres, *Uria aalge and U. lomvia*; tufted puffins, *Fratercula cirrhata*) and surface-feeders (black-legged kittiwakes, *Rissa tridactyla*). Knowledge of fluctuations in prey populations is also an important factor in understanding the recovery of seabirds injured by the T/V *Exxon Valdez* oil spill; however, it is expensive to conduct hydroacoustic and trawl surveys to assess forage fish stocks over such broad regions.

The presence of a large 150-200 charter boat fleet operating throughout Kachemak Bay and lower Cook Inlet during late May - early September offered a prime opportunity to explore the feasibility of using sport-caught Pacific halibut (*Hippoglossus stenolepis*) to obtain spatial and temporal information on capelin (*Mallotus villosus*) and Pacific sand lance (*Ammodytes hexapterus*), two forage fishes important to piscivorous seabirds (e.g., Piatt *et al.* 1991, Springer 1991, Piatt 1993). Many of these vessels fish for halibut almost every fair-weather day in lower Cook Inlet between Anchor Point and the shelf break and between Seldovia and Elizabeth Island. They also fish in Kennedy Entrance between the Kenai Peninsula and the Barren Islands, in the Barren Islands (as many as 18-20 boats were seen in the West Amatuli - Ushagat - Nord islands vicinities on some days in 1995-1996), and occasionally as far south as Shuyak Island (R. Swenson, Homer Ocean Charters, pers. comm.; D.G. Roseneau, pers. obs.). Many of these areas are also used heavily by foraging seabirds, including those nesting in the Barren Islands and at the Gull and Chisik islands colonies (Piatt 1993; J.F. Piatt, pers. comm.; D.G. Roseneau, pers. obs.).

Halibut are opportunistic predators that take a wide range of both fish and invertebrate prey, and smaller individuals between about 30 and 70 cm long tend to feed on a variety of miscellaneous fishes, including both sand lance and capelin (see Yang 1990). Halibut are usually associated with the bottom. However, fish weighing less than about 13-18 kg (commonly referred to as "chicken" halibut) have also been observed pursuing prey higher in the water column (J. Martin, Alaska Maritime NWR, pers. comm.; S. Meyers, Alaska Department of Fish and Game, pers. comm.), and in some instances they have even been seen jumping out of the water in large surface shoals of "bait-fish" (e.g., capelin; R. Swenson, Homer Ocean Charters, pers. comm.).

Based on the above information and the spatial and temporal distribution of the charter vessel;

fleet, we designed and implemented a pilot program to collect halibut stomachs during late May - early September 1995 to test the concept that these sport-caught fish could be used as sampling tools to assess the presence or absence and relative abundance of capelin and sand lance in Kachemak Bay and lower Cook Inlet waters. Results from this initial effort indicate that this relatively simple inexpensive technique can supply useful information on forage fish stocks in areas where seabird feeding and charter boat fishing activities overlap. As a result, we continued to use this method 1996-1997 to monitor relative abundance of forage fish and to compare with seabird prey.

NEED FOR THE PROJECT

A. Statement of Problem

Many seabirds were killed during the T/V Exxon Valdez oil spill (e.g., Piatt et al. 1990, ECI 1991), and populations of several species have still not recovered (e.g., Agler et al. 1994a,b; Klosiewski and Laing 1994) or have only partially recovered from the event (e.g., although common murre productivity is now within normal limits at the Barren Islands, population numbers have remained little changed at these injured colonies since the spill-Roseneau et al. 1995, 1996; D.G. Roseneau and A.B. Kettle, unpubl. data). Therefore, there is a need to understand seabird - forage fish relationships and ecological processes that may be influencing seabird recovery within the spill area.

B. Rationale

The study is one of several coordinated components of the APEX seabird - forage fish project (9y163). The work was integrated into the APEX study because data on availability of forage fish is a critical part of understanding the condition of the environment for sustaining recovery of seabirds injured by the Exxon Valdez oil spill and for identifying and defining ecological processes within the spill area.

C. Summary of Major Hypotheses and Objectives

The study contributes to testing 3 APEX project hypotheses: (a) composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near the nesting colonies; (b) changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks; and (c) seabird productivity is determined by differences in forage fish nutritional quality. Project objectives are to collect and analyze the kinds and types of data needed to help test these hypotheses.

D. Completion Date

An annual report will be submitted to the APEX project leader (D. Duffy) by 15 March 1999.

Field work will be completed in FY 99, and a final report summarizing the FY 95-99 findings will be submitted to the APEX project leader in FY 2000.

COMMUNITY INVOLVEMENT

Large format, computer-generated color posters summarizing annual results will be prepared and submitted to the Trustee Council for public display each year after data have been analyzed The posters are easy to transport and can be used by Trustee Council staff for a variety of purposes, including public displays at oil spill community meetings and schools. Abstracts of annual findings and the posters will also be available on-disk for inclusion in any on-line products that the Trustee Council may develop for public use. Field activities will be photographed and a file of 35 mm color slides will be compiled for Trustee Council use at community meetings and in public newsletters, displays, and on-line information services. Copies of annual and final reports will be available to the public in Homer and Anchorage. Study results will also be presented at public Trustee Council-sponsored meetings and workshops, and published in scientific journals.

FY98-FY2000 BUDGETS

Costs estimates for the FY 98 - FY 2000 studies are summarized below. Funds for attending APEX meetings and EVOS workshops are included in travel estimates. Projected costs for FY 98 - FY 2000 include small anticipated increases in salary costs.

	FY 98 Costs ($K) (1 Oct 1997 - 30 Sep 1998)	Projected FY 99 Costs ($K) (1 Oct 1998 - 30 Sep 1999)	Projected FY 2000 Costs ($K) (1 Oct 1999 - 30 Sep 2000)
Personnel	4.5	4.6	8.4
Travel	0.5	0.5	0.5
Contractual	2.5	2.8	
Commodities	1.2	1.2	
Equipment			
Subtotal	8.4	9.1	8.9
Gen. Admin.	0.9	1.0	1.2
Total	9.6	10.1	10.1

PROJECT DESIGN

A. Objectives

This study component is designed to be a low-cost way of obtaining data on temporal, spatial, and relative abundance data on forage fish in the northern Gulf of Alaska by having local charter boat operators collect stomachs from sport-caught halibut. The fresh stomachs from halibut caught near the Barren Islands, Kennedy Entrance, and Lower Cook Inlet on a weekly basis May 1 to September 1 will provide a basis for assessing availability of capelin, sand lance, and other forage fish to seabirds. Data collected during the project will be used in conjunction with chronology, productivity, feeding rates, and time-budget data collected on common murres, black-legged kittiwakes, and tufted puffins nesting in the Barren Islands and in Cook Inlet colonies.

B. Methods

Data Collection

This study component is designed to test the feasibility and effectiveness of obtaining low cost spatial and temporal information on forage fish in the northern Gulf of Alaska by having local charter boat operators collect stomachs from sport-caught halibut. Halibut are opportunistic aggressive predators that operate at a variety of depths in the water column, and both species prey heavily on some of the same forage fishes that murres, kittiwakes, and other seabirds eat when these prey are abundant (e.g., capelin, sand lance). Conversely, when forage fishes are scarce or absent, halibut and cod feed indiscriminately on a variety of other prey items that fish-eating seabirds may not be able to utilize (e.g., larger fishes and invertebrates).

The charter boat sport fishing fleet has grown dramatically in the northern Gulf of Alaska in recent years, and many of these vessels regularly fish for halibut in lower Cook Inlet between Anchor Point and the shelf break, Kennedy Entrance between the Kenai Peninsula and the Barren Is., the Barren Is. (as many as 18-20 boats were seen in the West Amatuli - Ushagat - Nord Is. Vicinities on some days in 1993-1994), the Kodiak Archipelago, the entrance to Resurrection Bay and Blying Sound, and in some areas of Prince William Sound. To test the sampling method, 3-4 Homer-based charter boat companies operating 1-6 vessels each and a similar number of Seward-based operators will be asked to voluntarily bring in stomachs from halibut caught near the Barren Is. and in Kennedy Entrance, lower Cook Inlet on a weekly basis during about May 1 - September 1. The Barren Is. - Kennedy Entrance - lower Cook Inlet area was included in the pilot study because murres, kittiwakes, and puffins nesting in the Barren Is. feed in it, Homer-based boats frequently visit it, and data from it will compliment FY95-FY97 seabird studies in the Barren Is. and surrounding region.

Depending on how individual charter boat skippers handle fish, stomachs will be removed and labeled at sea, stored in iced coolers, and brought back to Homer, or fish will be tagged with pertinent information when they are caught and their stomachs will be removed during cleaning at the Homer dock. Following schedules provided by the charter boat operators, vessels will be met to pick up stomachs, verify catch locations, and obtain other types of information, including the sizes of fish the stomachs came from, the depths the fish were caught at, and visual sightings of schooling fish and seabird melees. After stomachs are picked up, they will be taken to a wet-lab facility for same-day processing. At the lab, stomachs will be opened and checked for fish in the size ranges that murres, kittiwakes, and puffins typically eat (e.g., capelin, sand lance, herring, gadids, flatfishes). Fishes will be identified with the aid of standard keys, high quality photographs, and voucher specimens (the Principal Investigator is experienced in identifying all species of interest and will quickly teach volunteer assistants to accurately identify them).

Numbers and species and of forage fish found in the stomachs, catch dates and locations, and notes on other stomach contents, will be entered into a computer database. The database will be designed to allow information to be rapidly sorted into several distinct geographical areas (e.g., Barren Is., eastern and western Kennedy Entrance, lower Cook Inlet, lower Kachemak Bay) in weekly and monthly increments of time.

Subsamples of forage fishes recovered from the halibut and cod stomachs will be labeled and preserved in 10% buffered formaldehyde, 75% ethanol - 2% glycerin, or by freezing to allow future multiple uses, including analysis of stomach contents, aging via otoliths, and nutrient analysis. Samples preserved in formaldehyde will be shipped to Molly Sturdevant at the NMFS Auke Bay Laboratory on a monthly basis for eventual analysis of stomach contents. Specimens preserved in ethanol-glycerin or by freezing will be sent to other parties that have expressed interest in them (e.g., John Piatt, BRD; Dick Merrick, NMFS; Franz Mueter, IMS).

Data Analysis

Data from the FY95 forage fish sampling study was used to assess the effectiveness of the method in obtaining broad-scale low cost information on forage fish in the Gulf of Alaska. This information demonstrated that the technique was useful in obtaining low cost temporal, spatial, and relative abundance data on forage fish that can be integrated with seabird studies (e.g., general overall presence and absence; changes in relative abundance and species composition over time, particularly during pre-laying and chick-rearing periods). Data analysis is simple and straight-forward. Numbers and species information obtained from the halibut stomachs is annually organized by geographic area and time, quantified, and reduced to bar charts showing weekly and monthly changes in species composition and relative abundance in the areas of interest. Data from lower Cook Inlet, Kennedy Entrance, and Barren Is. waters will be compared with a variety of information collected on murres, kittiwakes, and puffins in the Barren Is. to see if relationships can be detected between reproductive variables and the species composition - relative abundance time series data generated by the forage fish sampling program. Products will include summaries of raw data, NOAA charts showing collection locations and times, and bar charts showing changes in relative abundance and species composition over time in the areas of interest. When complete, results will provide a 5-year look at relative abundance of forage fish in the study area.

C. Contracts and other Agency Assistance

1. Contracts: A contract will be executed with a volunteer to collect stomachs.

2. Existing Agency Programs: The Alaska Maritime National Wildlife Refuge will furnish all office and warehouse space, computers, and radio communications services needed for the project. The refuge will also donate up to 1 month of the project manager's time (G.V. Byrd, AMNWR supervising biologist). In addition, the refuge will provide several pieces of field equipment (e.g., vehicle, lab space).

D. Location

The FY 98 studies will be conducted at Homer, Alaska. The local community will not be affected significantly.

SCHEDULE

A. Measurable Project Tasks for FY 98-FY 2000

1 Feb - 30 Apr 1998:	Review study plan, arrange hiring of volunteer, purchase equipment/supplies. Develop partnerships with charter operators.
1 May - 1 Sep 1998:	Collect fish stomachs from charter operators and analyze contents
Oct..-Dec. 1998:	Analyze data and produce summary tables
Jan.-Mar 1999	Draft report, present findings at EVOS meetings
15 Mar 1999:	Submit final report to APEX Project Leader (D. Duffy).
16-30 Mar 1999:	Respond to comments, submit final version of report to APEX Project Leader (D. Duffy).
Mar.-Apr 1999:	Review study plan, arrange hiring of volunteer, purchase equipment/supplies. Develop partnerships with charter operators.
1 May - 1 Sep 1999:	Collect fish stomachs from charter operators and analyze contents
Oct..-Dec. 1999:	Analyze data and produce summary tables
1 Jan - 15 May 2000:	Complete analyses, prepare draft report of combined FY 95 - 99 results.

16 May - July 2000	Revise report and prepare manuscripts for publication
1 Aug - 30 Sep 2000	Complete final APEX report

B. Project Milestones and Endpoints

March 1998	Final draft of FY 97 results submitted to APEX Project Leader (D. Duffy).
September 1998	FY 98 Field work completed
March 1999	Final draft of FY 98 results submitted to APEX Project Leader(D. Duffy).
September 1999	FY 99 Field work completed
May 2000	First draft of Final Report FY95-99 to APEX Project Leader (D. Duffy).

C. Project Reports

See above Milestones

COORDINATION OF INTEGRATED RESEARCH EFFORT.

The FY 98 prey studies are fully coordinated and integrated with other components of the APEX seabird - forage fish project. The project is also closely integrated with a Minerals Management Service funded Biological Resources Division of U.S. Geological Survey study in Kachemak Bay and lower Cook Inlet. Forage fish data from the halibut stomachs will be compared with MMS-BRD trawl-hydro acoustics survey and seabird dietary data collected during other MMS and APEX studies in the same areas and times. Data will also be shared with a joint National Marine Fisheries Service-Alaska Dept. Of Fish and Game Barren Is. sea lion study. Specimens of forage fish will be sent to D. Roby for use in his energetics study (98163G). Roby will also receive data on prey species fed to chicks and specimens of prey for nutrient analysis. Piatt will also be sent specimens of fish for stable isotope analysis.

ENVIRONMENTAL COMPLIANCE

No permits are required for the study, and based on review of CEQ regulation 40 CFR 1500-1508, this project has been determined to be categorically exempt from the requirements of NEPA, in accordance with 40 CFR 1508.4.

PERSONNEL

A. Project Manager - G. Vernon Byrd

Vernon Byrd received a B.S. degree in wildlife management from the University of Georgia in 1968, did post-graduate studies in wildlife biology at the University of Alaska-Fairbanks in 1975, and completed a M.S. degree in wildlife resources management at the University of Idaho in 1989. His thesis, entitled "Seabirds in the Pribilof Islands, Alaska: Trends and monitoring methods", explored statistical procedures for analyzing kittiwake (Rissa spp.) and murre (Uria spp.) population data. Mr. Byrd has worked for the U.S. Fish and Wildlife Service for over 20 years, focusing on studies of marine birds in Alaska and Hawaii. His major interests center around monitoring long-term trends in seabird populations, including numbers of birds and reproductive performance at colonies. He has worked at murre colonies in the Aleutian Islands, the Bering and Chukchi seas, and western Gulf of Alaska. Mr. Byrd was a co-author of the final T/V Exxon Valdez oil spill damage assessment report for murres. Also, he was project manager of the 1993 and 1994 common murre restoration monitoring studies (Projects 93049 and 94039, respectively), and projects to remove predators from islands containing seabird colonies (Projects 94041 and 95041, in 1994 and 1995, respectively). Mr. Byrd has authored over 45 scientific papers and 50 U.S. Fish and Wildlife Service reports on field studies, and has made about 20 presentations on seabirds at scientific meetings. Mr. Byrd is the supervisory wildlife biologist at the Alaska Maritime National Wildlife Refuge, the premier seabird nesting area in the national public land system.

Selected Seabird Publications

Byrd, G.V., E.C. Murphy, G.W. Kaiser, A.J. Kondratyev, and Y.V. Shibaev. 1993. Status and ecology of offshore fish-feeding alcids (murres and puffins) in the North Pacific Ocean. Proceedings of "Symposium on the Status , Ecology, and Conservation of Marine Birds of the Temperate North Pacific". Canadian Wildlife Service, Ottawa.

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B. Project Leader - David G. Roseneau

David Roseneau received his B.S. degree in wildlife management and M.S. degree in biology from the University of Alaska - Fairbanks in 1967 and 1972, respectively. His thesis research was on the numbers and distribution of gyrfalcons, Falco rusticolus on the Seward Peninsula, Alaska. He joined the U.S. Fish and Wildlife Service in January 1993 and was project leader of common murre restoration monitoring Projects No. 93049 and 94039 in the Barren Islands during 1993 and 1994. Mr. Roseneau was also principal investigator of the APEX seabird studies pilot program in the Barren Islands in 1995 (Project 95163K). Prior to 1993, he was a consulting biologist for 20 years, and he has conducted and managed marine bird, raptor, and large mammal projects in Alaska and Canada for government agencies and private-sector clients. Mr. Roseneau has been involved in several large-scale murre (Uria spp.) population monitoring projects. During 1976-1983, as co-principal investigator of NOAA/OCSEAP Research Unit 460, he conducted monitoring studies of murres and black-legged kittiwakes (*Rissa tridactyla*) at capes Lisburne, Lewis, and Thompson in the Chukchi Sea, and St. Lawrence, St. Matthew, and Hall islands in the Bering Sea. He also studied auklets (*Aethia* spp.) at St. Lawrence and St. Matthew islands, and participated in murre and kittiwake projects at Bluff in Norton Sound. In 1984-1986, he participated in follow-up studies of murres and kittiwakes in the northeastern Chukchi Sea, and during 1987-1988, 1991-1992, and 1995 he helped conduct additional murre and kittiwake work at capes Lisburne and Thompson, and at Chamisso and Puffin islands. Mr. Roseneau is experienced in collecting and analyzing data on numbers, productivity, and food habits of seabirds; relating trends in numbers and productivity to changes in food webs and environmental parameters (e.g., air and sea temperatures, current patterns); and assessing potential impacts of petroleum exploration and development on nesting and foraging marine birds. He has broad knowledge of rock climbing techniques and has operated inflatable rafts and other outboard-powered boats in the Bering, Chukchi, and Beaufort seas and on various Alaskan rivers in excess of 2,800 hrs. Mr. Roseneau has also accrued several hundred additional hours operating time in small boats and larger, more powerful vessels (e.g. 25 ft, 300-400 hp HydroSports and Boston Whalers) in Kachemak Bay, Prince William Sound, and Kenai Peninsula and Barren Island waters. During his career, Mr. Roseneau has authored and co-authored over 70 reports and publications, including 23 on Alaskan seabirds.

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L
Historical Date Review

Synthesis and Analysis of Data Collected From Small-Mesh Trawl and Icthyoplankton Surveys in the Gulf of Alaska 1953-1996.

Project Number:	98163L
Restoration Category:	Research-Forage Species Assessment
Proposer:	Paul Anderson and John Piatt
Lead Trustee Agency:	DOI/NOAA
Cooperating Agencies:	ADFG, DOI(USGS), NOAA
Duration:	Four years
Cost FY 98:	$91,400
Cost FY 99:	$90,000
Cost FY 00:	$90,000
Cost FY 01:	$90,000
Geographic Area:	Prince William Sound, Kenai Peninsula, Lower Cook Inlet, Kodiak Island Group, and Alaska Peninsula to Unimak Pass. Entire spill affected area
Injured Resource:	Forage Species food base for a large variety of marine birds and mammals. Commercial Fisheries.

ABSTRACT

Large declines of apex predator populations (murres, kittiwakes, harbor seals, and Steller sea lion) have occurred in the Gulf of Alaska since the 1970s. This project encompasses a unique approach in understanding the dynamics of the forage species base in the Gulf of Alaska (GOA). This project will analyze the only known long-term data series that has shown, after preliminary analysis, that the GOA marine benthic and epi-benthic community has undergone dramatic changes during the past two decades. This project quantifies the spatial and temporal changes that have taken place and will ultimately test some hypothesis to determine the likely mechanisms that have driven these changes.

INTRODUCTION

In FY 96-97 the project continued refinement of the large small-mesh database for detailed analysis. Much of FY96 and FY97 was devoted to creating ARCINFO coverages of the existing geocoded data sets. These coverages were used to identify areas consistently sampled over long time periods. After delineating the area sampled over time, ARCINFO was then used to define these areas, the database was then modified with ADFG codes representing the sampled areas. Subsequent analysis was conducted for these defined areas without the need of mapping software. FY97 was the first year a preliminary analysis was conducted on the icthyplankton database for the Gulf of Alaska. The database was compiled and edited for errors and ARCINFO coverages were created to identify sampled locations on map backgrounds. These geocoded coverages were linked to size data collected from each sample. These data sets were converted to ARCVIEW format so subsequent analysis could take place in a PC work environment. The remainder of FY97 will largely be devoted to analysis of this dataset. In FY98 we will be designing the electronic data atlas as a major product, supplying the data needs for other researchers is an important project output. This part of the project will be completed and closed out in FY99. In FY96-97 three presentations and manuscripts were produced on project data. FY97-99 will be devoted to finishing the data analysis and additional manuscript preparation. FY98 will be the first year we request monitoring funds for the continuation of this valuable data series in the spill affected area. FY98 and on will continue this monitoring effort.

NEED FOR PROJECT

A. Statement of Problem

Since the late 1970's there has been a total reorganization of the marine ecosystem in the Gulf of Alaska (Piatt and Anderson 1996). Abruptly, the ecosystem transformed from crustacean dominated to a fish dominated regime in a period of about one year. In assessing the recovery of injured resources it is necessary to know what factors occurring naturally in the environment may be responsible for failure of some species to re-build or chronic low post-spill population levels. This project has found a link between pre-spill population declines and a Gulf of Alaska wide regime shift in the marine ecosystem. Assessment of the important food base will need to continue to properly judged the success or failure of injured species and commercial fisheries to recover subsequent to the oil spill.

B. Rationale

This project has been responsible for providing an important marine ecosystem index to judge the recovery of injured species and some commercial and subsistence fisheries activities. The index provided by the small-mesh data set gives researchers and managers the background they need to assess why population changes have occurred prior to the spill and what effect the relative abundance of the forage base may have on population recovery after the spill. The data from this project also help separate changes in commercial or subsistence resources were induced by the spill and those that can be explained by a Gulf of Alaska wide regime shift in the marine ecosystem.

We are in danger of loosing the continuity of the long-term small- mesh data set. Declines in commercially important shrimps have lessened the perceived need of resource agencies such as ours (NMFS and ADFG) to fund small-mesh trawl survey work. This study shows the value of a consistently collected data series in addressing some of the major concerns relating to food limitation on marine bird and mammal populations. Without support this data series will be increasingly under attack and probably reduced to a point where it will be of little use by future natural resource investigators in dealing with contemporary problems. Its important to point out that shifts in the components of the marine ecosystem can occur rapidly as presented in the annual report and enclosed manuscripts. By reducing survey frequency to once every three years (as is the situation now) the timing resolution of regime shifts is lost and correlations with bird and marine mammal populations will be degraded. In view of the above, we are requesting our first year of assessment funds for FY98 to augment agency survey frequency in the Kodiak Island, Shelikof Strait, and Kachemak Bay survey areas in an attempt to sustain the useability of this data series for the future. This is not a replacement of ADFG duties or authority, but rather augments what ADFG can reasonably survey given the resources available. This assessment funding will be used judiciously to survey important key areas where ongoing studies need continuous data on changes in the marine forage base. The assessment funding requested here only will allow a small but important effort, and will leverage agency assets such as survey gear, deck sampling equipment, and personnel.

C. Location

The project has been centered and most analysis activities conducted in Homer and Kodiak Alaska. Additional areas that are important in the project area are: Cordova, Kenai Peninsula, Barren Islands, Shelikof Strait and associated villages, Chignik, Akhiok, Old Harbor, Trinity Islands, Afognak, Lower Cook Inlet, Kachemak Bay, and Prince William Sound.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Community evolvement would help in identifying species changes that should be investigated in the formal database. These include a historical review of commercial fishery landings for major species to confirm the regime shift in marine species detected in scientific surveys. Observations and data gathering should concentrate on decline of spawning capelin runs, the decline of subsistence take on crustacean resources especially shrimp and crabs, and changes in marine bird and mammal populations. Further analysis of the available commercial fishery data will help identify changes in trophic level groups not sampled in the small-mesh surveys. Observations of the type outlined above would be helpful in verifying and validating results obtained from the survey databases.

PROJECT DESIGN

A. Objectives

The project's research and assessment objectives for FY98 and out years are outlined below:

1. Determine if and when changes in the forage base occurred in the Gulf of Alaska small-mesh survey database. What species were affected.

2. Investigate possible mechanisms for the observed changes in the species complex and develop and test hypothesis concerning these.

3. Investigate the early life history and dynamics of Pacific sand lance from Shelikof Strait icthyoplankton surveys 1972-96.

4. Design electronic format database server that can be Internet deployed to serve information to interested researchers and others.

5. Compile historic commercial fisheries catch information that provides information on other trophic groups that are not sampled by the surveys.

6. Assess forage species populations in key bays in the spill affected area during periods between triennial agency surveys.

B. Methods

Small-mesh Trawl Survey
See attached manuscripts to FY96 annual report

Icthyoplankton
Larval sand lance were collected from lower Cook Inlet to Unimak Pass with two types of sampling devices. The neuston layer was sampled using a "Sameoto sampler" (Sameoto and Jaroszyinski, 1969), with an opening of .3m by .5m and a mesh of 0.505mm. The water column from near-bottom to the surface was sampled using a MARMAP bongo sampler (Posgay and Marak, 1980) with 0.6m diameter opening and either 0.333 or 0.505mm mesh nets. Depths and position were recorded for each deployment of the sampling gear. Samples of sand lance and other planktonic species were preserved using 5% formalin-seawater solution buffered with either calcium carbonate or sodium tetraborate. Specimens were separated, counted, and up to 50 individuals of sand lance were measured to the nearest 0.1mm SL (Rugen, 1990).

C. Cooperating Agencies, Contract, and Other Agency Assistance

Overall coordination for this project is provide through the DOI and the Biological Resources Division (USGS). The ADFG is represented by both the Homer and Kodiak office staff, their cooperation is imperative since they contribute all fishery data statistics and have collected about one-half of the small-mesh trawl survey data. The NMFS in Kodiak is responsible for overseeing most of the analysis of the data and provides a UNIX workstation and software to assist in handling the large combined data sets. NMFS Kodiak was instrumental in designing the initial small-mesh trawl surveys and has collected about one-half of the total historic data set. Since there are differences in the temporal scale of sampling, combining the two sets gives the most complete picture of the changes to the marine ecosystem over a longer time span than if treated separately. Assessment planning in interim (2 out of 3) years will be a coordinated effort by all participants.

In FY98 ADFG Homer will be responsible for completing the addition of their portion of the data to the combined database. ADFG Homer will research the commercial catch data available and produce summaries used in the completion of project goals. ADFG Homer will also be evolved in any assessment charter and survey that is conducted in the Lower Cook Inlet area.

In FY98 ADFG Kodiak will assist in the cleanup of database issues and assist with the design criteria for the electronic database. ADFG Kodiak will be evolved any potential assessment effort and survey design.

NMFS Kodiak will continue overseeing data analysis, take lead role in manuscript preparation, coordinate forage species survey assessment (if funded), and database electronic design. A contract will be negotiated with a research associate (Ph.D. or equivalent) to assist in data analysis and manuscript preparation.

SCHEDULE

A. Measurable Project Tasks for FY98 (October 1, 1997 - September 30, 1999)

Oct 1 - November 31:	Prepare Presentation and Attend the 2nd International Pandalid Shrimp Symposium (tentative)
Oct 1 - September 30:	Analyze data from data sources
Jan 1 - Jul 31:	Outsource design of Electronic Database (PI supervise)
Jan 15 - 24:	Attend Annual Restoration Workshop
Feb 15 - Mar 31:	Prepare Annual Report and Attachments
Apr 1 - Jun31	Prepare Manuscripts for Publication
Jul 1 - Jul 30:	Contract and Award of Vessel Support for Limited Forage Assessment Survey
Aug 15 - Oct 30:	Conduct Assessment Survey During 15 day Period in this Time Window

B. Project Milestones and Endpoints

Presentation of project results at the 2nd International Pandalid Shrimp Symposium (tentatively planned for early FY98)

Publication of initial project results, in a major journal. During FY98

Completion of the electronic format project database design (FY98) and publishing to the Internet (FY98-99)

Publication of benthic community structure changes and hypothesis of mechanisms responsible for abrupt regime shifts

C. Completion Date

All portions of the research component for this project should be completed by the end of FY99 (September 30, 1999). Monitoring funding should continue until full recovery of all injured resources and services has occurred or agency funds are restored to continue annual small-mesh data collection in the spill-affected area.

PUBLICATIONS AND REPORTS

1. Pandalid Shrimp Declines in the Gulf of Alaska, A case of Forage Species Regime Shift, Paper for presentation and inclusion in the proceedings of the Second International Pandalid Shrimp Symposium.

2. Long-term Changes in the Gulf of Alaska Marine Ecosystem; Major journal article for Science or Nature.

3. Early life history and dynamics of Pacific Sand Lance in the Lower Cook Inlet and Shelikof Strait Region of Alaska. Journal Article for Fisheries Oceanography or Marine Ecology Progress Series.

4. Long-term Shifts in Benthic Commercial Fishery Species; A Case Study in the Gulf of Alaska -- Journal Article for Marine Ecology Progress Series.

PROFESSIONAL CONFERENCES

Anticipate attendance and presentation of project research at the Second International Pandalid Shrimp Symposium, being tentatively planned for late November 1997 in Halifax, Nova Scotia.

NORMAL AGENCY MANAGEMENT

This project coordinates and assists in acquisition of data bases from other agencies and defines procedures to aid in the quantification and analysis of spatio-temporal trends in abundances forage fishes and invertebrates. These activities are critical to on-going analyses and population assessment modeling for marine birds and mammals and for judging the effects of the EVOS on them. Without support for this project our ability to conduct and support analysis of this unique and standardized 25 year data series will be severely impaired. These analyses are essential for the understanding of how forage fish abundance may have affected the dynamics of marine birds and mammals. It is against this background of ecological change that effects of the EVOS must be objectively considered. This project combines the frame work for agencies to cooperate in solving problems together, with each contributing unique and necessary assets to solve these larger problems.

COORDINATION AND INTEGRATION

This study addresses a number of issues related to other components of the APEX project. Direct project coordination with Cook Inlet Seabird and Forage Fish Study , and Ecology and Demographics of Pacific Sandlance (Both projects under direction of Biological Resources Division (BRD) of U.S. Geological Survey (USGS)). Project database component for PWS has been provided to Tracey Gotthardt , a graduate student under Dr. Kathy Frost studying dietary changes in Harbor seals. In FY98 the project will attempt to test Dr. David Eslinger's (prof. University of Alaska, IMS) model on phytoplankton production and how it fits with the observed patterns of forage trophospecies year-class failure as detected in this study.

EXPLANATION OF CHANGES

This work has been lengthened and expanded as a result of the addition of icthyoplankton work that was added to the project in early FY97. As a result of this addition the research portion of the work is anticipated to end in FY99 instead of FY98 as originally proposed. This is the first year a request is being made to conduct monitoring as part of this project, this is not a new direction for this project. To make a reasonable assessment as to the recovery of injured resources a sound ecosystem survey background index will be needed. These funds only augment the regular agency spending for surveys which is funded every three years. We believe that it is imperative to request funding for sampling in the interim (2 year) periods. Funds are also needed to maintain the database as it continues to be collected. It is important to point out that only 22 small-mesh tows will be made in FY97, none in the spill affected area.

PRINCIPLE INVESTIGATORS

John F. Piatt, PhD., Research Biologist (GS-13)
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OTHER KEY PERSONNEL

Dr. James E. Blackburn, ADF&G Kodiak, is a database design expert and has worked extensively in fishery research in the Gulf of Alaska for over 20 years.

Dr. William Bechtol, ADF&G Homer, is fishery research biologist for the region covering Lower-Cook Inlet and the Kenai outer coast and Prince William Sound.

B. Alan Johnson, NMFS Kodiak, is staff senior biometrician at the Alaska Fisheries Science Center and has extensive experience in large data set analysis and statistical procedures.

LITERATURE CITED

See FY96 annual report for this project for a complete listing of cited literature.

COST ESTIMATE FOR CONDUCTING INTERIM YEAR ASSESSMENT OF FORAGE SPECIES FOR PROJECT 98163L

The plan below was estimated based on the ADF&G vessel Resolution, but it may not be available. It would be possible to charter a local vessel to do the work, but that will require a longer lead time to get the charter bid, etc. The preferred time for the survey is between about mid-August to mid-October.

Proposed Itinerary:

Marmot Bay	Uyak Bay
Chiniak Bay	Uganik Bay
Kiliuda Bay	Wide Bay
Two Headed Island	Chignik Bay
Alitak Bay	Kujulik Bay

Standard survey procedures will be employed. These typically produce eight tows per day, maximum with a production record of just over 4 per day including travel, weather delays, etc. In 1995 a survey of 21 days yielded 85 tows, and 19 days in 1992 yielded 76 tows, Both surveys in 1992 and 1995 covered the above areas in the 19 and 21 days used. The number of tows and the bays surveyed may be adjusted based on time available.

Acceptance of the funding is at the state Legislature's prerogative.

Estimated Costs of a Shrimp Survey

Vessel, Resolution		
23 days at $2750 per day includes 1 day loading, 1 day unloading, 21 days surveying and traveling ADF&G nets and equipment will be used.	$63,250	
Scientific Crew		
1 FB II	$ 6,969.11	
3 ea Technician 1 at $3,990.10	$11,970.30	
Note: Usually two technicians are used, but an additional person will allow more time to process fish. This includes three weekends at sea and standard sea duty pay.		
Subtotal		$82,189.41
State Overhead at 6%		$ 4,931.36
Grand Total		$87,120.77

M
Lower Cook Inlet

Numerical and Functional Response of Seabirds to Fluctuations in Forage Fish Density

Project Number:	96163 M
Restoration Category:	Research
Proposed By:	U.S. Geological Survey (PI- John F. Piatt)
Lead Trustee Agency:	DOI
Cooperating Agencies:	ADFG, USFWS
Duration:	4 years
Cost FY 98:	$267,700
Cost FY 99:	$267,700
Cost FY 00:	$180,000 (data analysis, reporting)
Cost FY 01:	$125,000 (data analysis, reporting)
Geographic Area:	Cook Inlet, Gulf of Alaska
Injured Resource:	Multiple resources

ABSTRACT

Cook Inlet Seabird and Forage Fish Studies (CISeaFFS) is a long-term study designed to measure the foraging (functional) and population (numerical) responses of six seabird species to fluctuating forage fish densities around three seabird colonies in lower Cook Inlet. This involves at-sea surveys for forage fish (hydroacoustics, trawling, seining) and seabirds (line transects), and some characterization of oceanography (AVHRR satellite imagery, CTD profiles, moored thermographs), while measuring aspects of seabird breeding biology (egg and chick production, chick growth, population trends) and foraging behavior (diets, feeding rates, foraging time) at adjacent colonies.

INTRODUCTION

Some seabird populations in the Gulf of Alaska have declined markedly during the past few decades (Hatch and Piatt 1995; Piatt and Anderson 1996). Whereas human impacts such as those from the *Exxon Valdez* oil spill can account for some proportion of these declines (Piatt et al. 1990c; Piatt and

Naslund 1995), natural changes in the abundance and species composition of forage fish stocks have also affected seabird populations (Decker et al. 1994; Piatt and Anderson 1996). Marine fish communities in the Gulf of Alaska changed dramatically during the past 20 years (Anderson et al. 1994). Coincident with cyclical fluctuations in sea-water temperatures, the abundance of small forage fish species such as capelin (*Mallotus villosus*) declined precipitously in the late 1970's while populations of large predatory fish such as walleye pollock (*Theragra chalcogramma*) and cod (*Gadus pacifica*) increased dramatically. Correspondingly, capelin virtually disappeared from seabird diets in the late 1970's, and were replaced by juvenile pollock and other species in the 1980's (Piatt and Anderson 1996). Seabirds and marine mammals exhibited several signs of food stress (population declines, reduced productivity, die-offs) throughout the 1980's and early 1990's (Merrick et al. 1987; Piatt and Anderson 1996). Similar trends in oceanography, seabird population biology and prey availability have been noted in the Bering Sea, although the cycle there appears to be offset by 4-5 years from events in the Gulf of Alaska (Decker et al. 1994, Springer 1992).

Factors that regulate seabird populations are poorly understood, but food supply is clearly important (Cairns 1992b). In many cases, anthropogenic impacts on seabird populations cannot be distinguished from the consequences of natural variability in food supplies (Piatt and Anderson 1996). Thus, 'management' of seabird populations remains an uncertain exercise. For example, how can we enhance recovery of seabird populations lost to the *Exxon Valdez* oil spill if food supplies in the Gulf of Alaska limit reproduction? Would commercial fishery closures reduce or increase food availability to seabirds? What are the minimum forage fish densities required to sustain seabirds, and how do we maintain those critical densities?

We are attempting to answer some of these questions by studying seabird and forage fish interactions in lower Cook Inlet. Upwelling of oceanic water at the entrance to Cook Inlet creates a productive marine ecosystem that supports about 2-3 million seabirds during summer. More seabirds breed here than in the entire northeast Gulf of Alaska (including Prince William Sound) and concentrations at sea (up to 90 kg/km^2) are among the highest in Alaska (Piatt 1994). For these reasons, the greatest damage to seabirds from the *Exxon Valdez* oil spill occurred in lower Cook Inlet (Piatt et al. 1990).

Pilot studies were initiated in 1995. The overall objective was to quantify and contrast seabird-forage fish relationships at three seabird colonies in lower Cook Inlet: Chisik Island, Gull Island (Kachemak Bay), and the Barren Islands. The abundance and species composition of forage fish schools around each colony were quantified with hydroacoustic surveys, mid-water trawls, and beach seines. At each colony, we measured breeding success, diet composition, and foraging effort of several seabird species including: common murres, black-legged kittiwakes, pigeon guillemots, pelagic cormorants, glaucous-winged gulls, tufted puffins and horned puffins. Preliminary analyses indicate that the types and quantities of forage fish available to seabirds at each colony differed significantly, and this influenced breeding success of seabirds at each colony.

In 1996, this research program was refined and expanded where appropriate. For example, we increased hydroacoustic sampling of nearshore habitats, tried some new fishing techniques (pair trawls, cast-nets), increased study effort on some species of seabirds (pigeon guillemots, puffins, cormorants) and forage fish (sandlance), and increased coordination of seabird studies at the three colonies (for example, we synchronized feeding watches and census counts with respect to breeding phenology). The basic components of this study have not changed, however, and we will measure the same fundamental parameters of forage fish and seabird biology for the duration of the 10-year study (1995-2005).

NEED FOR THE PROJECT

A. Statement of the Problem

Research has provided few clear examples of how aspects of seabird population biology or feeding ecology vary with changes in prey availability (Hunt et al. 1991). Consequently, it has been difficult to assess the degree to which the *Exxon Valdez* oil spill affected seabirds because natural changes in forage fish stocks may have also contributed to declines and reduced productivity of seabird populations. It is currently impossible to predict whether seabird populations will (or can) recover from losses incurred from the spill. The basic problem is that known ecological relationships between seabirds and forage fish are largely descriptive-- few or no quantitative data exist to model functional relationships in the spill area.

B. Rationale

Functional relationships between seabird predators and their prey are poorly known because the vast majority of seabird research has been conducted on colonies without benefit of concurrent studies at sea on prey availability and seabird foraging behavior (Hunt et al. 1991). The response of seabirds to environmental change can vary widely among species, and is influenced by a host of physical and biological factors. Differential adaptations of seabirds for exploiting plankton and fish, widely-varying foraging abilities and breeding strategies, and complex relationships between oceanography and prey dispersion, abundance, and behavior all serve to complicate our interpretation of changes in seabird population biology. Therefore, in order to assess the potential for recovery of seabirds affected by the *Exxon Valdez* oil spill, a concurrent, multi-disciplinary study of oceanography, forage fish, and seabirds is required.

C. Summary of Major Hypotheses and Objectives

We are attempting to define relationships between seabird population dynamics and food supply. For any species, this relationship can be characterized by quantifying components of the "numerical (population) response" and "functional (foraging) response" of seabirds to variations in prey density (Holling 1959; Murdoch and Oaten 1975; Piatt 1987). The "numerical response" includes components of population biology such as adult survivorship, clutch size, and reproductive success. The "functional response" includes components of foraging such as feeding rate, time spent foraging, and foraging range.

Therefore, the overall objective of this study is to quantify components of seabird reproductive and foraging biology at colonies while simultaneously measuring the distribution, density and species composition of forage fish schools in adjacent waters. It has been hypothesized (Table 1) that these components are non-linear functions of prey density and sensitive to different thresholds of prey density

(Piatt 1987, Cairns 1987, 1992a,b). Data collected in this study will allow us to characterize response curves and thresholds for several different seabird species and then go on to test other hypotheses about seabird-forage fish relationships (Table 2). For example, is seabird recovery from the *Exxon Valdez* oil spill limited by current forage fish densities? Do different seabird species have different thresholds to prey density? Can some species adjust foraging effort to compensate for fluctuating prey densities? Can seabirds compensate for differences in prey quality? Do weather and oceanographic conditions influence prey distribution and therefore seabird foraging success? None of these questions (hypotheses) can be addressed without a clear understanding of the underlying functional and numerical responses.

D. Completion Date

Marine ecosystems can vary markedly over time and between geographic areas, so our approach of studying three different colony areas simultaneously during several breeding seasons is an appropriate and cost-effective research strategy. We anticipate that it will take a minimum of five summers (FY 1995-1999) of field research to quantify the functional and numerical responses of seabirds to fluctuations in forage fish density. It will require a minimum of two additional years (FY 2000-2001) to analyze data and publish the findings of the study in scientific journals.

COMMUNITY INVOLVEMENT

Gull Island in Kachemak Bay is owned by the Seldovia Native Association (SNA). Limited subsistence use occurs during summer, with occasional egging and harvesting of juvenile birds (Fred Elvsaas, pers. comm.). It is also a major tourist attraction for visitors to Homer. Permission to work on and around the island was obtained in 1995 under the provision that annual reports of findings be made available to the SNA. In 1997, we plan to visit the SNA in Seldovia to discuss our work, and present an overview of our research in lower Cook Inlet at the next Cook Inlet Keepers Symposium in Homer (June 1). We have informed local tour boat operators about our activities so that our presence at the island can be explained to visiting tourists. Chisik Island and the Barren Islands are managed by the Alaska Maritime National Wildlife Refuge. We have employed tourist charter vessels from Homer to support field camps at these colonies. Chisik Island supports a small, seasonal fishing community and we have chartered small vessels for research there, and informed most of the summer residents about the purpose of our activities.

FY 98 BUDGET

<u>Summary EVOS Budget FY 1998</u>:

	$1000's
Personnel	51.8
Travel	0.0
Contractual	130.0
Commodities	69.0
Equipment	0.0

Subtotal	250.8
Gen. Admin.	16.9
Total	267.7

Funding for the project is anticipated from three major sources: EVOS Trustees ($268 K), Minerals Management Service ($150 K), and U.S. Geological Survey ($120 K). A detailed budget for EVOS funds is attached. The following table shows how other funds will be allocated.

Detailed MMS and BRD BUDGET FY 1998:

	$1000's
PERSONNEL	
Piatt, GS-13 10 months	66.1
Drew, GS-11 8 months	40.2
van Pelt, GS-7 10 months	26.4
Abookire, GS-7 12 months	31.7
Speckman, GS-7 10 months	26.4
Snegden, WG-4 9 months (+OT)	28.0
Biotech (GS-5) 3X4 months	23.8
Subtotal	242.6
TRAVEL	
Volunteers (6) per diem	7.2
Volunteers (6) RT airfare Anchorage	5.4
Biologists (7) per diem	3.2
RT airfare ANC-HOM (15)	2.7
Subtotal	18.5
COMMODITIES & EQUIPMENT	
Satellite imagery	3.0
Computers/supplies	2.0
Digital bathythermograph (4)	0.9
Misc. scientific equipment	2.5
Communications	0.5
Subtotal	8.9
TOTAL MMS and NBS BUDGET	270.0

PROJECT DESIGN

A. Background

Concurrent or coordinated studies of seabird breeding biology, feeding ecology, prey abundance and oceanography are remarkably few (e.g., Safina and Burger 1985, 1988; Monaghan et al. 1989, 1994;

Hamer et al. 1991, 1994; Uttley et al. 1994). Following a collapse of capelin stocks and concern (Brown and Nettleship 1984) about the possible consequences for Atlantic Puffins (Fratercula arctica), detailed studies of the relationships between oceanography, capelin (Mallotus villosus), cod (Gadus morhua), common murres (Uria aalge), Atlantic puffins (Fratercula arctica), and baleen whales were conducted in eastern Newfoundland in 1981-1985 (Montevecchi and Piatt 1984, 1987; Piatt and Nettleship 1985; Burger and Simpson 1986; Schneider and Piatt 1986; Cairns et al. 1987, 1990; Piatt 1987, 1990; Schneider and Methven 1988; Methven and Piatt 1989, 1991; Piatt et al. 1989; Schneider 1989; Burger and Piatt 1990; Schneider et al. 1990; Nettleship 1991; Piatt and Methven 1992).

Results of these studies provide an empirical basis for hypotheses about relationships between seabirds and their prey in a variable marine environment (Table 1). Relationships between population biology and feeding ecology can be quantified within an established framework of predation theory (Holling 1959; Murdoch and Oaten 1975; Piatt 1987). Adult survival and reproductive success (the "numerical response") of higher vertebrates depends largely on the rate at which food (energy) can be extracted from the environment (the "functional response").

For individual seabirds, the functional response incorporates all parameters relating to the capture of prey (Table 1). Studies have demonstrated or hypothesized that these parameters are non-linear functions of prey density that operate over time-scales of hours to days, and spatial scales of meters to kilometers. For example, foraging time declines with increasing prey density (Cairns et al. 1987; Monaghan et al. 1989, 1994) allowing more free time for other activities (Burger and Piatt 1990). Similarly, as prey densities increase, foraging ranges may contract by 10's of km (Cairns et al. 1990; Monaghan et al. 1994) resulting in a considerable reduction in foraging energy expenditure (Cairns et al. 1987) and greater prey harvests in the vicinity of colonies (Cairns et al. 1990).

Numerical response parameters for seabirds (Table 1) are, in the absence of stochastic mortality events (e.g., oil mortality), a direct function of food availability over longer time scales (months and years) and larger spatial scales (100's to 1000's of kilometers). Thus, population change in seabirds reflects day-to-day foraging success integrated over reproductive time-periods and the area over which populations are distributed (Cairns 1987, 1992a,b; Piatt 1987).

The numerical and functional responses of individual species to changes in prey density are almost always non-linear, frequently sigmoidal, and species-specific with regard to absolute density thresholds (Holling 1959; Murdoch and Oaten 1972; Piatt 1990; Piatt and Methven 1991). In other words, some seabird species may prosper at low levels of prey density while others require much higher densities (Piatt 1987, 1990). Cairns (1987) further hypothesized that components of the numerical and functional response in individual species of seabirds are sensitive to different levels (thresholds) of prey density. For example, adult survivorship (Fig. 1) is probably quite high over a wide range of medium to high prey densities, but at some low, critical level, adult survival diminishes rapidly. In contrast, when seabirds are constrained to forage locally during the breeding season and food demands are high (for both adults and chicks), then moderate to high prey densities are required to maintain high breeding success (Fig. 1).

Some species may be able to buffer against variation in their numerical and functional response by adjusting their foraging effort as prey densities fluctuate (Piatt 1987, 1990; Burger and Piatt 1990; Uttley et al. 1994; Monaghan et al. 1994). Other species may have little buffering capacity because they are pushed to their limits even under normal circumstances (Goudie and Piatt 1991; Hamer et al. 1994). Thus, in some species (e.g., murres), chick feeding rates or breeding success may not be affected over a wide range of prey densities because adults simply spend more time foraging to compensate for the change in prey density. Components of numerical and functional responses which may be buffered (Table 1) are therefore less sensitive indicators of prey fluctuations (Burger and Piatt 1990).

Numerical and functional responses are scale-dependent, and may be evident only when examined over appropriate temporal or spatial scales (Schneider and Piatt 1986; Piatt 1987, 1990). Weather, wind, and oceanographic processes profoundly influence the biology and distribution of prey species (Schneider and Methven 1988; Methven and Piatt 1991), and may largely determine the temporal and spatial scales at which seabird foraging occurs (Schneider 1989). Although physical processes can influence the density and availability of prey to seabirds, they should not change the basic direction and form of numerical and functional responses (Table 1), and probably have minimal effects on thresholds-- which are largely a species-specific function of seabird body size and behavior (Piatt 1987, 1990; Goudie and Piatt 1991).

The challenge is to measure the form and scale of seabird responses to prey fluctuations in light of variability in the marine environment. Quantifying responses of higher vertebrates in the field can be difficult because of logistical difficulties in measuring key parameters (Goss-Custard 1970), and the lack of power to manipulate predator and prey densities over the full range of possibilities (Piatt 1990). For seabirds, it requires the coordination of studies on breeding biology and behavior at colonies, and studies of seabird and prey dispersion at sea in relation to local oceanography.

B. Objectives

1) To describe and quantify the numerical and functional responses of seabirds (Table 1) to seasonal and annual fluctuations in local prey density at three colonies in lower Cook Inlet.

2) To describe spatial distributions of seabirds and prey, and measure the absolute densities of some prey schools, around three seabird colonies in lower Cook Inlet.

3) To test a number of hypotheses (Table 2) about how responses of different seabird species vary with regard to prey characteristics and oceanographic conditions.

4) To gather baseline data for lower Cook Inlet on: i) seabird populations, breeding biology, diets, and distribution; ii) prey distribution, relative abundance, and composition; and, iii) basic oceanographic parameters.

C. Methods

Measuring Responses: A variety of techniques can be used to measure the numerical and functional responses of seabirds to prey density (Table 1), and all have been field-tested or refined in previous studies. The basic elements of the study require:

1) Hydroacoustic and fishery (trawl, gill-net, trap) sampling of an appropriate area around a colony study site (e.g., Piatt 1987, 1994; Piatt et al. 1990a; Hunt et al. 1993). Because potential foraging area increases geometrically with distance from the colony, the areal extent of surveys must balance the need for sampling of important foraging areas within the range of birds, with practical limitations of time and resources. Fish catches are needed to groundtruth hydroacoustic surveys, and to assess species and age-class composition of prey schools (Piatt 1987; Schneider and Methven 1988).

2) Concurrent measures of physical parameters such as wind speed, sea state, sea surface temperature and salinity, and salinity-temperature profiles of the water column (e.g., Schneider and Methven 1988; Piatt et al. 1990a; Hunt et al. 1993).

3) Measuring components of the numerical response (Table 1). Most of these parameters can be easily measured at the colony by direct observation or measurement (e.g., Gaston et al. 1983; Harris and Wanless 1988; Wanless et al. 1982). Use of remote surveillence equipment can be helpful for measuring some parameters-- reducing disturbance and increasing the intensity of observations (e.g., Piatt et al. 1990b). Estimating survival is a more time-consuming activity. It requires banding and re-sighting of adults in subsequent years (Sydeman 1993; Hatch et al. 1994).

4) Measuring components of the functional response (Table 1). Diet components require collection of adult and chick prey items, at colonies and at sea (e.g., Piatt 1987; Burger and Piatt 1990). Study of aggregation behavior require simultaneous surveys of seabird and prey dispersion at sea (Piatt 1990, 1994; Piatt et al. 1990a). Aspects of seabird foraging behavior (range, dive times and depths, activity budgets, chick feeding rates) can be studied by a combination of observations at colonies and the use of remote sensing equipment-- in particular radio telemetry (e.g., Wanless et al. 1988, 1991; Monaghan et al. 1994; Uttley et al. 1994), time-depth recorders (TDR's; Croll et al. 1992; Burger et al. 1993), and activity budget recorders (Cairns et al. 1987, 1990).

As a practical matter, it takes a minimum of one year to obtain a numerical response data point (e.g., breeding success vs prey density) from one colony. However, many functional response parameters can be measured against prey density on a daily basis, and so multiple data points can be obtained within a breeding season. Response curves cannot be characterized unless an adequate number of data points are obtained both above and below threshold values (Hassell and May 1974). For example, one might measure murre breeding success and local prey density over 15-20 years, but if murres always had high breeding success (because seasonal prey densities never fell below threshold levels), then one could not properly characterize a numerical response curve for murres nor determine the threshold prey density required for successful breeding (Fig. 2). For this reason, it would take a minimum of about 15-20 years, and perhaps much longer, to assess the threshold prey densities required to support seabirds at a single colony site (Table 1, Fig. 2). In contrast, it should only require a few years to charcterize functional response thresholds to varying prey density.

Study Design: The approach used in this study will be to quantify the numerical and functional responses of seabirds at spatial scales ranging from fine (m to km, Gull Island in Kachemak Bay) to moderate (1-100's km, lower Cook Inlet). Similarly, and where possible, variability in response parameters will be measured at small (daily, seasonal) and moderate (annual) temporal scales. At fine and moderate spatial scales, six species of seabirds will be studied simultaneously at three different colonies in lower Cook Inlet. Species to be studied include two surface-feeding seabirds (kittiwake and glaucous-winged gull), two pelagic-diving seabirds (common murre and puffin), and two benthic-diving seabirds (cormorant and guillemot). Some of these species forage mostly near shore (<5 km) whereas others feed more offshore (± 60 km; Piatt 1994).

Studies will be carried at Gull, Chisik and Barren islands in lower Cook Inlet (Fig. 3). Gull and Chisik islands provide an excellent contrast for studies of numerical and functional responses because they: i) have a similar suite of breeding species; ii) have markedly different population dynamics (Slater et al. 1994); and, iii) differ markedly in their local oceanographic regimes. Whereas Gull Island seabird populations have increased by 40-80% over the last decade (Fig. 4), Chisik Island populations have declined by similar magnitudes during the same time period. Breeding success of kittiwakes at Gull Island has been consistently high during the past decade (1983-1994), whereas breeding success of kittiwakes at Chisik Island, and indeed, throughout the Gulf of Alaska (GOA), has been very low during the same period. Kittiwakes have failed at Chisik in almost every year (n=10) of study since 1970. The Barren Islands have not been studied as well, but they share a similar suite of species and breeding success has varied between poor and excellent during the past 20 years (Manuwal 1980; Boersma et al. 1993; Roseneau et al. 1994).

The Alaska Coastal Current enters Cook Inlet around the Barren Islands (Fig. 5), leading to intense upwelling of cold, nutrient-rich waters onto shallow shelf areas of southeast Cook Inlet (Piatt 1994). This apparently enhances fish production on the shelves, which in turn supports high densities of coastal and shelf species of seabirds around the Barren Islands and in Kachemak Bay. In contrast, warm southward-flowing waters on the west side of Cook Inlet support lower densities of seabirds (Agler et al., unpubl. data), and presumably lower densities of forage fish species. During the course of this study, oceanographic features will be characterized by taking temperature-salinity profiles of the water column and sea surface, and from AVHRR satellite imagery.

The distribution and abundance of prey species will be measured hydroacoustically (using a BIOSONICS DT4000 digital echosounder) and with trawls (bottom, midwater) over an area extending at least 60 km away from the colonies and including all of lower Cook Inlet (Fig. 3). This is an expansion of the area studied in 1995, and is made possible by using the USFWS Research Vessel "Tiglax", which will be available for this work from July 14-26 in 1996. Trawling with be conducted from a different vessel (ADF&G "Pandalus") during the time that hydroacoustic surveys are conducted from the "Tiglax". Shoreline habitat (<100 m from shore) within the core study areas (Fig. 3) will also be hydroacoustically surveyed in a small vessel (11 m) at the same time. To examine variability at fine temporal and spatial scales, transects will be conducted around Gull Island repeatedly during the breeding season. A subset of transects from the large-scale and fine-scale surveys will be randomly selected to extrapolate total abundance of prey and seabirds within foraging range of each colony. Prey specimens collected from trawls and seabird chicks will be examined to assess species composition, sex-ratios, body condition, and energetic content. In addition to trawling, we will sample nearshore fish schools using beach seines, a Kodiak pair-trawl, gill-nets and cast-nets.

It would be desirable to measure as many response parameters (Table 1) as possible at Gull, Chisik and Barren islands. Based on our experience in 1995, efforts will concentrate on measuring those parameters that are most important and logistically feasible. For the numerical response, basic data will be gathered (where possible) on clutch size, brood size, hatching success, and/or fledging success to obtain some measure of overall breeding success for all six seabird species. Chick growth rates and fledging weights will be measured for a few species (e.g., kittiwakes, murres, puffins). To obtain these data, field camps will be established on Chisk and Barren islands, and Gull Island will be visited frequently by boat.

To measure functional response parameters, we will focus our efforts on Gull and Chisik islands and coordinate with the AMNWR to collect similar data at the Barren Islands. Seasonal variability in activity budgets and chick feeding rates will be assessed through a combination of direct observations at the colonies (blind watches), use of video cameras, and a pilot study using radio telemetry to monitor colony attendance and foraging activity (e.g., Wanless et al. 1988, 1991; Monaghan et al. 1994; Uttley et al. 1994). Aggregation behavior and foraging ranges will be assessed from the pelagic surveys and radio telemetry. Diet information will be obtained by collecting adults at sea and chick meals at the colonies. Only 15 adults of the common species (murres, kittiwakes, puffins; populations greater than 10,000's in study area) will be collected at each colony, under Federal and State collecting permits. Traditional dietary analyses will be supplemented with studies using stable isotope ratio analyses (Hobson et al. 1994). Whole prey obtained from seabirds and by net-sampling will be analyzed for proximate lipid content (Montevecchi and Piatt 1984).

In addition to the above, field work in 1998 will include studies on Pigeon Guillemots in Kachemak Bay. Guillemots breed along the south shore of Kachemak Bay in about 20 different areas, but are concentrated in 4 sites. As with kittiwakes and murre, we will measure breeding parameters (hatching, fledging, chick growth) and feeding behavior (meal composition, delivery rates), and census populations, using methods previously established by Prichard (1997) and Roby et al. (1996) in Kachemak Bay and Hayes (1995) in Prince William Sound.

Hypothesis Testing: Data gathered over many years on numerical and functional responses of seabirds to variations in prey density (Table 1) can be used to test a variety of hypotheses (Table 2) about how seabirds respond to changes in their marine environment.

At the largest scales of study, we wish to know whether long-term changes in forage fish abundance are due to changes in marine climate (hypothesis 1; Anderson et al. 1994), and whether these changes are responsible for seabird population declines (hypothesis 2; Piatt and Anderson 1996). As oceanographic conditions may cycle over periods of 18 years (Royer 1993; Appendix 1), it would probably take at least

1-2 cycles to assess relationships between oceanography, forage fish, and seabird population changes. However, some historical data for the past 20 years are available already (Piatt and Anderson 1996), and analysis of more historical data might be adequate to test hypothesis 1.

We can test hypothesis 3 (Piatt and Anderson 1996) in the absence of historical information if we establish present-day forage fish densities and measure numerical and functional responses to prey fluctuations around colonies impacted by the Exxon Valdez oil spill. As described above, this might require 15-20 years of study at any one colony. However, this study is designed to measure and contrast the functional and numerical responses of coexisting seabird species at thriving and failing colonies. This greatly increases the probability of obtaining sufficient data to characterize responses over a range of high and low values, and decreases the time needed to do so from 15-20 years to perhaps 5-10 years (Table 2).

Hypotheses (3-5) about the exact form of numerical and functional responses (Cairns 1987), differences between species in their responses (Goudie and Piatt 1991), and variability in responses (Piatt and Anderson 1996) can all be tested within the course of the proposed study. Similarly, with concurrent studies of oceanography, it should be possible to also test hypotheses (7-11) about how weather and oceanographic conditions influence prey density and distribution in the water column, and ultimately seabird foraging success (e.g., Schneider and Methven 1988; Methven and Piatt 1991; Hatch et al. 1993).

The remaining hypotheses can be tested by special studies. Prey species will be collected from trawls and chick meals, and analyzed for proximate composition (Montevecchi and Piatt 1984, 1987) to determine if they differ significantly in quality (hypothesis 12). Such analyses have already been completed for 10 forage fish species from the Gulf of Alaska (van Pelt et al., submitted). Effects of differing prey quality on chick growth, foraging effort, and breeding success (hypotheses 13-15) require directed studies at colonies. Such a study was initiated in 1996 at Kachemak Bay (Romano, APEX project 96163 N) and will continue in 1997. Finally, the hypothesis (16) that different forage fish have different schooling characteristics can be tested by detailed hydroacoustic and trawl surveys of forage fish in Kachemak Bay. Whether prey schooling characteristics affect prey capture rates (hypothesis 17) could perhaps be determined in a laboratory or aquarium study. Such a study is not currently planned as part of this program.

D. Contracts and Other Agency Assistance

An Interagency Agreement as been established with the Alaska Department of Fish and Game, and 30K will be transferred in 1998 to charter the R/V "Pandalus", a 20 m research vessel based in Homer. As in 1995/96, the charter provides a vessel with mid-water trawl capabilities, accomodations for 4 researchers, a crew of 3 including Captain, deckhand and cook, and food while at sea. This vessel will be used to trawl for fish schools located on hydroacoustic surveys in June-August.

A Research Work Order has been established with the University of Washington. In 1998, we will transfer 100K which will be used to support a post-doctoral student (Alexander Kitaisky), working under supervision of Dr. John Wingfield, to be involved with field work and studies of food stress in seabirds. We plan to continue collaboration with Wingfield and Kitaisky for the duration of this project (1997-1999). This research work order is also planned to support a Ph.D. student (Suzann Speckman) in studies on hydroacoustics (abundance, distribution, density of different fish species), and an M.Sc. student (Stephani Zador) in studies of murre foraging behavior in relation to fluctuations in prey abundance.

E. Location

As noted above, research will be based out of the Kasitina Bay Research Lab in Kachemak Bay. Research will be conducted at and around Gull Island in Kachemak Bay, Chisik Island in western Cook Inlet, and the Barren Islands at the mouth of Cook Inlet. Communities that may have an interest in results of the study include Anchor Point, Homer, Seldovia, English Bay, Port Graham, and Kodiak.

SCHEDULE

A. Measurable Project Tasks for FY 98

January-April:	Preparations for field work, equipment acquisition, hiring personnel, establish contracts and work orders
May:	Initiate seabird and hydroacoustic surveys in Kachemak Bay. Trawl sampling in mid-May. Set up field camps and/or study plots and gather data on seabird populations and productivity on Chisik, Gull, and Barren Islands.
June:	Continue pelagic surveys, and colony observations. Trawling in Kachemak Bay on mid-June. Test other fishing methods (pair-trawl, gill-nets, etc.). Colony censusing and plot monitoring.
July:	Continue pelagic surveys, and colony observations. Initiate pilot studies using radio telemetry. Trawling and hydroacoustic surveys in lower Cook Inlet, in July using M/V "Tiglax" and R/V "Pandalus". Initiate colony observations on chick feeding activity and adult attendance.
August:	Continue pelagic surveys, colony observations, telemetry studies, feeding rate and attendance observations, and fish sampling.
September:	Field work ends in mid- September. Field camps removed

from Chisik and Barren Islands. Hydroacoustic surveys and nearshore fish sampling continue to end of September.

October-April 97: Data analysis and compilation of results.

February-March: Preparations for FY 99 research.

February 1997: Annual Report on FY 98 research.

April 1997: Initiate field work for 1999.

B. Project Milestones and Endpoints

The entire project revolves around our ability to accomplish objective 1: To describe and quantify the numerical and functional responses of seabirds to seasonal and annual fluctuations in local prey density at three colonies in lower Cook Inlet. Objective 3 will require at least three years of work before attempting to summarize conclusions. Objectives 2 and 4 will necessarily have been accomplished if objective 1 is achieved. At a minimum, to do this requires that in each year of the project we have:

1) Obtained quantitative measures of clutch size, brood size, hatching success, fledging success, or overall breeding success for each of six seabird species breeding at the three study colonies.

2) Obtained quantitative estimates of relative acoustic biomass of forage fish within foraging range of the three study colonies.

3) Obtained quantitative measures of fish school composition and absolute estimates of identified forage fish school densities in each study area.

4) Obtained quantitative estimates of seabird diet composition, chick feeding rates, adult foraging effort, and adult foraging dispersion at each of the three study areas.

With these minimum data collected in each year, it should be possible by the year 1999 to plot numerical and functional response parameters against acoustic estimates of prey density to resolve the characteristics (shape, threshold) of seabird reponses to varying prey density.

C. Project Reports

February 15, 1998: Annual Report and Summary of work accomplished in summer 1997, and preliminary findings.

March 15, 1998: Interim Report to summarize research findings from work in summers, 1995-1997. To include more extensive analyses of results and conclusions, especially from 1995-1996 work.

February 15, 1999: Annual Report and Summary of work accomplished in summer 1998, and preliminary findings.

February 15, 2000: Annual Report and Summary of work accomplished in summer 1999, and preliminary findings.

April 15, 2001: Draft Final Report of field research, 1996-1999.

September 1, 2001: Final Report.

In addition to the above, results will be published opportunistically in conference proceedings and scientific journals as analysis and synthesis take place.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This long-term study plan addresses a number of research issues related to management and conservation of seabirds in Alaska as addressed by the U.S. Fish and Wildlife Service (USFWS) 'Seabird Management Plan' (USFWS Region 7, Migratory Bird Management). The proposed work will complement and be coordinated with: i) long-term studies conducted by the Alaska Maritime National Wildlife Refuge (AMNWR, USFWS Region 7), which includes annual monitoring of seabird productivity at 9 major seabird colonies throughout Alaska; ii) research being conducted by the National Marine Mammal Laboratory (Seattle) on forage fish abundance and composition around Stellar sea lion rookeries in Alaska; iii) comparable studies (APEX) of seabird-forage fish interactions being supported by the *Exxon Valdez* Oil Spill Trustees in Prince William Sound; iv) ongoing studies of seabird populations in areas of oil and gas development conducted by the Minerals Management Service (MMS) in Alaska and the U.S. Geological Survey (BRD); and, v) ongoing studies of marine fish and oceanography conducted by the University of Alaska, Fairbanks out of the Kasitina Bay Marine Lab in Kachemak Bay.

In FY 98, additional funding from Minerals Management Service is anticipated to equal $150,000 (budget pending). Base funds from BRD to support the principal investigator in FY 98 are anticipated to equal $120,000 (budget pending), and most of this will be directed to the Cook Inlet study. Logistic support from the AMNWR in FY 98, including use of a Boston Whaler, zodiacs, vehicles, etc., is valued at approximately $30,000.

ENVIRONMENTAL COMPLIANCE

Permits for fish collections are required from the State of Alaska (ADF&G). Permits for collection of seabirds are required from the U.S. Fish and Wildlife Service and the State of Alaska (ADF&G). No other permits or environmental evaluations are required to carry out the proposed research.

PERSONNEL

Project Leader- Dr. John F. Piatt, Research Biologist (GS-13) with the Alaska Science Center, Biological Resources Division, USGS, in Anchorage. Obtained a Ph.D. in Marine Biology from Memorial University of Newfoundland in 1987 (dissertation on seabird-forage fish interactions). Since 1987, studied seabirds at colonies and at sea in Gulf of Alaska, Aleutians, Bering and Chukchi seas. Author on 45 peer-reviewed scientific publications about seabirds, fish, marine mammals, and effects of oil pollution on marine birds. Other BRD staff are listed in the budget.

Post-doctoral Fellow- Dr. Alexander Kitaisky, University of Washington. Masters research in the Sea of Okhotsk on seabird feeding ecology, chick growth and physiology. Ph.D. with Dr. George Hunt, Jr., on comparative ecology and physiology of puffins and auklets in the Sea of Okhotsk and Gulf of Alaska.

Cooperators: Following are anticipated collaborations for field and laboratory research in 1998 to accomplish goals for EVOS Trustee and MMS funded research in lower Cook Inlet.

Vernon Byrd, Leslie Slater, Dave Roseneau, Art Kettle (Alaska Maritime National Wildlife Refuge, Homer). Including financial and logistic support for colony work in lower Cook Inlet and for research cruises on the M/V Tiglax.

Paul Desjardins, James Brady (Alaska Department of Fish and Game, Homer and Anchorage). Including boat charter and logistic support for trawl sampling with the M/V Pandalus.

Richard Merrick (National Marine Mammal Lab, Seattle). Collaboration on hydroacoustic and trawl data collection around Barren islands, stable isotope studies of food-webs.

Marc Romano, Dan Roby (Cooperative Research Unit, Oregon State University). Graduate student research on effects of diet quality of kittiwake and puffin chick growth.

Keith Hobson (Canadian Wildlife Service, Saskatoon). Stable isotope analyses of seabirds and prey items, assistance in the field with sample collections.

George Rose (Memorial University of Newfoundland, St. John's, Newfoundland). Laboratory support and consultation for analysis of hydroacoustic data.

Brenda Norcross (Institute of Marine Science, UAF). Trawl collections and identification of forage fish around Barren islands and in Kachemak Bay.

signed: John Piatt

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Table 1. Characteristics and measurement of seabird numerical and functional response parameters.

Measurable Parameters	Hypothesized Relationship to Prey Density				Measurement Time		Methods
	Direction	Form	Threshold	Buffer	Parameter	Response	
Numerical Response							
Adult survivorship	positive	-exponential	low	no	2 year	15-20 years	Banding/re-sighting
Juvenile survivorship	positive	-exponential	moderate	no	2-5 year	15-20 years	Banding/re-sighting
Clutch size	positive	-exponential	moderate	maybe	1 year	15-20 years	Visual observations (VO)
Brood size	positive	-exponential	moderate	maybe	1 year	15-20 years	VO, Remote camera observation
Hatching success	positive	sigmoidal	moderate	yes	1 year	15-20 years	Visual observation
Fledging success	positive	sigmoidal	moderate	yes	1 year	15-20 years	VO, Remote camera observation
Breeding success	positive	sigmoidal	moderate	yes	1 year	15-20 years	VO, Remote camera observation
Chick growth rate	positive	sigmoidal	moderate	yes	1 year	15-20 years	Direct measurement
Chick fledging weight	positive	sigmoidal	moderate	yes	1 year	15-20 years	Direct measurement
Functional Response							
Adult foraging time activity	negative	logarithmic	low	no	days	3-5 years	VO, Radio telemetry, TDR's
Adult free time activity	positive	-exponential	moderate	no	days	3-5 years	VO, Radio telemetry
Adult meal size	positive	sigmoidal	moderate	yes	days	3-5 years	Adult collections
Adult body mass	positive	-exponential	low	no	days	3-5 years	Adult collection/capture
Dive time, frequency, depth	negative	logarithmic	moderate	no	days	1-2 years	TDR's, Radio telemetry
Prey capture rate	positive	-exponential	moderate	yes	hours	1-2 years	Aquarium observations
Aggregative response (tracking)	positive	sigmoidal	moderate	no	hours	1-2 years	At-sea bird/hydroacoustic surveys
Aggregation index (group size)	positive	-exponential	low	no	hours	1-2 years	At-sea bird surveys
Foraging range	negative	logarithmic	moderate	no	days	3-5 years	At sea surveys, Radio telemetry
Adult diet diversity	negative	logarithmic	low	no	days	3-5 years	Collections, Stable isotopes
Chick diet diversity	negative	logarithmic	low	no	days	3-5 years	Collections, Stable isotopes
Chick feeding rate	positive	sigmoidal	moderate	yes	days	3-5 years	VO, Remote camera observations
Chick meal size	positive	-exponential	low	yes	days	3-5 years	Chick meal collections

Table 2. Hypotheses about relationships between seabirds, forage fish, and oceanography.

Hypothesis	Measurement	Scale of Study	
		Temporal	Spatial (km^2)
1. Long-term changes in forage fish abundance and species composition in Alaska are a function of ocean climate	Hydroacoustic and trawl surveys; Predator diets; Oceanographic studies; Analyze historical data	18-36 Years	10,000's
2. Seabird breeding failures and population declines are due to changes in forage fish density/composition	Numerical and functional response to changes in prey density (see Table 1); Historical data	18-36 Years	10,000's
3. Seabird recovery from *Exxon Valdez* oil spill is limited by existing forage fish density/composition	Numerical and functional response to existing prey densities; Contrast thriving and failing colonies	5-10 Years	1,000's
4. Seabird species have different thresholds and/or respond to different levels of prey density	Contrast functional and numerical response of different seabird species	2-3 Years	100's
5. Large seabirds have more free time to adjust foraging effort as prey density fluctuates	Contrast functional response of different seabird species	2-3 Years	100's
6. Variability in numerical and functional response higher in low density specialists	Contrast variablity in functional and numerical response of different seabird species; Historical data	5-10 Years	100's
7. Prey density/distribution at sea surface is a function of thermocline/ pycnocline depth	Hydroacoustic/trawl surveys; Oceanographic parameters	2-3 Years	10's
8. Weather (wind, sea state) affects foraging success of seabirds	Functional response parameters in relation to weather; Prey disperion and mixing of water column	1-2 Years	10's

Table 2 (cont.). Hypotheses about relationships between seabirds, forage fish, and oceanography.

Hypothesis	Measurement	Scale of Study	
		Temporal	Spatial (km^2)
9. Annual variability in weather accounts for annual variability in foraging and breeding success	Functional and numerical response in relation to seasonal weather	5-10 Years	100's
10. Kittiwake (BLKI) foraging success limited by availability of prey at the sea surface	Contrast numerical and functional response of BLKI with diving species (murre, puffin, cormorant) at the same colony; Measure prey at surface	3-5 Years	100's
11. Prey availability for all seabirds limited by vertical distribution rather than overall abundance	Hydroacoustic and bird surveys, oceanography, Functional response	3-5 Years	100's
12. Prey species differ in quality (primarily energy content)	Collect prey from trawls, seabirds, and measure proximate composition	1-2 Years	N/A
13. Seabird chick growth limited by prey quality (energy content)	Experimental study of chick growth on low and high quality diets	2-3 Years	Colony
14. Seabirds work harder (adjust time foraging) to feed on low quality prey	Contrast functional response at colonies dependent on low and high quality prey	2-3 Years	Colonies
15. Seabird breeding success limited by prey quality (energy content)	Contrast colonies dependent on low and high quality prey using historical data and directed studies	2-3 Years	Colonies
16. Forage species have different schooling behaviors/densities	Hydroacoustic/trawl surveys	1-2 Years	10's
17. Seabird prey capture rate depends on schooling characteristics of prey	Laboratory/aquarium study of foraging behavior	1 Year	N/A

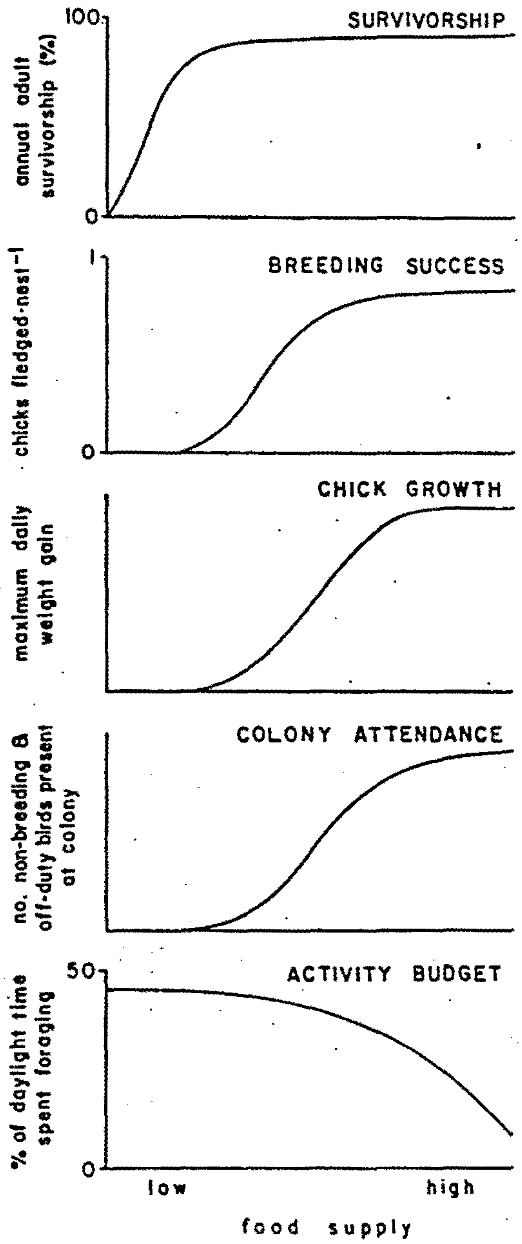

Fig. 1. Hypothesized form of numerical and functional responses of seabirds to variations in prey density. From Cairns (1987).

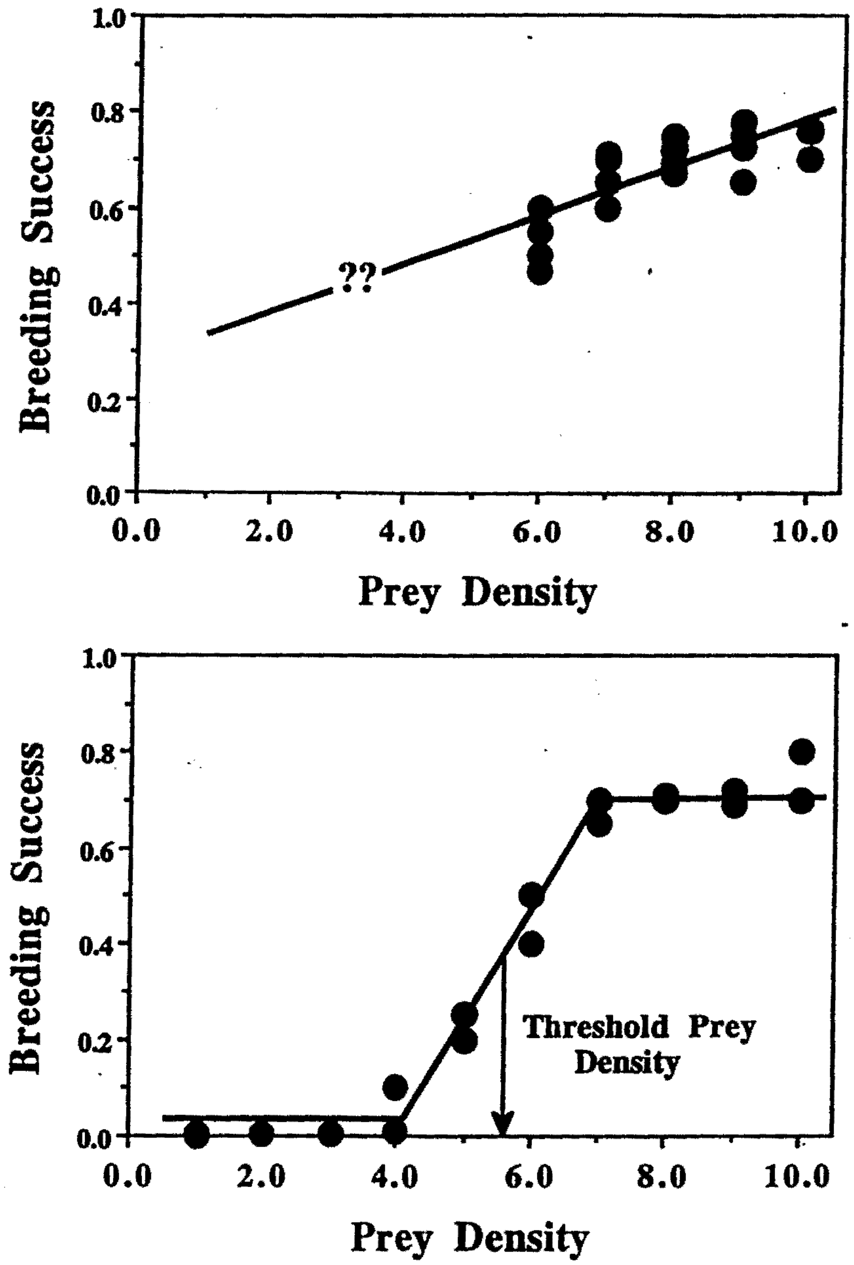

Fig. 2. Hypothetical results of a 15-20 year study of seabird breeding success versus prey density at a consistently successful colony (top graph), and at a colony with widely-ranging levels of breeding success (bottom graph).

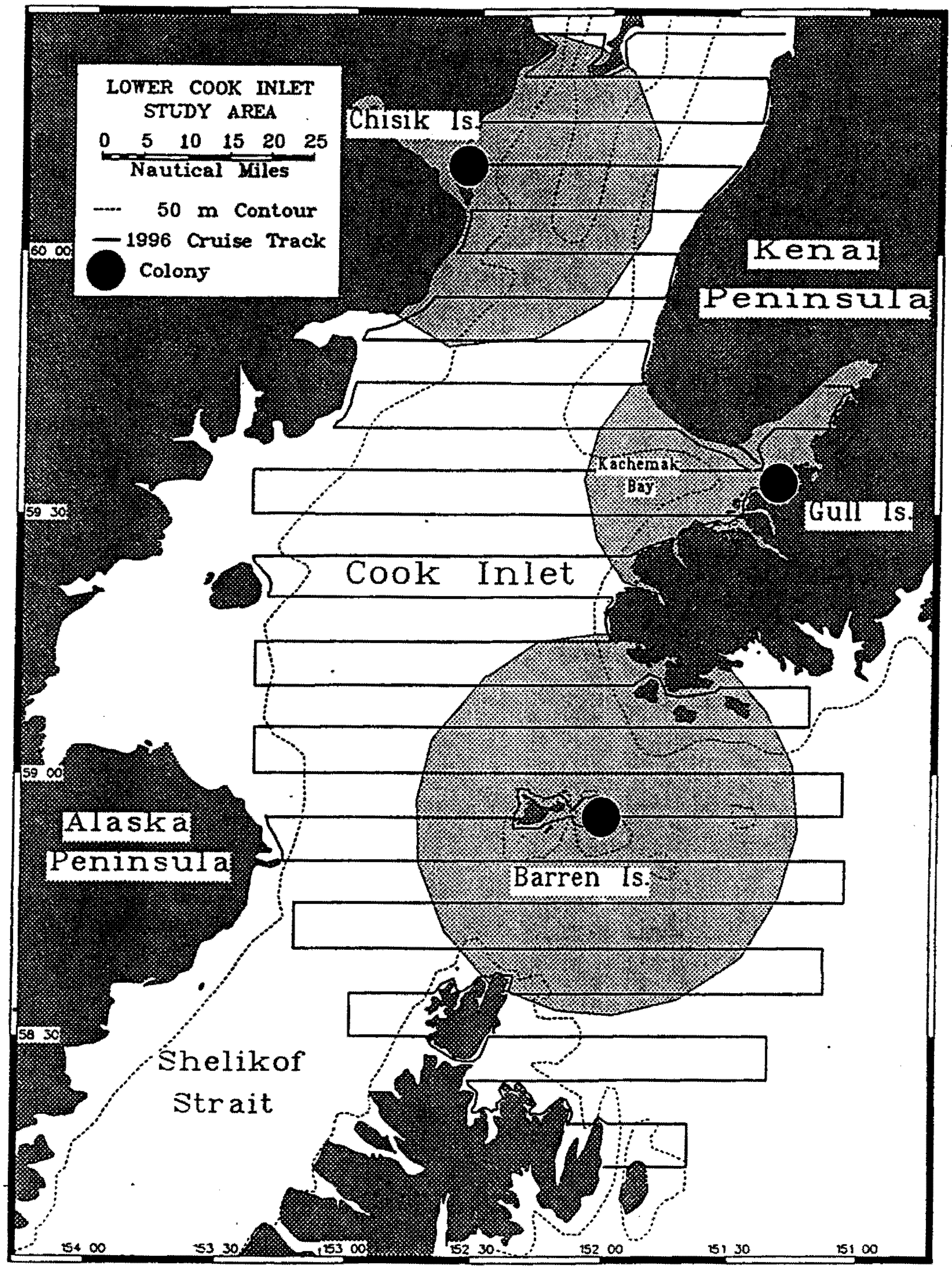

Fig. 3. Study areas in lower Cook Inlet. Seabird breeding biology and foraging behavior will be studied at Gull, Chisik and Barren islands. Minimal seabird foraging ranges (40 km) from colonies are shown as shaded areas, and represent core study areas around each colony. Solid lines indicate potential cruise track for 1996 hydroacoustic surveys to be conducted from the M/V "Tiglax".

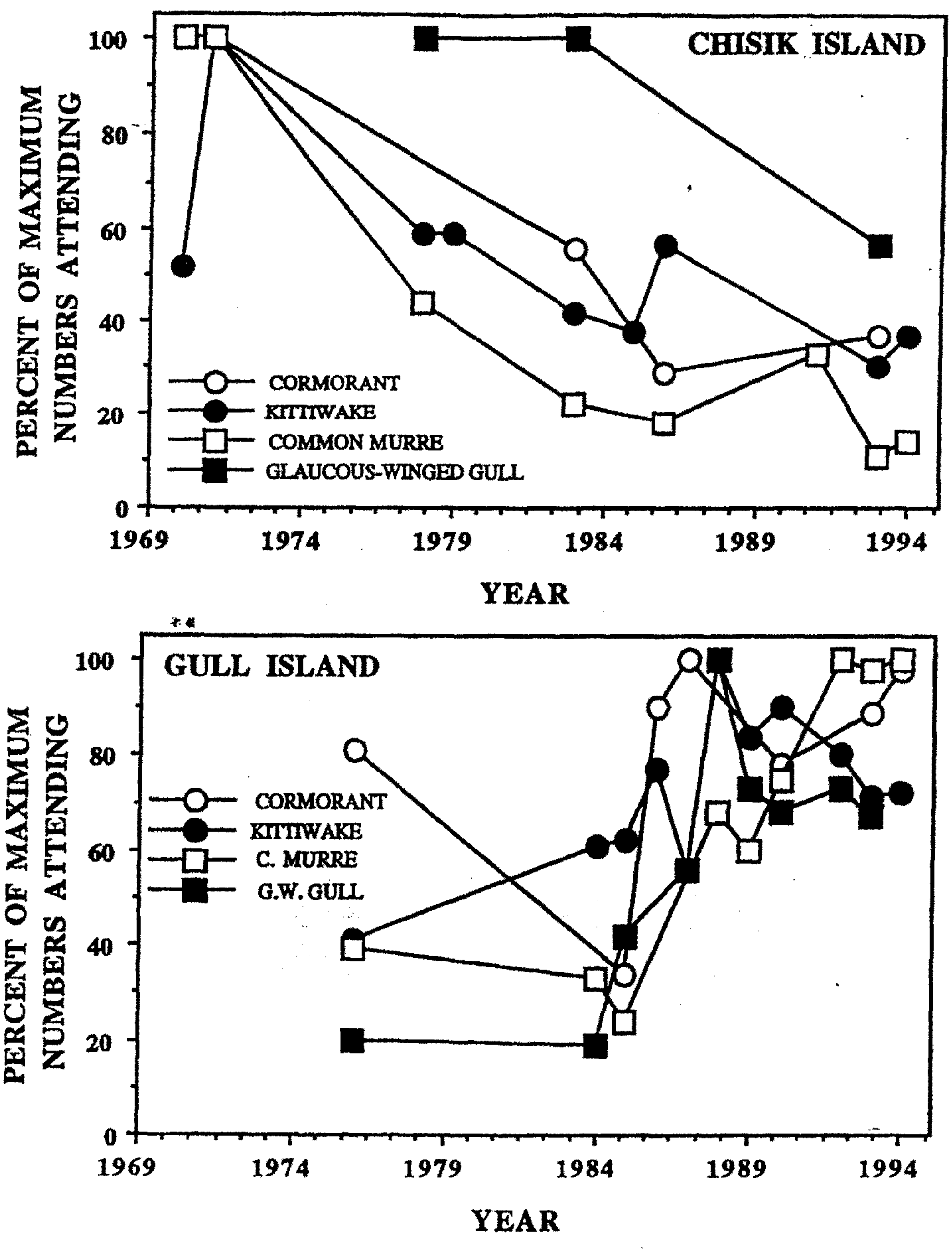

Fig. 4. Seabird population trends at Chisik and Gull islands. Counts for all species were scaled to the percentage of maximum numbers ever observed on all-island counts or study plots (from Slater et al. 1994). Most recent whole-island counts for all species combined were 13,000 and 22,000 individuals at Gull and Chisik islands, respectively.

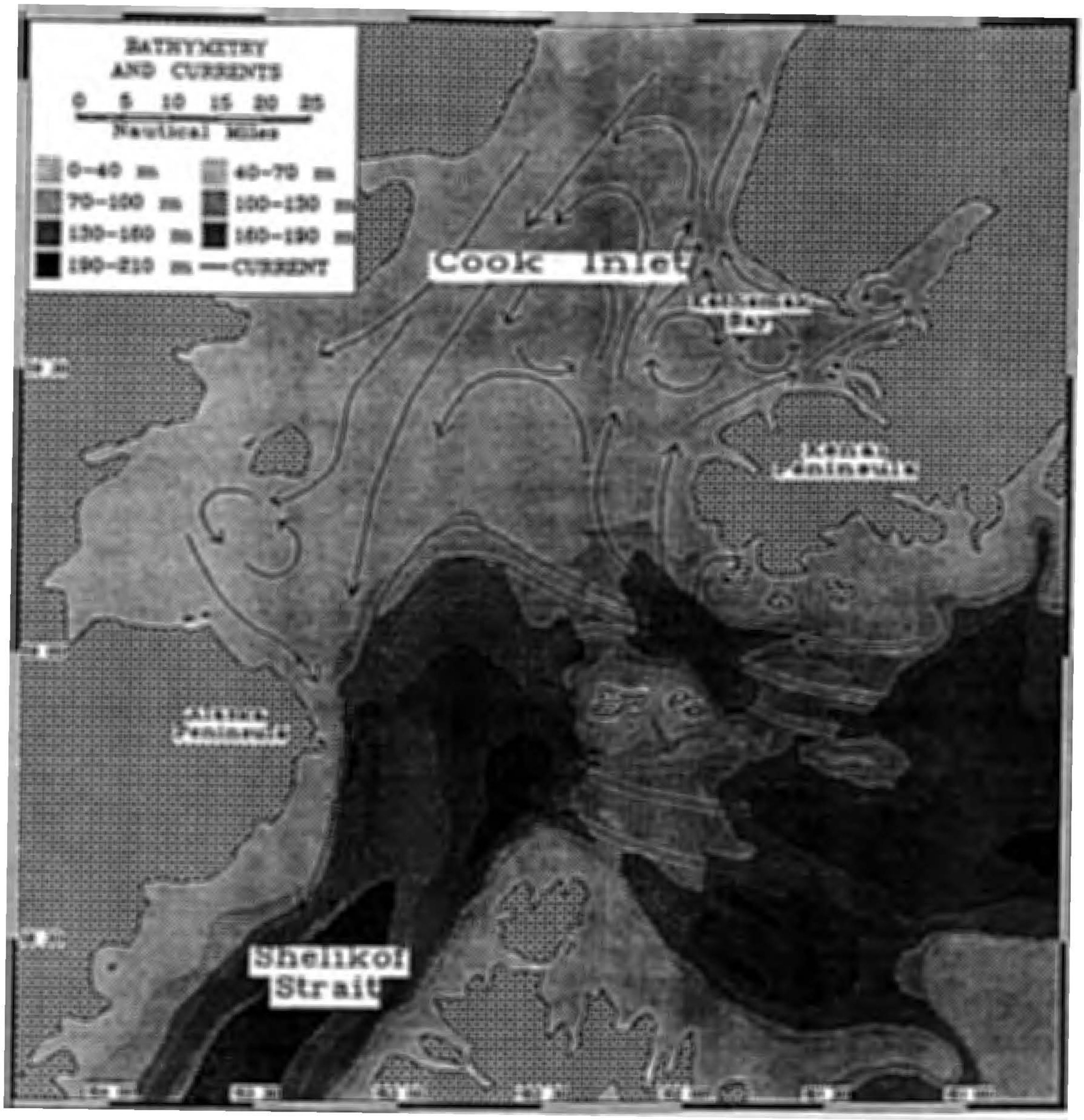

Fig. 6. Bathymetry and prevailing summer currents in lower Cook Inlet (from Piatt 1994; after Burbank 1977, Muench et al. 1978).

N
Captive Rearing

Project Title: Effects of Diet Quality on Postnatal Growth of Seabirds: Captive Feeding Trials

Project Number:	98163N
Restoration Category:	Research
Proposer:	Biological Resources Division / US Geological Survey
Lead Trustee Agency:	DOI
Duration:	3 years (Feb. 1996 - September 1998)
Cost FY 96:	$20,000
Cost FY 97:	$30,000
Cost FY 98:	$30,000
Geographic Area:	Barren Islands, Kachemak Bay, Lower Cook Inlet
Injured Resource:	Multiple (Common Murre, Pigeon Guillemot, Marbled Murrelet)

ABSTRACT

Declines in the availability of high quality forage fishes (herring, sand lance, capelin) have apparently contributed to the lack of recovery of some fish-eating seabirds (murres, guillemots, murrelets) that were injured by the *Exxon Valdez* oil spill. This experimental study tests the hypothesis that diet quality (lipid content, energy density, lipid:protein ratio) constrains the growth, development, fat reserves, and survival of young piscivorous seabirds.

INTRODUCTION

This study is relevant to the management of declining seabirds and marine mammals in the *Exxon Valdez* oil spill (EVOS) area because it is designed to develop a better understanding of how shifts in the diet of breeding seabirds affect reproductive success. Reproductive success in seabirds is largely dependent on foraging constraints experienced by breeding adults. Understanding the role of diet quality as a constraint on productivity of seabirds breeding in the EVOS area will be highly relevant for designing management initiatives to enhance productivity of declining species. If forage fishes that are high in lipids are an essential resource for successful reproduction, then efforts can be focused on assessing stocks of preferred forage fishes and the factors that impinge on the availability of these resources within foraging distance of breeding colonies in the EVOS area. As long as the significance of diet composition is not understood, it will be difficult to interpret shifts in the utilization of forage fishes and develop a management plan for effective enhancement of critical food resources.

This research is the first experimental study to investigate the effects of diet quality on growth and development of nestling kittiwakes and puffins. The research will result in a fundamental advance in our understanding of the significance of prey composition for both Black-legged Kittiwake (*Rissa tridactyla*) and Tufted Puffin (*Fratercula cirrhata*) reproduction, as well as for other pelagic seabirds and marine mammals that breed in the EVOS area. The research is providing new information relevant to several additional areas of study: (1) comparative biochemical composition and nutritive quality of key forage fishes, (2) factors such as age class, sex, size, and reproductive status as they influence the nutritive quality of forage fishes, and (3) the energetic consequences to seabirds of foraging on different prey with differing energy content. This research is also the first to (1) use captive feeding trials to investigate the relationship between nutritive quality of the diet and growth performance of kittiwake and puffin chicks, and (2) relate differences in prey quality to food requirements in kittiwakes and puffins. In addition, the results will have broader implications for our understanding of dietary constraints on reproductive success in other seabirds in the EVOS area (i.e., Common Murre, Pigeon Guillemot, Marbled Murrelet) and will enhance our understanding of the adaptive significance of prey preferences in these seabirds. These results are crucial for understanding the factors limiting populations of marine birds and mammals in the EVOS area.

NEED FOR PROJECT

A. Statement of Problem

Recent declines among populations of top trophic level predators in the Northern Gulf of Alaska have been linked to decreasing availability of forage fishes. Several species of seabirds, including Black-legged Kittiwakes, Common Murres (*Uria aalge*), and Pigeon Guillemots (*Cepphus columba*), have experienced population declines in the EVOS area in recent years. Total breeding failure has been recorded at several sites (Chisik I., Middleton I., etc.). A lack of high quality, lipid-rich forage species to provision nestlings has been hypothesized as a factor in these declines. Also, in some areas the species composition of Tufted Puffin diets has undergone a marked change (Piatt and Anderson 1996), apparently in response to changing prey availability. Determining the relative nutritional value of particular forage fishes for seabirds breeding in the EVOS area is necessary to assess the impact of changes in forage fish availability on seabird productivity.

B. Rationale

A major change in the taxonomic composition of several piscivorous seabird diets has been observed in the Northern Gulf of Alaska during the past 20 years. Specifically, seabirds switched from diets dominated by oily fishes, like capelin and sand lance, to those dominated by juvenile walleye pollock and other gadids (Piatt and Anderson 1996). In addition, the lack of high quality forage fish has been theorized as contributing to the lack of recovery of some seabird species following the *Exxon Valdez* oil spill. Juvenile pollock are lower quality (due to lower lipid content and energy density (kJ/g)) than other prey found in diets of nestling seabirds, such as capelin or sand lance (Baird 1991; Roby et al. 1996, Van Pelt et al. in review). The energy density of juvenile pollock is c. 2.2 kJ/g wet mass, whereas that of capelin and sand lance varies from 2.6-7.6 kJ/g wet mass, depending on sex and age class (Roby et al. 1996, J. Piatt, unpubl. data, this study).

Adult birds that rely on low quality prey to provision their young may experience lower productivity. If an adult were to provide the same amount of energy to its young in the form of juvenile pollock as it could by provisioning with sand lance or capelin it would have to deliver nearly twice as much food. This may not be possible due to time and energy constraints, unless pollock are readily available close to the colony. Consequently, slower growth and lower fledging weights would be expected in nestlings fed primarily pollock diets, resulting in fewer birds surviving to fledge and a reduction in post-fledging survival.

This research is providing a better understanding of the relationship between diet quality and seabird productivity. Captive nestlings fed controlled diets of either pollock, capelin or sand lance are being used to assess the effects of variation in lipid:protein in the diet. Also, by comparing results using two different seabird species as subjects we are gaining insight into differences in dietary requirements among seabirds.

C. Summary of Major Hypotheses and Objectives

Our primary hypothesis is that seabird diets consisting of high-lipid forage fishes (e.g., herring, sand lance, capelin) result in higher growth rates, shorter development times, and fledglings with larger energy reserves when compared to nestlings fed low-lipid forage fishes (walleye pollock, Pacific cod, tomcod). Nestlings are being raised in captivity on carefully controlled diets (either sand lance, capelin, herring, or juvenile walleye pollock) in order to unambiguously test the diet quality hypothesis as a constraint on production of young seabirds. The specific hypotheses to be tested by this research are (1) that sand lance, herring, and capelin are of significantly higher nutritional value for seabird nestlings than juvenile walleye pollock, (2) that lipid content is the main factor influencing nutritional quality of sand lance, herring, capelin, and juvenile pollock, (3) that chicks fed on sand lance, herring, and capelin will grow faster and fledge earlier at higher body mass and with larger fat reserves than those fed on juvenile pollock, and (4) that differences in growth performance due to diet quality will be more pronounced in a species of seabird that grows rapidly and is capable of raising multiple-chick broods (kittiwake) compared to a species that grows more slowly and raises only one-chick broods (puffin).

The overall objective of the proposed research is to determine the relationship between diet quality and the growth and development of seabirds damaged by the Exxon Valdez oil spill. Emphasis will be placed on examining the role of lipid content and lipid:protein ratios on postnatal growth in Black-legged Kittiwakes and Tufted Puffins.

D. Completion Date

This project will be completed in September 1998, after two breeding seasons and sufficient time to complete laboratory analyses, analyze data, and prepare manuscripts for publication.

FY 98 BUDGET

Personnel	
Graduate Research Assistant, 12 months	13.2
Tuition for GRA @ $1,850 / term (spring)	1.85
Lab technician, 3 months @ $1,000 / month	3.0
Subtotal Personnel	18.05
Travel	
Travel to EVOS meetings, 3 Corvallis to Anchorage rt	3.0
Lodging and per diem while in Anchorage @ $120 / day	0.96
Travel to Pacific Seabird Group Conference and A.O.U. meeting	1.0
Lodging and per Diem while at PSG and A.O.U. @ $80 / day	0.64
Subtotal Travel	5.6
Contractual Services	
Page charges, telecommunications, postage, visual aids	1.35
Subtotal Contractual Services	1.35
Supplies	
Solvents, thimbles, weigh pans, for laboratory analyses	2.0
Subtotal Supplies	2.0
Indirect Costs to BRD/USGS (10%)	3.0
TOTAL PROJECT COST	**30.0**

PROJECT DESIGN

A. Objectives

1. Determine the effect of differences in lipid content (% wet mass) of forage fishes on the growth and development of seabird nestlings.

2. Determine the effect of differences in lipid:protein ratios of forage fishes on the growth and development of seabird nestlings.

3. Determine if there are interspecific differences among seabirds in growth response of nestlings to variation in diet quality.

METHODS

The research design utilizes a combination of captive feeding experiments and laboratory analyses. The captive-rearing experiment is being conducted at the Kasitsna Bay Laboratory of the Institute of Marine Science, University of Alaska Fairbanks, during the summers of 1996 and 1997. Chicks used in the study are being collected from either East Amatuli Island in the Barren Islands group or colonies in Kachemak Bay. A sample of kittiwake chicks and puffin chicks are removed from their nests at 6-10 days post-hatch. Kittiwake thermoregulation is well-developed at 6-8 days post-hatch (Barrett 1978). Puffin chicks are independent of parental brooding at 5 days post-hatch (Wehle 1983) and thereafter can be maintained in captivity at ambient temperatures without an artificial heat source. All chicks are placed in individual indoor cages for captive feeding experiments. Cages consist of covered plastic buckets with the bottom cut out and replaced with a floor of hardware cloth. This design makes cleaning cages much easier and, by placing a pan underneath, excreta can be collected conveniently. Each excreta collection is made for all subjects over a 24 hour period, and four total collections are made for each of the subjects over the course of the experiment These excreta samples are then analyzed for energy content (kJ / g dry mass).

The samples of kittiwake and puffin chicks are divided into four diet treatment groups, each receiving a daily ration of one of the following: (1) 100 g of juvenile walleye pollock (2) 56 g of Pacific herring, (3) 100 g of herring, and (4) 190 g of juvenile walleye pollock. The 56 g herring ration is similar in caloric content to the 100 g pollock diet, as is the 100 g herring ration and the 190 g pollock ration, based on published values of energy density in the two species of forage fish. These estimated caloric contents are verified by laboratory analysis prior to the captive feeding trials. Variables that are measured daily in captive chicks include: (1) total body mass, (2) wing length, (3) culmen length, and (4) tarsus length.

When captive-reared chicks reach early fledging age (31 days post-hatch for kittiwakes and 40 days post-hatch for puffins) they are sacrificed and frozen for later body composition analysis in the lab at Oregon State University. Average total body water, lean mass, total body fat, ash-free lean dry mass, ash mass, and ratio of body fat to lean dry mass (fat index) are determined for each species and each diet treatment group. Carcasses are weighed, partially thawed, plucked, and reweighed to determine plumage mass. Plucked carcasses are air-dried to constant mass at 60° C in a forced convection oven in order to determine moisture content. Dried carcasses are ground and homogenized by passing repeatedly through a meat grinder. Aliquots of the dried homogenate are extracted in a soxhlet apparatus using petroleum ether as the solvent system in order to determine fat content and lean dry mass by subtraction. Extracted aliquots are ashed in a muffle furnace at 550ºC to determine ash content and ash-free lean dry mass by subtraction. Body composition of chicks from the captive-feeding experiments are compared to determine the effects of energy intake and diet composition on the allocation of assimilated resources to growth in lean mass and fat reserves.

Samples of juvenile pollock and juvenile herring that are fed to captive kittiwake and puffin chicks are shipped frozen to the laboratory at Oregon State University, where they are subjected to proximate analysis. In the lab, forage fish specimens are dried to constant mass in a convection oven at 60º C to determine water content. Lipid content of the dried forage fish is determined by solvent extraction using a soxhlet apparatus and hexane/isopropyl alcohol 7:2 (v:v) as the solvent system. Lean dry fish samples are ashed in a muffle furnace at 550ºC in order to calculate ash-free lean dry mass by subtraction. Energy content of chick diets are calculated from the composition (water, lipid, ash-free lean dry matter [protein], and ash) of forage fish along with published energy equivalents of these fractions (39.4 kJ/g lipid; 17.8 kJ/g protein)(Schmidt-Nielsen 1990:171).

C. Contracts and Other Agency Assistance

The field portion of this research is being carried out by Marc Romano, a M.S. candidate in the Department of Fisheries and Wildlife at Oregon State University. Dr. John Piatt of the Biological Resources Division of the U.S. Geological Survey serves as field supervisor and provides logistical support. Dr. Dan Roby of the Oregon Cooperative Wildlife Research Unit at Oregon State University guides the lab analyses conducted by Marc Romano at OSU.

D. Location

The captive-rearing experiment is being conducted at the Kasitsna Bay Laboratory of the Institute of Marine Science, University of Alaska Fairbanks, located in Kachemak Bay, Alaska. Chicks used in the study are collected from either East Amatuli Island in the Barren Islands group or colonies in Lower Cook Inlet.

SCHEDULE

A. Measurable Project tasks for FY 98

January - June, 1998	Complete lab analysis of birds and fish from Summer 1997 field season.
January, 1998	Present results of project at annual meeting of the Pacific Seabird Group.
January, 1998	Present results at EVOS Restoration Workshop.
February, 1998	Present results of FY 97 research to APEX peer reviewers.
March, 1998	Submit annual report on results of 1997 research.
June, 1998	Defense of M.S. thesis.
June - September, 1998	Preparation and submission of manuscripts to peer-reviewed journals
September, 1998	Final Report presented to Trustee Council.

B. Project Milestones and Endpoints

The three project objectives will be completed by the termination of the project in September 1998.

C. Project Reports

February, 1998:	Annual Report and summary of work accomplished in summer of 1997, and preliminary findings.
September, 1998:	Final Report.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This research will serve to aid in the long-term management of seabird populations in relation to changes in forage fish stocks. The findings of this project will be of use to both the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS), among others. The proposed work will complement and be coordinated with: i) long-term research conducted by Dr. John Piatt and the Biological Resources Division U.S. Geological Survey, on the response of seabirds to fluctuations in forage fish densities (Project Number 98163 M); ii) annual studies conducted by the Alaska Maritime

National Wildlife Refuge (AMNWR, USFWS Region 7) in Lower Cook Inlet and the Northern Gulf of Alaska; and iii) studies supported by the *Exxon Valdez* Oil Spill Trustees investigating seabird-forage fish interactions in Prince William Sound (APEX).

PERSONNEL

Dr. John Piatt of the US Geological Survey serves as field supervisor for the research, assisted in study design and analysis, and helps to coordinate logistics. Dr. Dan Roby serves as the advisor for the graduate research assistant and also has guided the design and analysis of the research. Field and lab work is being carried out by Marc Romano, who is a M.S. candidate at Oregon State University.

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O
Statistical review

Statistical Review

Project Number:	98163 O
Restoration Category:	
Proposer:	Dr. Lyman L. McDonald, Western EcoSystems Technology, 2003 Central Avenue, Cheyenne, Wyoming 82001
Lead Trustee Agency:	NOAA
Cooperating Agencies:	USFWS
Duration:	3 Years
Cost FY 96:	$30,000
Cost FY 97:	$20,000
Cost FY 98:	$20,000
Cost FT 99:	$35,000
Geographic Area:	Prince William Sound, Cook Inlet and Gulf of Alaska
Injured Resource/Service:	Statistical Review of Study Design and Analysis

ABSTRACT

Non-standard statistical problems in the Alaska Predator Ecosystem Experiment (APEX) in Prince William Sound, Alaska, include severe logistical constraints on field sampling plans, analysis of data with unequal length transects, spatially correlated data, and estimation of resource selection functions. Our responsibility as biometricians is to provide review of and advice for modifications in study protocols for the 1998 field season in order to help insure that appropriate statistical inferences can be made during the analysis phase of the studies. We will also provide advice and assistance during statistical analysis of data and report preparation based on data collected through the 1997 field season.

Statement of Problem and Rationale

Constraints on sampling designs for acoustic survey of nearshore forage fish, analysis of fish diets, ocular observations of foraging sea birds, and collection of extensive data at seabird colonies continue to call for non-standard study designs and statistical analyses. We will continue to work with the APEX Principal Investigators in modification of future data collection methods. Data collection methods will call for close coordination of sampling efforts in the SEA and NVP projects. Dr. McDonald is working in a similar capacity on the EVOS Trustee's Nearshore Vertebrate Predator (NVP) project and can help provide continuity between sampling methods to yield comparable data of mutual interest to these two projects.

The sampling design used for collection of the 1995 and 1996 offshore acoustic survey and sea bird foraging data was a systematic placement of survey lines with a random starting point. Collection of 1997 data in the off-shore areas will continue to use the same sampling plan. Near-shore sampling in 1997 will follow the 1996 near shore methods for survey of 1 km wide shoreline segments with a replicated systematic sample of lines positioned at about 45 degrees to the shoreline. Data on adjacent lines in the systematic sampling plans are potentially correlated. Current analyses for abundance and distribution of forage fish and foraging sea birds are following statistical procedures specifically developed for spatially correlated data.

Summary of Major Hypotheses and Objectives

We will continue to interact with the Principal Investigators of the various segments of the APEX to help develop testable hypotheses and to insure that appropriate statistical procedures are used in the analyses. In particular, our specialty includes analysis and modeling of resource selection by animals and we will be working closely with David Irons, William Ostrand, Art Kettle, and Dave Roseneau of the USFWS, and John Piatt of the NBS to quantify and model habitat and food selection by sea birds. We will continue to work with Lew Haldorson and Ken Coyle in estimation of abundance and distribution of forage fish based on the spatially correlated data collected in 1997 and future field seasons. Interaction with other PI's will be as requested.

Completion Date

Completion dates will depend on completed interactions with the various segments of the APEX. Sampling protocols, standard operating procedures, draft reports, and final reports will be issued as appropriate with individual Principal Investigators.

COMMUNITY INVOLVEMENT

Community involvement will be the responsibility of the individual Principal Investigators.

Proposed FY 98 Budget :

Position	Months	Cost per Month		Subtotal
Senior Biometrician	0.75	14400		$10800
Biometrician II	0.5	10400		5200
Travel:		No. Trips	Cost/ticket	
DIA to Anchorage		2 trips @	900	1800
Meal Per Diem		10 days @	45	450
Hotel Per Diem Winter		4 days @	75	300
Hotel Per Diem Summer		4 days @	110	440
Car Rental		10 days @	40	400
Commodities:				
Long Distance Telephone				400
Shipping, Postage				150
Supplies				60
		TOTAL		$20,000

PROJECT DESIGN

Not Applicable

SCHEDULE

A. Measurable Project Tasks for FY 98:

1 Oct. to 1 Dec. 97:	Participate in spatial analysis of 1995, 1996, and 1997 acoustic survey data. Prepare for Trustee review of 1997 data and analyses. If necessary, begin contacts with Principal Investigators to develop modifications in protocols for collection of data during the 1998 field season.
1 Dec. 97 to 15 Mar. 98:	Interact with Principal Investigators in preparation of Report on 1995-97 data and modification in 1998 data collection protocols.

15 Mar. to 31 Aug. 98:	Consult via telephone with Principal Investigators on necessary modifications of field methods during data collection and possibly visit field study sites to observe data collection procedures.
1 to 30 Sept. 98:	Consult with Principal Investigators on initial analysis of 1998 field data.

B. Project Milestones and Endpoints

Written study protocols and standard operating procedures are primarily the responsibility of the individual Principal Investigators. We will provide consultation and assistance on development of study protocols emphasizing statistical issues. We anticipate that relatively more time will be required in FY 99 than in FY 98, because of the more extensive data analyses expected for the final reports and professional publications.

C. Project Reports

Project reports are primarily the responsibility of the individual Principal Investigators. We will provide consultation and assistance in data analysis and review of statistical analyses.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Dr. McDonald is a member of the Nearshore Vertebrate Predator Project. Sampling of nearshore forage fish will be coordinated between the two projects in so far as possible.

ENVIRONMENTAL COMPLIANCE

Not Applicable

PERSONNEL

Dr. Lyman L. McDonald, Senior Biometrician
Dr. John Kern, Biometrician II
Western EcoSystems Technology, Inc.
2003 Central Avenue
Cheyenne, WY 82001

Q
Modelling

THE FACTORS THAT LIMIT SEABIRD RECOVERY IN THE EVOS STUDY AREA: A MODELING APPROACH SUBMITTED UNDER THE BAA

Project Number:	98163Q
Restoration Category:	Research
Proposer:	H.T. Harvey & Associates
Lead Trustee Agency:	NOAA
Cooperating Agencies:	DOI, UA, OSU
Alaska SeaLife Center:	No
Duration:	2nd year
Cost FY 98:	$65,200
Geographic Area:	No field work anticipated
Injured Resource/Service:	All seabird species being considered by APEX

ABSTRACT

We propose to use models to assess ways in which food supply could be affecting recovery of seabirds in the EVOS study area. We will continue to develop models of foraging effort and success as it relates to breeding productivity. In the second year of effort, in particular, we will adapt models prepared in 1997 for Pigeon Guillemots and Black-legged Kittiwakes in Prince William Sound to these species plus Common Murre in Lower Cook Inlet. Results will test the degree to which food limitation is affecting recovery, indicate the mechanisms by which this could come about, and identify the scale at which interactions are occurring between food availability and the colonies being studied by APEX. Moreover, results should help to "aim" the APEX research effort so that sufficient data are collected to fulfill the overriding APEX objective: to understand the ways in which food supply is limiting seabird recovery.

INTRODUCTION

The APEX Project underway in Prince William Sound is based on the assumption that reduced food supply during the chick provisioning period of seabird reproduction is slowing the recovery of seabird populations from mortality incurred during the *Exxon Valdez* oil spill (EVOS). This assumption has precedent, in that it was argued to be the case for similar species at the same latitude nesting around the British Isles (Furness & Birkhead 1984, Cairns 1989; see below). However, the assumption has not been tested among the Prince William Sound and Lower Cook Inlet colonies and, as shown by Furness & Birkhead (1984) and Ainley et al. (1995), geographic scale figures importantly in the way that the effect could come about.

We propose here to use models to assess the ways in which food supply could be affecting recovery. For seabirds nesting in the EVOS study area, we will develop models of foraging effort and success as it relates to breeding productivity. Results not only will test the degree to which the assumption of food limitation is valid, but will indicate the scale at which researchers should be assessing interactions between food availability and the colonies being studied. Moreover, results also should provide ways to "aim" the APEX research effort so that sufficient data are collected to provide input into the overriding APEX objective: to understand the ways in which food supply is limiting recovery of seabirds in the EVOS study area. Our work will be based on existing data (e.g. the Alaska Seabird Colony Register) and certain results of ongoing APEX studies (e.g. foraging range of affected species in the region). We will work closely with APEX PIs, soliciting their input in all phases of our effort.

NEED FOR THE PROJECT

A. Statement of Problem

The factors that affect the size or growth of seabird populations are complex and more than one mechanism may be involved. It has been theorized, in general, that the size (and therefore the growth, too) of a seabird population in a region is affected by food supply during breeding and/or nesting space; influencing population growth, as well, are the contributions of density-dependent mortality during the non-breeding season (a function also of food supply) and social factors related to colonial nesting (Birkhead & Furness 1985; Cairns 1989, 1992). In some cases nesting space appears to be the more important ultimate factor (e.g., Duffy 1983; Ainley & Boekelheide 1990) and in others it is argued that food is the more important, especially during the chick provisioning period (e.g., Ashmole 1963, 1971; Furness & Birkhead 1984, Cairns 1989).

The geographic structure or distribution of a seabird population in a region (i.e., the size and spacing of colonies) is also affected by availability of nesting habitat and food (Furness & Birkhead 1984, Cairns 1989). These resources are allocated by an interplay of forces, both "positive" (favoring coloniality) and "negative" (favoring solitary living) (Ainley et al.

1995). As summarized by Wittenberger & Hunt (1985) and Burger & Gochfeld (1990), negative forces, such as interference and exploitative competition, counter the positive ones, such as group defense against predators and facility in gaining mates. If the size distribution of colonies is stable, this implies both sets of forces to be at work. Negative forces, mediated proximally through emigration to colonies with more favorable conditions or establishment of new colonies, act on colony size through a negative feedback loop: the greater the colony size, the greater the impact of negative forces, thus, encouraging a reduction in colony size. Positive factors, in contrast, result in positive feedback: to new recruits, high density areas are the most attractive. If positive forces are sufficiently strong relative to negative ones, new colonies would not be established.

The factors that affect total population size come to bear when new colonies are formed or depleted ones re-established. Many studies of seabirds have found that when breeding density at large colonies is high, prospectors are more likely to settle at smaller colonies nearby, thus, increasing the emigration rate from the central colony and increasing growth rate of small colonies (e.g. Potts 1969, Potts et al. 1980, Birkhead & Hudson 1977, Coulson et al. 1982). Conversely, small colonies decrease more rapidly than larger colonies, as demonstrated in studies of kittiwakes *Rissa* sp. (Coulson 1983) and murres *Uria* sp. (Takekawa et al. 1990). Additionally, inverse relationships between colony size and breeding success and chick growth also provide indirect evidence for food limitation (studies of murres: Hunt et al. 1986, Gaston et al. 1983).

B. Rationale/Link to Restoration

The APEX project should provide much insight about the ecological processes that affect the well being, growth, and size of seabird populations in Prince William Sound and Cooke Inlet (EVOS study area). However, the project's underlying assumptions need to be fully tested so that the mechanisms by which food limitation is affecting population growth can be fully appreciated and to insure that sufficient data on pertinent aspects of seabird life history are being collected so that, in the end, an integrated explanation of population limitation is available. A meaningful way by which to carry out this test is to use models, both foraging and demographic.

C. Location

The data used in the modeling will come from Prince William Sound and Cooke Inlet as a result of the APEX project and other efforts such as the Alaska Seabird Colony Register. Our effort will be conducted on computers at our home offices. The benefits of the project will be realized in the EVOS area, as results will help to direct restoration of seabird colonies there.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

All communities affected by the APEX project will be involved indirectly in the proposed work.

PROJECT DESIGN

A. Objectives

Hypotheses to be evaluated by exploratory modeling using existing data: Under the null hypothesis,

1. Annual survivorship, age of first breeding, foraging range, feeding frequency of chicks, and reproductive success are not related to food availability. We hypthosize that feeding frequency of chicks and breeding success in large colonies should be lower than in small colonies.

2. No differences in 1 will be evident in pre- and post-spill comparisons, where possible.

B. Methods

We will be keying analyses on APEX species and those identified as not recovering (kittiwake, murres, pigeon guillemots). We will consider marbled murrelets, but recognize the problematic nature of acquiring data on the natural history of this species.

To test Hypothesis 1, we will be constructing models of demography and foraging energetics as related to breeding success, as follows.

Demographic Analysis. Demographic and reproductive data from colonies that are not recovering will be used to determine those aspects of colony performance that are having the most significant effect in delaying or preventing recovery. Where data are available, we will construct simple life table models of pre- and post-spill colonies to determine which demographic factors contribute the most to declining (or not growing) colony sizes. This analysis will help to determine when and on what age-class the effects of food limitation would be most significant, and help to provide further insight into the mechanism(s) underlying poor colony performance.

Foraging Energetics and Breeding Success. Understanding the linkage between food availability and breeding success is critical to formulating a model that can predict the effect of perturbations of food supply on seabird populations. These relationships were modeled in detail by Ford et al. (1982) for oil spill-induced perturbations of murre and kittiwake populations on the Pribilof Islands. This model concluded that the effects of direct adult mortality during an oil spill were of greater significance than the concurrent reduction in food supply, but did not address the effects of long-term decreases in food availability.

Food availability, and how it effects prospects for recovery from catastrophic events (such as oil spills) were considered in a more recent model constructed by Nur et al. (1992). This model was directed toward recovery of the populations of three seabird species, including the common murre. It was found, indeed, that food availability has importance influences on recovery, as it affects many of the demographic parameters that cause a seabird population to grow (e.g., chick production, survivorship, age of first breeding, and breeding probability). Most of these parameters concern aspects of seabird life history that bear on adults and subadults. The modelling was based on empirical data on seabird populations at the Farallon Islands, California.

We are taking an empirical approach for the present study, as well, relying on data from ongoing and future studies in Prince William Sound and Lower Cook Inlet (APEX). Emphasis has been placed on describing the relationship between the quantity and quality of food delivered to the chicks and subsequent reproductive success, and the relationship between food availability and delivery rates. This analysis has already revealed APEX data gaps relating to the linkage between food availability, breeding success and population growth, and that these findings have provided guidance for subsequent field studies. We anticipate that additional points will arise that will help to guide the APEX project.

Providing Input to the APEX Ecosystem Model. Seabird populations are important components of North Pacific marine ecosystems. Many of the data that would be required to estimate the impact of seabirds on lower trophic levels are already available. Predicting the effects that perturbation of lower trophic levels would have on seabird populations is more problematic. Such predictions will require understanding of the linkage between food availability in terms of the distribution, timing, and nature of the food supply, and the quantitative effect that this will have on various aspects of reproductive success. Establishing the exact nature of these relationships is beyond the scope of our study, but we will be able to determine what factors appear to be the most critical, and help to target ongoing research programs toward this goal.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

The proposed analysis will be conducted by individuals from private institutions. However, PI's will consult frequently with the biologists from Trustee agencies who are collecting the data in the APEX project. Agency personnel will likely be co-authors of the reports or publications prepared. The other institutions and agencies involved include Department of the Interior, University of Alaska, and Oregon State University.

SCHEDULE

A. Measurable Project Tasks for FY 98 (October 1, 1997 - September 30, 1998)

Jan. 1- :	Assemble data resulting from APEX during FY 95-97, from pre- and immediately post-spill studies, from the Alaska Seabird Colony Register, and the models prepared during year 1 of this project.
January 22-25:	Attend annual Restoration Workshop.
February 1 - 30 June:	Continue to assemble data; adapt models derived in year 1 to Lower Cook Inlet and species therein (including Common Murre).
1 July - 31 August:	Refine models of seabird foraging effort/breeding productivity.
1 - 30 September:	Finish final report for review.
Winter 1998-99:	Revise final report.

B. Project Milestones and Endpoints

30 September 1998:	Final report, with foraging/energetic model.
January 1999:	Present papers at annual meeting of Pacific Seabird Group: *A foraging/energetic model to explain lack of recovery of seabirds in Lower Cook Inlet.*
15 April 1999:	Submit final version of final report.
Spring 1999:	Submit two papers for publication in either *Condor, Auk* or *Colonial Waterbirds.*

C. Completion Date

A draft final report will be available by 30 September 1998.

PUBLICATIONS AND REPORTS

Besides a final report, we anticipate two publications as identified above under Milestones and Endpoints.

PROFESSIONAL CONFERENCES

We anticipate presenting two papers, as identified under Milestones and Endpoints, at the annual meeting of the Pacific Seabird Group in winter 1998-99.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project depends fully on integration with almost all studies in the APEX project.

PROPOSED PRINCIPAL INVESTIGATORS

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PERSONNEL

David G. Ainley, PhD, has investigated the ecology of seabirds for 25 years, having conducted studies in Alaska, California, Mexico, Hawaii and Antarctica. Much of his research has involved the species of seabirds affected by EVOS, especially guillemots and murres. He has published over 125 scientific papers and has authored three books and 2 monographs. With Glen Ford, he participated in development of demographic models to assess impacts of catastrophic events on seabird populations in California (for NOAA, Gulf of the Farallones National Marine Sanctuary).

Selected Ainley Publications

Ainley, D.G. & R.J. Boekelheide (eds.). 1990. Seabirds of the Farallon Islands: Ecology, Structure and Dynamics of an Upwelling System Community. Stanford University Press, Palo Alto. 425 pp.

Ainley, D.G. N. Nur & E. J. Woehler. 1995. Factors affecting the size and distribution of pygoscelid penguin colonies in the Antarctic. Auk 112: 171-182.

Ainley, D.G., L.B. Spear & S.G. Allen. In press. Temporal and spatial variation in the diet of the Common Murre in California. Condor.

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R.Glen Ford, PhD, was trained in mathematical ecology at University of California, Berkeley, and has been investigating the quantitative ecology of seabirds for the past 20 years, especially in regard to species of the eastern North Pacific, Gulf of Alaska and Bering Sea. He is well versed in GIS applications, having developed software that has been used widely by marine ornithologists, including those studying marbled murrelets in Alaska. He has modeled impacts of oil spills to marine bird populations and conducted computer simulations of the response of seabirds to perturbations in their food supply. Dr. Ford has authored 23 scientific papers (and 28 reports), including 11 on marine birds.

Selected Ford Publications

Ford, R.G., J.A. Wiens, D. Heinemann & G.L. Hunt, Jr. 1982. Modeling the sensitivity of colonially breeding marine birds to oil perturbation. J. Appl. Ecol. 19:1-31.

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David C. Schneider, PhD, has been involved in a number of studies on the distribution of seabirds in relationship to marine features and has constructed bioenergetic and carbon models to assess the role of seabirds in nutrient cycling in the Bering Sea, Benguela Current, and elsewhere. He has authored over 50 publications, including the recently published book: *Quantitative Ecology: Spatial and Temporal Scaling*. Currently, he holds a position at the Institute of Cold Ocean Science, Memorial University, Newfoundland.

Selected Schneider Publications

Schneider, D.C. 1995. Spatial and temporal scaling of energy flux through populations of marine nekton. Pp. 419-428 in (E. Runde & K.J. Erikstad, eds.) Ecology of Fjords and Coastal Waters. Elsevier, Amsterdam.

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R
Marbled Murrelets

Marbled Murrelet Productivity Relative to Forage Fish Availability and Other Environmental Factors in Prince William Sound and Kachemak Bay

Project Number:	98173 R
Restoration Category:	Research
Proposer:	U.S. Fish and Wildlife Service (PI - Kathy Kuletz)
Lead Trustee Agency:	DOI-FWS
Cooperating Agencies:	NOAA, ADFG
Alaska SeaLife Center:	NA
Duration:	2 years + 1 year synthesis
Cost FY 98:	$120.1
Cost FY 99:	$120.0
Cost FY 00:	$60.0
Cost FY 01	0
Geographic Area:	Prince William Sound
Injured Resource:	Marbled Murrelet

ABSTRACT

This project investigates the hypothesis that forage fish abundance is limiting marbled murrelet reproductive success and thus recovery. We will compare forage fish abundance, as determined by APEX and SEA studies, to an index of murrelet productivity. Intra- and inter-annual comparisons will be made among 3 sites in Prince William Sound. Murrelet prey species will be determined by observing birds on the water during the chick rearing period. In subsequent years we will integrate data on terrestrial and marine habitat use to make a descriptive model of adult and juvenile murrelet distribution. This project responds to the Trustees' suggestion that a murrelet project be done in the context of the APEX project.

INTRODUCTION

Marbled murrelets (*Brachyramphus marmoratus*) are the most abundant seabird in Prince William Sound (PWS) in the summer, but their population has declined by 67% between 1972 and 1989 (Klosiewski and Laing 1994), and the hypothesis of the APEX project is that lack of food has been the primary cause of decline for the murrelet and other marine species. The first and primary objective of the murrelet project is based on the hypothesis that marbled murrelet productivity depends on the density and distribution of forage fish. We will test this hypothesis by comparing murrelet abundance and productivity spatially and temporally, relative to the distribution and abundance of forage fish as determined by APEX. To assess murrelet productivity we will be applying the murrelet productivity index (MPI) developed by project 95031 and published in Kuletz and Kendall (in press).

INTRODUCTION

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Our studies in 1994 and 1995 at two sites suggested a relationship between murrelet productivity and forage fish availability. The 1994 pilot surveys at Port Nellie Juan and Naked Island were compared to their 1995 surveys (Kuletz et al. 1996). In 1995, peak juvenile occurrence was 7-10 days earlier and juvenile density and HY:AHY ratios were significantly higher, whereas adult densities were the same both years. There were no significant differences between sites on the same year. These results agree with preliminary analyses of other EVOS studies on the timing of the spring plankton bloom and relative fish abundance in 1994 and 1995. Comparisons between the MPI and fish abundance over multiple years can demonstrate whether the timing and abundance of forage fish influence murrelet reproductive success.

In addition to the abundance of prey, the quality of prey can be equally important to the reproductive success of seabirds (Pearson 1968, Harris and Hislop 1978, Hunt et al. 1981, Vermeer 1979, 1980, Monaghan et al. 1989). In most of its range, murrelets appear to select sandlance (Sealy 1975, Carter 1984, Burkett 1995). In PWS, the diet of adult murrelets has changed from primarily sandlance in the early 1970's to primarily cod species between 1989 and 1991 (Kuletz et al. 1996b). In contrast, murrelets collected in Kachemak Bay in 1990 were still feeding on sandlance. This change in prey type may be one of the factors responsible for the population decline in PWS. The second objective of this project is based on the hypothesis that sand lance is the preferred prey of murrelets where it is available, and productivity is positively correlated with the proportion of sand lance in the diet. To examine the effect of prey species, we will compare murrelet diet with the relative abundance of species as determined by APEX, to determine if there are regional differences in diet and if there is a general correlation with intra- and inter-annual productivity.

Murrelets depend on forage fish such as Pacific sandlance, (*Ammodytes hexapterous*), capelin (*Mallotus villosus*), juvenile herring (*Clupeidae spp*) and juvenile pollock (*Gadidae spp*) (Oakley and Kuletz 1979, Krasnow and Sanger 1986, Sanger 1987, Kuletz, unpubl. data). The APEX project, concurrent with the murrelet project, will be the first opportunity to analyze the abundance of different prey types relative to murrelet foraging, prey selection, and murrelet productivity.

The final phase of this project will synthesize the marine habitat, diet, and terrestrial habitat used by murrelets to model their distribution and factors affecting productivity. Objective 3 is based on the hypothesis that the foraging and nesting ecology of murrelets enables them to dominate the avifauna of PWS because they can exploit prey that is dispersed. However, at some scale murrelet distribution and productivity must be determined by a combination of terrestrial (nesting) and marine (foraging) habitats. Even in PWS, some areas consistently have more murrelets and produce more chicks, than other areas (Kuletz et al. 1996). For example, Naked Island, with high proportions of high-volume forests and surrounded by a large shallow-water shelf, has relatively high murrelet productivity. We will attempt to define what combination of features promote high murrelet density.

The limited data available on the distribution of fish in PWS suggest, circumstantially, that fish determine murrelet distribution. Although some areas of PWS have higher densities of murrelets than others, marbled murrelets are typically observed as singles or in pairs, and they are the most evenly dispersed seabird in PWS (Klosiewski and Laing 1994, Agler et al. 1994). Forage fish are also widely dispersed in PWS, often in very small patches < 3 m across (Ostrand and Maniscalco 1996, Coyle, University of Alaska, Fairbanks, pers. comm.). Although this is not direct evidence of interaction between murrelets and forage fish, the distribution of marbled murrelets may reflect the distribution of their prey.

Marbled murrelets forage on small schools of fish in nearshore, shallow waters, or areas of upwelling (Kuletz et al. 1995a, Ostrand and Maniscalco 1996). The foraging locations of radio-tagged birds and density of murrelets relative to marine habitat (Kuletz et al. 1995a, 1996) have suggested that some hydrographic features attract murrelets, presumably because prey are consistently available there. The mechanisms of how murrelets obtain food, or what physical and biological features they respond to, will be examined in conjunction with the seabird/fish interaction portion of APEX (Project 98163B).

Although murrelets can use small, dispersed patches of prey typical of PWS, certain hydrographic features probably result in regions of relatively high prey abundance (Haney and McGillivary 1985, Hunt et al. 1990, Coyle et al. 1992), or bring prey to the surface at frequent and predictable intervals (Burrell 1987, Hunt 1995). Such regions should support higher densities of murrelets than less productive or less predictable sites. If murrelets nest preferentially in the vicinity of these 'hot spots' (ie., an average of 20 km from nest to forage locations, based on the forage range of murrelets radio-tagged in PWS [Kuletz et al. 1995a]), productivity, as measured by the abundance of juveniles at sea, should also be higher there.

NEED FOR THE PROJECT

A. Statement of Problem

The marbled murrelet is a threatened species under the Endangered Species Act in California, Oregon and California and a species of concern in Alaska. The murrelet is the most abundant seabird in PWS in summer, and the *Exxon Valdez* oil spill caused the largest single-event mortality of marbled murrelets in the world (Carter and Kuletz 1995). Although murrelets suffered high mortality in the 1989 spill (Ecological Consulting, Inc. 1991, Piatt et al. 1990, Kuletz 1996), the spill cannot account for the 67% reduction in numbers observed in post-spill years (Klosiewski and Laing 1994); nor has the population increased since 1989 (Agler et al. 1994).

In other areas, marbled murrelet populations have declined primarily due to the loss of old-growth forest nesting habitat (Stein and Miller 1992). However, a comparatively small proportion of potential nesting habitat has been harvested in PWS. Changes in the food supply can also affect seabird populations (Cairns 1989, Monaghan et al. 1989, Furness and Nettleship 1991). Murrelet reproduction may be limited by food if adults can not provide sufficient quantity or quality of prey to their chicks. Because other piscivorous birds and marine mammals in PWS have declined as well, (Frost et al. 1994, Klosiewski and Laing 1994), a lack of food resources is the main hypothesis of the APEX project. In contrast, Kachemak Bay populations of piscivorous birds remain stable, and higher resource availability may explain the difference between the two regions.

B. Rationale / Link to Restoration

If food is limiting murrelet reproductive success, it is likely that recruitment is limiting recovery of the population. Because murrelets are probably long-lived (Beissinger 1995), changes in the population due to low reproduction may not be evident for a decade or more, which may preclude timely management decisions. We will use information on the physical and biological factors that influence murrelets, to develop a descriptive model of murrelet productivity. In both PWS and Kachemak Bay there will be concurrent studies of forage fish abundance, distribution, species and processes affecting prey availability. This is a unique opportunity to approach the restoration of murrelets within the context of its ecosystem, while simultaneously comparing two distinct regions. Ultimately we will improve our ability to predict how management options will affect the recovery of murrelets.

C. Location

This project will occur in Prince William Sound, and through a cooperative effort with project 97163M (Cook Inlet studies), in Kachemak Bay. The 3 PWS study sites will be lower Valdez Arm, Naked Island, and Jackpot Bay/Dangerous Passage. These areas were selected because of the availability of historic data on murrelets and overlap with the APEX fish sampling. They are separated by at least 16 km, the average distance traveled between feeding and nest sites by murrelets in PWS, and twice the distance that a juvenile murrelet tagged at its nest moved over a 2 week period (Kuletz et al. 1995a). In Kachemak Bay there will be 2 sites - the south inner bay and south outer bay.

The National Coast Guard dock at Valdez and local hotel facilities will be used during surveys of Valdez Arm. At Naked Island we will share field camps used by project 98163F (guillemots), which will require a U.S. Forest Service permit. The camp site at Jackpot Bay, which will be shared with project 98163G (seabird energetics), was purchased by the *Exxon Valdez* Trustee Council in 1997.

In Kachemak Bay the Homer boat harbor will be used, but primary residence and operations will be on the south side of the bay, and we will stage from Seldovia or the University of Alaska Marine Lab at Kasitna Bay. Our operations in Kachemak Bay will be done in conjunction with Project 98163M (Cook Inlet studies). Both projects will also be coordinating with the Alaska Maritime National Wildlife Refuge for occasional logistical support.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Murrelets are not used for subsistence by local communities. They are, however, subject to gillnet mortality (Wynne et al. 1992, Carter et al. 1995). Gillnet by-catch, and observations by fishermen, could identify areas with high juvenile murrelet activity or concentrations of post-breeding adult murrelets. The principal investigator is currently a member of the Seabird Network Bycatch Working Group (fish1ifr@aol.com), an international group of biologists, fisheries managers and conservation organizations working to develop options to reduce seabird, and especially marbled murrelet bycatch.

In late summer, dead juvenile murrelets have been found by residents in the spill area. These carcasses often show evidence of starvation and they can be a valuable source of data. Such opportunistic samples will be solicited through educational posters and notification of local fishing and recreation groups. In 1994 and 1995 we displayed a poster soliciting murrelet carcasses in Whittier and Cordova, and local residents contributed samples. We will continue this effort in PWS communities, and in Homer and Seldovia on Kachemak Bay. We will also maintain contact with the Bird Treatment and Learning Center in Anchorage, which has notified us of murrelet fledglings they receive and raise. These contacts have provided data on body weight and photographs of juvenile plumages.

PROJECT DESIGN

A. Objectives

Using the murrelet productivity index (MPI), the goal is to determine if food is limiting marbled murrelet productivity, and if so, what are the mechanisms. The specific objectives are:

1. Assess the relationship between relative prey abundance and distribution and murrelet productivity within and between sites in Prince William Sound and Kachemak Bay.

2. Describe the diet of marbled murrelets in PWS and KB during the chick rearing period.

3. Model the distribution of adult and juvenile murrelets in Prince William Sound and Kachemak Bay relative to terrestrial and marine features to assist restoration efforts.

B. Methods

Objective 1: Assess the relationship between food and murrelet productivity.

The main hypothesis of this objective is that murrelet productivity will be higher in areas and in years when forage fish availability is relatively higher. Data on food availability will be obtained through the APEX forage fish studies (97163A - forage fish abundance in PWS and 97163M - Cook Inlet studies). It is not possible to study murrelet reproductive success by standard means at nest sites because of their highly dispersed, secretive, inland nesting habits. We will use a productivity index, based on the at-sea ratio of juveniles to adults, that was developed for southcentral Alaska (Kuletz et al. 1995a, 1996, Kuletz and Kendall, in press) in conjunction with researchers at lower latitudes (Ralph and Long 1995, Strong 1995). We used the foraging ranges of adults (Kuletz et al. 1995a) to determine dispersal of study sites.

Data Collection

Murrelet Productivity.-- We will conduct shoreline at-sea surveys at 3 of the PWS sites surveyed in 1995 and 2 new sites in Kachemak Bay, Lower Cook Inlet (Fig. 1). Two crews, one in PWS and one in Kachemak Bay (1 driver and 2 observers each) will survey from 25 ft. Boston Whalers using standard FWS protocol (Klosiewski and Laing 1994). The surveys will follow established FWS shoreline transects that are digitized on Atlas/GIS files (Strategic Mapping, Inc. 1992). At each site, a total of approximately 40 km of shoreline will be surveyed. Surveys will be conducted between 0600-1600 hours (murrelet counts vary significantly earlier or later in the day [Carter and Sealy 1990, Kuletz 1994, Appendices]). Each site will take one day to survey per sample. (See Murrelet Productivity Protocols:A, for details).

In 1995 we found a significant relationship between the number of adults at a site in June and the number of juveniles there in late summer. Because adults leave in late summer, the June population is most representative of the local breeding population, and thus June adult counts may be the most reliable for juvenile : adult ratios (Kuletz and Kendall, in press). We will continue the June surveys in 1998, and our baseline surveys will be conducted 1-15 June. The numbers of murrelets in each area in June will be used for comparison to late summer juvenile counts.

Juvenile surveys will be conducted at the study sites between 25 July and 25 August. Each site will be surveyed about twice per week, with the crew rotating among sites to minimize temporal effects. In early June, day-to-day variability is relatively low, and 2 or 3 replicates per site is adequate. Juvenile surveys in late summer must accommodate inter-annual changes in peak fledging dates, and higher day-to-day variability (Kuletz et al. 1996), therefore, each site will have 6 replicates. Thus, in PWS, there will be at least 9 surveys in June (3 sites x 3 replicates) and 18 surveys in July/August (3 sites x 6 replicates). At Kachemak Bay murrelets are concentrated along the south side (Kuletz 1989, 1996), where we will survey two sections, approximately 30-40 km each. In Kachemak Bay there will be 6 surveys in June (2 sites x 3 replicates) and 12 surveys in July/August (2 sites x 6 replicates). More replicates will be obtained in July/August if weather and logistic arrangements permit.

Observers will be trained to score birds by plumage and behavioral characteristics (Carter and Stein 1995, Kuletz et al. 1996), using photos, study skins, drawings and on-sight training to standardize observers. (See Murrelet Productivity Protocols:A.3, for details).

Hydroacoustics. -- The main hypothesis, that food is limiting murrelet productivity, will be tested by comparing the average juvenile ratio among sites relative to local prey availability. All study sites overlap with the APEX sites, either in PWS or Kachemak Bay, and relative prey abundance will be obtained from that project.

Data analysis. -- As in 1995, we will test for differences in the absolute numbers and ratios of juveniles : adults among sites, using Z tests on the standard error of the ratios (Manley et al. 1993). The ratio of juveniles will also be calculated relative to total murrelets in June (presumably the local breeding population), and compared among sites with a Kendall *taub* correlation test. A non-parametric ranking test will be used to determine if relative prey abundance among the six sites is correlated with relative murrelet and juvenile murrelet density.

Objective 2: Describe the diet of marbled murrelets in PWS and Kachemak Bay during the chick rearing period.

We will document murrelet prey species by visual observations of murrelets on the water holding fish in their bill. We will primarily target prey items destined for chicks and thus will concentrate prey observation surveys during the peak chick-rearing period, and near sunset (See Murrelet Productivity Protocols:B, for details). The beginning of chick-rearing will be based on first observation of birds holding fish on the water surface or an adult flying with a fish in its bill.

The main observation sessions will be conducted in late June to mid July. Opportunistic observation sessions will be made throughout the July/August juvenile surveys. We will attempt to obtain a minimum of 50 identified prey items per site at four sites: Naked Island and Jackpot/Dangerous Passage in PWS, and Glacier spit (inner bay) and Herring Islands area (outer bay) in Kachemak Bay.

To determine if murrelets are taking prey in relation to relative abundance, the murrelet diet will be compared spatially and temporally with the fish species identification and relative abundance data conducted by APEX projects 98163A,B and M.

Objective 3: Factors affecting murrelet distribution and modeling murrelet distribution

This portion of the project will be a synthesis effort following the successful completion of the previous objectives and compilation of data from other APEX and SEA projects..

The marine habitat requirements of murrelets are only partially understood. Project 97163B, the seabird/fish interaction component of APEX, will examine the mechanisms that influence seabird distribution at sea. However, the study of seabird/fish interactions often examines small-scale relationships to describe mechanisms. Because of the distribution and scarcity of juvenile murrelets, the murrelet productivity project will work primarily on a larger scale, with the study sites as sample units. The murrelet project will use criteria developed by 96163B and 97163B that describe small-scale characteristics of 'good' foraging habitat to rank marine habitats contained in each study area. These results will be integrated with data collected by 97163A (fish populations) and the murrelet project to describe murrelet distribution relative to mid-scale food availability and environmental factors.

The distribution of adults and juveniles at sea may be partially determined by nesting distribution, or the combination of terrestrial and local marine habitats. Therefore, environmental data for the murrelet study areas will include spatial data from GIS bathymetric and terrestrial coverages as well as temporal data collected on-site. Temporal data will be collected during the murrelet surveys prior to each transect, and will include air and surface temperature and salinity, presence of glacial ice, water clarity (by Secchi disk), sea conditions, weather, time and observed feeding activity. We will calculate tide with a Paradox (Borland, Inc. 1992) script (Kuletz / FWS files). Shoreline and bathymetric features will be taken from GIS at the transect level (small scale) and averaged for the site (mid scale). We will test for differences between adult and juvenile habitat associations with log-linear analysis at the transect level. Descriptive statistics and non-parametric ranking will be used to distinguish study areas of low and high murrelet density.

C. Cooperating Agencies, Contracts and Other Agency Assistance

We have the expertise and technical support to perform the majority of our geographic information system (GIS) needs. As coverages are developed for nearshore and pelagic areas of Prince William Sound by other projects, we may require agency support to obtain files. Our study will integrate data on forage fish and oceanographic conditions obtained by APEX (NOAA) and the SEA studies.

SCHEDULE

A. Measurable Project Tasks for FY 98 (October 1, 1997-September 30, 1998)

Oct. 1- Dec. 31:	Prepare GIS coverage of transects and study sites
	Prepare NEPA compliance documents and USFS permits
	Rewrite and submit manuscripts submitted to journals
January:	Present paper at Pacific Seabird Group meeting
	Attend annual Restoration Workshop
Feb 1-March 15:	Arrange logistics for boats, equipment, contracts
March 1-May 30:	Hiring and training
April 15:	Submit Annual Report (FY97 findings)
June 1 - 15:	Conduct baseline surveys
June 15-July 20:	Enter data, prepare for late-summer surveys
	Conduct diet observations at PWS and Kachemak Bay
July 21-August 20:	Juvenile surveys
Aug 21-Sept 1:	Store equipment, data entry
September 1- 30:	analysis of field data

B. Project Milestones and Endpoints

The primary objective of this project (Objective 1) depends on obtaining a reliable index of relative forage fish abundance to correlate with the juvenile : adult murrelet productivity index. The success of this portion of the project will be determined by the end of the first season. Data with finer resolution, specifically biomass calculations based on ground-truthing of digital hydroacoustic data, may be obtainable in 1998 or 1999. Intra-annual comparisons of the productivity and fish indices will be made available in annual reports. A synthesis of inter-annual comparisons will be reported in the final report. Spatial comparisons will also be made between PWS and Kachemak Bay, in cooperation with project 97163M (Cook Inlet studies), to be presented in the final report.

The second objective will be met by preliminary examination of FY97 observation sessions, which will be used to refine the methodologies used in FY98. This objective has two components- descriptive and comparative. The objective will be met when we can provide a list of the prey used by murrelets feeding chicks, and the relative importance of different species among sites, regions, and temporally. The second component will be addressed by comparing murrelet diet with the prey types identified through the APEX forage fish projects.

The third objective will be a synthesis of results from FY97-99, and will be met when we have information sufficient to model terrestrial and marine habitat and prey use by murrelets. The data on forage fish distribution and mechanisms of fish availability to murrelets (APEX studies) will be necessary to complete these objectives, so that interim analyses will be finalized after all field work is completed.

C. Completion Date

All of the objectives will be met by FY 01. ?

PUBLICATIONS AND REPORTS

April 15, 1998:	Annual Report and Summary of work accomplished in summer 1997, and preliminary findings.
April 15, 1999:	Annual Report and Summary of work accomplished in summer 1998, and preliminary findings.
April 15, 2000:	Annual Report and Summary of work accomplished in summer 1999, and preliminary findings.
April 15, 2001:	Draft final report of research, 1997-1999.

Interim aspects of this study will be submitted for publication in journals periodically between 1998-2000. Following the final field season, synthesis papers will be submitted. In addition, the Principal Investigator will be co-author on papers related to the pigeon guillemot project in FY97 (see 96163E, kittiwakes and 97163F, guillemots). Proposed articles derived from the murrelet project are listed below:

> Terrestrial and marine factors determining the at-sea distribution of marbled murrelets in Prince William Sound, Alaska.
>
> Factors influencing the distribution of juvenile marbled murrelets in Prince William Sound, Alaska.
>
> Spatial and temporal differences in the diet of marbled murrelets in southcentral Alaska and possible effects on productivity.
>
> The relationship between indices of forage fish abundance and marbled murrelet productivity in 1997 and 1998 in southcentral Alaska.

PROFESSIONAL CONFERENCES

Annual findings will be presented at symposia and conferences. Preliminary findings of the population changes will be presented at the International Symposium on Changes in Pacific Seabirds in Asilomar, California in 1998.

NORMAL AGENCY MANAGEMENT

It is not part of normal agency management in Region 7 of U.S. Fish and Wildlife Service to monitor the productivity of marbled murrelets.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The marbled murrelet is one of the injured species that is targeted by the APEX project (97163). Because the marbled murrelet requires specific methods and protocols not consistent with that of other seabirds being studied, the murrelet project is proposed independently. However, it will be fully integrated with APEX and the study design has been developed interactively with APEX principal investigators.

This project is dependent on the APEX project to provide fish abundance data to test the main hypothesis (Project 97163A). The mechanistic interactions between murrelets and forage fish described by Project 97163B (seabird foraging) will be used to develop the integrated terrestrial/marine murrelet distribution model. Productivity comparisons among years will be made in the context of other seabirds (Projects 97163E, kittiwakes and 97163F, guillemots). The relative value of different prey species, critical to the diet hypothesis of this project, will be described by Project 97163G (seabird energetics).

The comparison between PWS and Kachemak Bay will be done in conjunction with Cook Inlet studies (97163M), which will also provide relative forage fish abundance for that region. Information exchange relative to herring and other nearshore prey will occur between this project and the SEA and NVP projects. Although this project was initiated for the marbled murrelet, data for both *Brachyramphus* species (marbled and Kittlitz's) can be collected simultaneously, and thus will benefit the Kittlitz's murrelet restoration effort.

PROPOSED PRINCIPAL INVESTIGATOR:

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PRINCIPAL INVESTIGATOR

Kathy Kuletz received her B.S. degree in Biology from California Polytechnic State University, San Luis Obispo (1974), and her M.S. degree in Ecology and Evolutionary Biology from University of California, Irvine (1983). Her thesis was on the foraging and reproductive success of pigeon guillemots at Naked Island, Prince William Sound. Ms. Kuletz has worked in Alaska since 1976 for Dames and Moore Consulting, LGL Alaska Research and the U.S. Fish and Wildlife Service. Since 1989 she has been Principal Investigator for the marbled murrelet damage assessment and restoration studies. She has been working with the Pacific Seabird Group Marbled Murrelet Technical Committee to develop protocols for inland and at-sea murrelet surveys. She participated in and assisted in the writing of the Pacific Seabird Group Restoration Workshop in 1995.

Peer-reviewed publications:

Carter. H.R. and K.J. Kuletz. 1995. Mortality of marbled murrelets due to oil pollution in North America. Pages 261-270 *In*: C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael and J.F. Piatt (eds), Ecology and Conservation of the Marbled Murrelet. USDA For. Serv. Gen. Tech. Rep. PSW-GTR-152.

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Recently submitted:

D.K. Marks and K.J. Kuletz. Use of Forested &Unforested Nesting Habitat by Marbled Murrelets in Southcentral Alaska (written for Condor).

Kuletz, K.J. Marbled Murrelet Synthesis Account for *Exxon Valdez* Oil Spill Restoration Notebook. EVOS Restoration Notebook Series.

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OTHER KEY PERSONNEL

Field Supervisor/GIS Assistant: Steve Kendall

Mr. Kendall will supervise data collection in the field in the absence of the project leader. He will prepare maps, coordinate logistics with other projects, assist in data entry, conduct at-sea surveys and provide GIS data and analysis for reports. He has extensive experience conducting at-sea surveys in Alaska from his work on USFWS boat surveys, as a boat operator and biologist. Mr. Kendall has provided GIS support and analysis for previous murrelet studies and marine bird surveys of Prince William Sound, lower Cook Inlet and Southeast Alaska.

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S
Jellyfish

JELLYFISH AS COMPETITORS AND PREDATORS OF FISHES

Project Number:	98163S
Restoration Category:	Research and Monitoring
Proposer:	University of Maryland System, Center for Environmental and Estuarine Research, Horn Point Environmental Laboratory
Lead Trustee Agency:	NMFS
Cooperating Agencies:	
Alaska SeaLife Center:	JNo.
Duration:	First year, 4-year project
Cost FY 97:	$103.5
Cost FY 98:	$110.6
Cost FY 99:	$ 70.2
Cost FY 00:	$ 67.0
Geographic Area:	Prince William Sound
Injured Resource:	Predators of forage fish e.g. pigeon guillemots, murrelets, and zooplanktivorous fishes i.e. Pacific herring, pink salmon

ABSTRACT

At high densities, jellyfish can seriously effect populations of zooplankton and ichthyoplankton, and may be detrimental to fisheries through competition for food with fishes and by direct predation on the eggs and larvae of fish. I propose to examine the roles of jellyfish as competitors and predators of fishes. This will be accomplished by participating in ongoing APEX research cruises in Prince William Sound, in which zooplankton, ichthyoplankton, and gelatinous zooplankton distributions and densities will be determined. Additionally, medusae will be collected for gut content analysis and gut passage time experiments to calculate feeding rates on zooplankton and ichthyoplankton. Feeding rates will be correlated with medusa size and prey densities in order to be able to predict the importance of

predation and competition in future years from population data only. This project will coordinate with the APEX project, which will provide logistic support in the field, analysis of zooplankton and ichthyoplankton from the samples, and dietary data for the forage fishes, which is critical in determining dietary overlap with jellyfishes and the potential for competition. In collaboration with APEX and SEA scientists, I plan to compile historical, existing and future data in order to obtain the most comprehensive picture of the importance of jellyfish in PWS.

INTRODUCTION

I propose to examine the importance of jellyfish and ctenophores as competitors and predators of fishes. When herring larvae hatch, a suite of jelly and ctenophore species are present in British Columbia that eat the larvae (PURCELL, 1990). Population densities of these predators are higher in bays and inlets than along open coast (PURCELL, 1990). The same species are present in Alaskan waters, including *Aequorea victoria,* which was the key predator at herring spawning grounds of Vancouver Island. *Aequorea* and large scyphomedusae present in Alaska during the summer (i.e. *Cyanea capillata, Phacellophora camtschatica, Chrysaora fuscescens*) are predators of the pelagic eggs and larvae of fish species in addition to herring, many of which are commercially important (e.g. rockfish, cod, flatfish; FANCETT, 1988; PURCELL, 1989, 1990) and are important as forage fish of marine vertebrates, specifically piscivorous fish, sea birds, and harbor seals. Medusae have potentially great effects on fish populations because of their often great abundances and feeding that increases directly with prey density without saturation.

Not only do these predators feed directly on the early stages of fish, but they eat the same zooplankton foods as well (Table 1)(PURCELL, 1990, PURCELL and GROVER, 1990; BAIER and PURCELL, 1997). The dual role of soft-bodied plankton as predators and competitors of fishes has been suggested many times (e.g. PURCELL, 1985; ARAI, 1988), but seldom has been evaluated directly (existing studies are PURCELL and GROVER, 1990; BAIER and PURCELL, 1997). The following background provides details of research on gelatinous species to determine their effects on ichthyoplankton and zooplankton populations.

Dietary analyses. Copepods are the main prey items of most gelatinous predators, however, the diets of some species include high proportions of fish eggs and larvae when available (Table 1). Such predators include hydromedusae, in particular *Aequorea victoria,* whose diet consisted of almost exclusively Pacific herring (*Clupea harengus pallasi*) larvae in April when the larvae hatched (PURCELL and GROVER, 1990) and a variety of eggs and larvae of other species of fish later in the spring in addition to gelatinous and crustacean prey (PURCELL, 1989). Semaeostome scyphomedusae may also contain large numbers of ichthyoplankton prey when available in addition to gelatinous and crustacean prey (e.g. *Cyanea capillata, Chrysaora quinquecirrha* in FANCETT, 1988 and PURCELL *et al.*, 1994, respectively). Prey selection by these predators for fish eggs and larvae has been positive in every case in which it was calculated (FANCETT, 1988; PURCELL, 1989; PURCELL *et al.*, 1994).

Predation effects by pelagic cnidarians on fish larvae often are substantial ($\geq$ 30% d^{-1} of the populations) in environments where predators are numerous, as for the scyphomedusan *Chrysaora quinquecirrha,* the hydromedusan *Aequorea victoria,* and the siphonophores *Rhizophysa eysenhardti* and *Physalia physalis* (PURCELL, 1981, 1984, 1989; PURCELL and GROVER, 1990; PURCELL *et al.*, 1994). The numbers of bay anchovy eggs and larvae in the gut contents of C. *quinquecirrha* were significantly related to prey density and medusa diameter (PURCELL *et al.*, 1994). Predation by C. *quinquecirrha* on bay anchovy eggs averaged 19% of the population over 9 sampling days in Chesapeake Bay. Other estimates of predation effects by pelagic cnidarians on fish eggs were low (0.1 to 3.8% d^{-1}; FANCETT and JENKINS, 1988). Intense daily predation on ichthyoplankton can have serious consequences since the spawning period of the fishes may be limited (e.g. Pacific herring spawn once annually).

Several estimates of predation effects of gelatinous species on copepod populations suggest that the effects are too small to cause prey population declines (e.g. $\leq$ 10% d^{-1}; KREMER, 1979; LARSON, 1987a; PURCELL and NEMAZIE, 1992; PURCELL, WHITE, and ROMAN, 1994). However, some studies indicate much higher predation and possible reduction of zooplankton standing stocks (e.g. $\leq$ 20% d^{-1}; DEASON, 1982; MATSAKIS and CONOVER, 1991; PURCELL, 1992). Copepod capture by *Chrysaora quinquecirrha* was significantly related to prey density, medusa size, and temperature. During July and August 1987 and 1988 in two tributaries of Chesapeake Bay, medusae consumed from 13 to 94% d^{-1} of the copepod standing stocks, and may have caused the observed copepod population decline.

The possibility of competition for food among jellyfish and fish has been directly examined in only a few studies. Potential competition between medusae and first-feeding herring during one spring in British Columbia was found unlikely to be important due to the great abundance of copepod nauplii consumed by the larvae (PURCELL and GROVER, 1990). However, when the prey were copepodites, chaetognaths consumed significant percentages of the same prey as fish larvae off the southeast U.S. coast (BAIER and PURCELL, 1997).

At high jellyfish densities, as can occur especially in semi-enclosed bodies of water such as PWS, predation on copepods may limit copepod populations and cause competition for food with zooplanktivorous fish species and fish larvae . Predation by jellyfish on fish eggs and larvae can be very severe. Medusae that specialize on soft-bodied prey like ichthyoplankton (*Aequorea, Cyanea, Chrysaora*) often occur in areas of intense spawning activity and are major sources of fish egg and larva mortality.

Abundance of jellyfish in Prince William Sound. In July, 1996, I was invited to participate in the SEA sampling in PWS by Dr. Gary Thomas. During the field work, I observed the abundance of jellyfish in northern PWS from aerial surveys and from trawls and acoustic surveys. Massive aggregations of *Aurelia* 1/4 to 2 km long were seen commonly from the air and by acoustics. *Cyanea* and *Aequorea* were distributed throughout PWS, but had higher densities in some areas (e.g. Irish Cove). The plane and acoustics boat would notify the seiner where to set his net on a fish school, but often more jellyfish than fish were in the net. I also compiled existing data from the Alaska Dept. Of Fish and Game collected during SEA cruises that showed in drift seines, which were not set specifically on fish schools, jellyfish biomass often exceeded fish biomass in PWS (Fig. 1). Researchers from SEA and APEX have observed the great abundance of jellyfish in PWS and recognize the need to understand their effects on the zooplankton and fish populations there.

NEED FOR THE PROJECT

A. Statement of Problem

The project will address two of the main causes of natural mortality in fish populations, namely predation and food limitation (through competition). It will specifically target forage fish species such as Pacific herring, sand lance, and juvenile pollock that are major prey of sea birds (e.g. pigeon guillemots) and other vertebrates (i.e. harbor seals) that have not recovered from the Exxon Valdez Oil Spill. This project addresses the APEX hypothesis that sea bird recovery has been hampered by changes in their food base (i.e. forage fishes).

B. Rationale/Link to Restoration

Many natural factors that cannot be controlled by human efforts affect mortality in fish populations. It is important to estimate the magnitude of the various sources of mortality in order to evaluate those that are most important. This research will contribute to understanding the dynamics of forage fish populations, by determining the magnitude of jellyfish predation on their zooplankton foods and direct predation on their eggs and larvae. The forage fish populations continue to be reduced relative to pre-EVOS levels, and that would contribute to the lack of recovery of vertebrate species that depend on forage fish for food.

C. Location

Prince William Sound

COMMUNITY INVOLVEMENT

This project will use local personnel associated with the boat charters. During my visit to Cordova in July 1996, I gave a public presentation on the importance of jellyfish as predators and competitors of fishes and an interview with Sound

Waves, which was broadcast locally and in Anchorage. Similar efforts at public education will be made throughout this project.

PROJECT DESIGN

A. Objectives

1. Determine the species composition, size distributions, and abundances of jellyfish and ctenophores in Prince William Sound.

2. Determine the gut contents for key gelatinous predators (*Aurelia, Cyanea, Chrysaora, Phacellophora, Aequorea* and other hydromedusae, *Pleurobrachia* ctenophores).

3. Determine the gut passage (digestion) times for key predator species fed key prey taxa (e.g. copepods, larval herring).

4. Calculate size-specific feeding rates for each key predator species based on gut contents and gut passage times, and correlate feeding rates with medusa size and prey densities in order to be able to estimate feeding impacts in other years from jellyfish size distributions and jellyfish and zooplankton densities.

5. Calculate dietary overlap indices for medusae and forage fish species.

6. Calculate predation impacts on key prey taxa based on feeding rates and densities of predator and prey species.

7. Contribute these results to the APEX, SEA and overall EVOS modeling efforts.

8. Compile historical data (Alaskan peninsula) and all available EVOS data (PWS) on jellyfish distributions and abundances.

B. Hypotheses

This project will test the following null hypotheses:

1. Distributions and abundances of jellyfish are independent of zooplankton, ichthyoplankton, and forage fish distributions.

2. Abundances of key predator species are similar among years (specifically addressing "river-lake" processes).

3. Jellyfish diets do not overlap with forage fish diets, and consequently, they are not competitors for zooplankton prey. Competition for copepods could amplify diet switching by fishes from copepods to fish.

4. Jellyfish predation does not limit zooplankton populations, and consequently competition for food does not occur between them.

5. Jellyfish are not important predators of ichthyoplankton.

6. Long-term jellyfish population abundances along the Alaskan Peninsula do not correlate with environmental factors or abundances of other species (i.e. shrimps, fish).

C. Methods

Distribution and abundance. This project will utilize zooplankton samples collected by APEX investigators using a fine mesh CALVERT plankton net with flowmeter. All but one gelatinous species (lobate ctenophore *Bolinopsis*) from this area preserve well in 5% Formalin. My technician will assist APEX in the analysis of these samples; the data will be stored in the APEX data base. Zooplankton will be identified and counted from subsamples. Ichthyoplankton and small gelatinous species will be removed from whole samples. Small hydromedusae, ctenophores and ichthyoplankton will be identified and counted by my technician. Data on zooplankton and ichthyoplankton densities, as well as CTD data, will be made available to me from APEX for all appropriate cruises.

Quantitative samples will be taken with a 1 m^2 NIO/Tucker Trawl (505 or 1000 m mesh) at the same times and locations as the zooplankton samples to determine abundances of large medusae (*Cyanea, Chrysaora, Phacellophora, Aurelia, Aequorea*). The samples will be processed on board ship; the medusae will be identified, counted, the swimming bell diameter measured, and biovolumes of each species measured. I trained SEA investigators during 1996 so that such data will be taken routinely on all SEA cruises, and I will train APEX investigators according to the same protocol.

These data on gelatinous zooplankton distributions and abundances will be compared with those for zooplankton, ichthyoplankton, and forage fish species, with the cooperation and assistance of APEX investigators. Data management and analysis will be accomplished in direct collaboration with APEX scientists in order to maximize the comparability of results.

Gut contents. Gut contents of small hydromedusae and ctenophores will be analyzed from specimens picked out of the above zooplankton samples. Additional specimens may need to be collected in gentle net tows using a 1-m diameter soft mesh (1.6 mm) plankton net that reduces gut evacuation and cod-end feeding (as in PURCELL 1990). Individual collection, which is preferable, is not practical for these small species. Individual large medusae (*Cyanea, Chrysaora, Phacellophora, Aurelia, Aequorea*) will be dipped from the surface at sampling locations. This will be done during trawls and net collections, and will not interfere with APEX operations. Collection by SCUBA divers is desirable, but impractical due to the large time investment. At least six specimens of each species present will be collected at each station, if possible. The medusae will be immediately preserved in 5% Formalin. The samples will be transported to J. Purcell's laboratory for later gut analysis using a dissecting microscope (available at HPEL). Prey taxa in the guts will be identified, counted, measured with the aid of a CUE-2 image analysis system available at HPEL. Collection of uncontaminated gut contents in this way is preferable to retrieval of specimens from plankton nets, which can result in extraneous prey being ingested from the net, or in evacuation of gut contents (see PURCELL, 1989). The gut content method minimizes laboratory artifacts, and it reveals the true diets of the predators. Feeding rates estimated from gut contents in the field always have been higher when compared with laboratory-determined rates (SULLIVAN and REEVE, 1982; PURCELL, 1982, 1992; PURCELL and NEMAZIE, 1992).

Alternatively, feeding rates can be measured in laboratory containers by determining the change in prey densities over time. Such methods may be adequate for small, inactive predators (but see PURCELL and NEMAZIE, 1992). However, the key jellyfish species in Prince William Sound are large and active, especially considering the extension of tentacles, and extremely large containers would be necessary for undisturbed feeding. When comparisons of results among container sizes have been made, feeding always has been lower in the smaller containers, indicating interference with feeding in containers. For example, DE LAFONTAINE and LEGGETT (1987) found significantly lowered feeding rates by *Aurelia aurita* in all containers less than 6 m^3 in volume. Therefore, the gut content method is clearly preferable for this study.

The diameter of an additional 20 specimens of each species will be measured live and then remeasured after preservation (1, 3, and 6 months storage) to determine correction factors for shrinkage due to preservation, in order to convert sizes of preserved gut content specimens to sizes of specimens collected in the trawls.

Gut passage times. Individual medusae will be collected in dip nets or by SCUBA divers and transported in buckets of water to a shore-based laboratory (School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, located in Juneau, AK). They will be maintained at water temperatures found in PWS in ≥ 20 liter containers of seawater with *Artemia* nauplii. The medusae will be allowed to clear their guts of natural prey (8-12 h), then they will be allowed to feed briefly on copepods, herring larvae, or other key prey taxa. The medusae then will be transferred immediately, and at 1 h intervals, to clean containers of filtered seawater with *Artemia*, which promotes natural gut emptying as digestion of the test prey proceeds. After each medusa transfer, the water will be poured through a 60 m screen and the crustacean exoskeletons or fish eye lenses counted and measured using a dissecting-microscope, thus recording all crustaceans or herring egested each hour (as done for *Chrysaora* in PURCELL, 1992). Alternatively, for small medusae species, the disappearance of prey may be monitored visually for individual specimens (as done for *Aequorea* in PURCELL, 1989). The time between ingestion and egestion of the prey remains will be used in calculations of feeding rates.

Accurate determination of gut passage times is laborious because the times may depend on prey size or type, temperature ($p = 0.001$), and numbers of prey in the gut ($p = 0.08$)(PURCELL, 1992). Medusa size did not significantly affect gut clearance times (PURCELL, 1992; PURCELL et al., 1994). Generally digestion of copepods requires about 2 to 4 h for a variety of pelagic cnidarian species occurring at greatly different temperatures (e.g. LARSON, 1987a; PURCELL, 1982, 1992; PURCELL AND NEMAZIE, 1992). Gut passage times for fish larvae are dependent on larval size, with small larvae (e.g. bay anchovy < 4 mm) being digested in 1 h at 26°C and large larvae (e.g. herring 8 to 15 mm) being digested in 2 to 6 h at 8°C (PURCELL, 1981, 1989; PURCELL *et al.*, 1994). Gut passage times will be measured over the range of temperatures appropriate for each species (between 5 and 15°C), for a variety of prey types, and for different numbers of ingested prey, and analyzed in a multiple regression for each species, which then can be used to calculate digestion rates from field data (as in PURCELL, 1992).

Calculations of feeding rates and impacts. Data on the numbers of prey in the guts will be divided by gut passage times to calculate feeding rate (No. of prey eaten h^{-1} $medusa^{-1}$). Multiple regression analyses will be conducted for each key predator species and each key prey species where the independent variables are water temperature, prey density, and medusa diameter, and the dependent variable is feeding rate (see PURCELL, 1992; PURCELL *et al.*, 1994). These multiple regressions can then be used to calculate feeding rates for medusae from other years and locations given population density data. The individual feeding rates will be multiplied by medusa densities and divided by prey densities to determine the daily impacts of the medusae on the various prey populations.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

This project as part of the APEX project will work closely with Subproject A of APEX. The data will also be essential for the carbon balancing models of PWS that are ongoing.

SCHEDULE

A. Measurable Project Tasks for FY 98 (October 1, 1997 - September 30, 1998)

Oct. 1 - April 30:	Analyze field samples from summer 1997, data analysis
January:	Attend Annual Restoration Workshop
May 1 - August 31:	Field sampling
July - September:	Gut clearance rate experiments
September:	Begin analysis of 1998 field samples

B. Project Milestones and Endpoints

1998. Complete analysis of 1997 field samples and data. Qualitatively evaluate effects of each key predator species on each key prey species in order to plan future work. Begin analysis of 1998 field samples and data. Compile historical data from the Alaskan Peninsula, and begin compilation of earlier SEA and APEX jellyfish population data.

1999. Complete analysis of 1998 field samples and data. Intensive gut passage experiments. Begin analysis of 1999 field samples and data, and calculations of feeding rates and impacts.
Continue compilation of all EVOS jellyfish population data and begin multi-year data analyses. Begin preparation of manuscripts.

2000. Complete analysis of 1999 field samples and data. Continue calculations of feeding rates and impacts. Complete compilation of EVOS jellyfish population data and begin multi-year data analyses. Continue preparation of manuscripts.

2001. Complete multi-year data analyses and calculations of feeding rates and impacts for 1997-1999. Preparation of manuscripts.

C. Completion Date

The field work will be completed in 1999. Because of the ongoing nature of the gut passage experiments and because 1999 will include field work, all of the objectives will not be met until FY 2001.

PUBLICATIONS AND REPORTS

It will be too early in the project to submit manuscripts for publication in 1998. Manuscripts are anticipated featuring the predation effects of each key predator species, and an overview manuscript on the 3-year predation effects on the key prey species. A separate manuscript on dietary overlap among jellyfish and forage fishes, and the potential for competition for zooplankton prey is anticipated. I expect one manuscript will cover the species distributions and abundances of gelatinous predators historically along the Alaska Peninsula, and a separate manuscript that covers SEA and APEX data in PWS. Because I will rely on APEX investigators for zooplankton, ichthyoplankton and fish gut content data, and on APEX and SEA investigators for some population data on jellyfish, the analyses and manuscript preparations will be highly collaborative efforts and the manuscripts multi-authored. The required reports will be prepared in each year.

PROFESSIONAL CONFERENCES

I will present results from this research at one meeting in 1998, either The American Society of Limnology and Oceanography, which will meet with the American Geophysical Union, or the Early Life History Meeting of the American Fisheries Society, or another meeting if more appropriate.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will coordinate with the APEX project sampling. As planned, my project will be able to utilize their ship time and their zooplankton, ichthyoplankton, and forage fish collections, thus maximizing the return on those sampling efforts. The work proposed involves extensive collaboration with the APEX and SEA research teams. I hope to be able to produce a comprehensive picture of the importance of jellyfish in PWS, which will be best achieved with the cooperation of both groups. I have spoken with several PIs (Cooney, Thomas, Kline, Brown, Duffy, Haldorson, Wright, Sturvesant, Anderson) and believe a great deal can be learned through these multiple collaborations. The major equipment items will be provided by the APEX project.

PROPOSED PRINCIPAL INVESTIGATOR

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PERSONNEL

Jennifer E. Purcell, Principal Investigator

Education:

B.S., Stanford University, Stanford, California, 1976
M.S., Stanford University, Stanford, California, 1976
Ph.D., University of California, Santa Barbara, California, 1981

Professional Experience:

Postdoctoral Scholar and Investigator, Woods Hole Oceanographic Institution, Woods Hole, MA, 1981-1983.
NATO Postdoctoral Fellow, University of Victoria, Canada, 1983-1984, and Visiting Scientist, 1984-1986.
Assistant Professor, College of Oceanography, Oregon State University, 1984-1986.
Visiting Assistant Professor, Friday Harbor Laboratories, University of Washington, 1986-1987.
Assistant Professor, Horn Point Environmental Laboratory, University of Maryland System, 1987-1992.
Visiting Assistant Professor, The Whitney Laboratory, University of Florida, 1990-1991.
Associate Professor, Horn Point Environmental Laboratory, University of Maryland System, 1992-present.

Research Interests:

Trophic ecology, population dynamics, and physiology of gelatinous zooplankton. Predation on ichthyoplankton and gelatinous zooplankton. Selective predation.

Background Relevant to the Proposed Research:

I have had extensive experience studying soft-bodied zooplankton as predators and competitors of larval fishes. I have 11 peer-reviewed publications (of 43 total) specifically on that topic, most of which are in the following Literature Cited section. The remaining are listed below. I also have considerable experience in the waters of the northeast Pacific from Oregon to Alaska. I spent all or part of eight years working in those waters, including nearshore and offshore operations. The following citations include 3 on salps from Ocean Station P. My experience with sampling includes the special techniques for gelatinous zooplankton, including dry-suit diving; MOCNESS, Tucker Trawl, plankton net and diaphragm pump sampling for zooplankton and ichthyoplankton; and Otter Trawl and Mid-water Trawl collection of fish.

In July 1996, I participated in field sampling with the SEA program. This enabled me to observe the incredible abundances of jellyfish in PWS firsthand, and to see the seining operations and aerial surveys as well as the plankton sampling. In July 1997, I plan to participate in APEX field work in PWS, and begin gut clearance studies at the School of Fisheries and Ocean Sciences of the University of Alaska, Fairbanks, at Juneau, AK. In anticipation of devoting major effort to the study of jellyfish in PWS, I have requested a sabbatical leave from my university beginning in Fall 1997, to be hosted in Juneau. This will greatly facilitate collaboration between myself and APEX investigators.

My responsibilities will be to participate in all APEX cruises in 1998 and some in following years. I will train APEX personnel and my technician in the methods needed so that data can be collected on all cruises regardless of my presence. I will oversee all aspects of this research, closely supervise my assistant, and have primary responsibility for data analysis and preparation of reports and manuscripts. I will hire a technician devoted to this project who will be responsible for gut analysis of the jellyfish and for the gut passage experiments, and will participate in some cruises. Additional responsibilities of the technician will include data base management and analyses of the data with my supervision.

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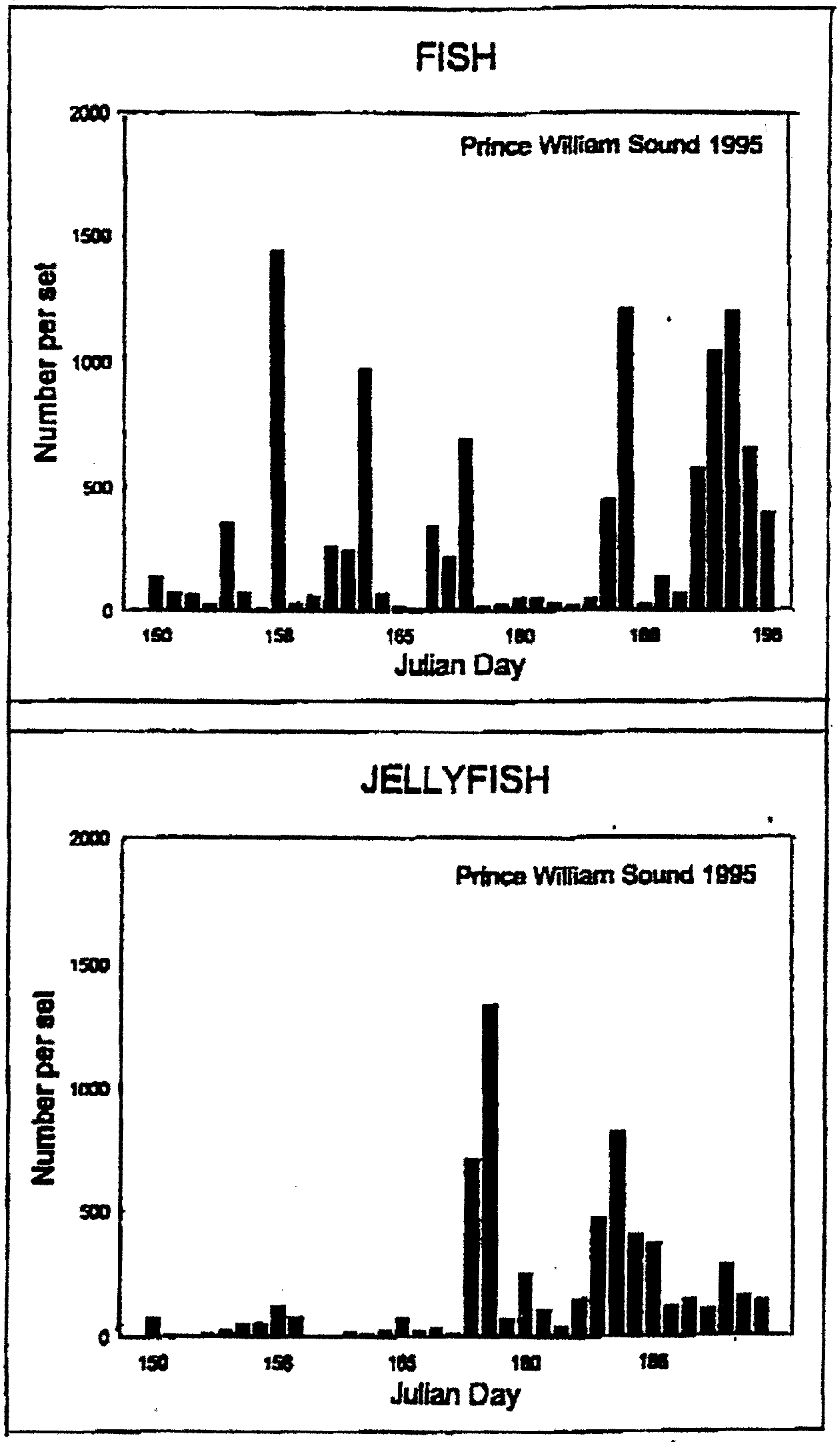
Table 1. The diets of jellyfish contain mostly zooplankton, in addition to ichthyoplankton

	% of prey in jellyfish diets					
Species	Copepods	Cladocerans	Meroplankton	Larvaceans	Fish eggs and larvae	Gelat. Zoopl.
Cyanea capillata[1]	10.7	29.1	2.6	30.5	14.3	9.0
Aurelia aurita[2]	55.3	12.5	0.6	-	30.3	1.3
Aequorea victoria[3]	42.9	0	6.5	35.1	2.5	13.0
Chrysaora quinquecirrha[4]	48.2	10.6	0.7	-	40.4	-

[1] Fancett and Jenkins (1988), Jul-Oct, 1984-1986, Australia
[2] Moller (1984), May-June, 1979, Germany
[3] Purcell (1989). After herring larva hatch. April, 1983, British Columbia
[4] Purcell et al. (1994), July, 1991, Chesapeake Bay



Catches of jellyfish in drift trawls often exceeded catches of fishes in June 1995 in PWS. Data courtesy of Dr. Mark Willette, Alaska Dept. of Fish and Game, Cordova, AK.

Protocols

MARBLED MURRELET PROTOCOL - VERSION 1.1 3/10/97

Marbled Murrelet Protocol for studies (APEX Projects) in Prince William Sound and Kachemak Bay for field season 1997.

Compiled by Kathy Kuletz and John Piatt

A. Productivity

1. *Survey design and general methods*

Productivity will be gauged by an index based on the relative numbers of after-hatch-year (AHY) birds and hatching-year (HY) birds on the water. A study site is an area with approximately 40 km of continuous shoreline. There will be 3 study sites in Prince William Sound (PWS) and 2 sites in Kachemak Bay. Surveys at a given site should be separated by at least 2 days. One survey crew will rotate among sites in PWS, another crew will rotate between shoreline and pelagic/coastal surveys in Kachemak Bay.

General aspects of the at-sea surveys will follow the protocol developed for the boat surveys conducted by Migratory Bird Management (Klosiewski and Laing 1994, unpubl. protocol). Surveys will be conducted from small boats, usually 25 ft. whalers, although in some instances 15 ft inflatable can be used. Normal cruising speed during surveys for the boat will be approximately 8-10 kph. The boat will travel parallel to shoreline 100 m from shore, and observers will count all birds and mammals from shore to 200 m offshore. Where bottom topography prohibits traveling close to shore, the boat will parallel the shoreline as close as possible and count birds from shoreline to 200 m offshore. Surveys will be conducted between 0600-1600 hours.

In PWS, we documented that few juvenile mamu were >200 m offshore, and those were inside bays. In Kachemak, however, reconnaissance surveys indicate that murrelets, including juveniles, are relatively common >200 m offshore, especially in areas with kelp beds. Therefore, in 1997 we will survey both shoreline and pelagic/coastal transects in Kachemak Bay. The pelagic/coastal transects will be selected from a systematic selection of 2 km transects, to total about 30 km. Pelagic/coastal transects will run perpendicular to the nearest shoreline, including islands. On these, observers will record all birds and mammals 100 m from either side of the boat. If a transect runs into shore, the section <200 m from shore will be recorded separately.

Although we will be recording all marine species, murrelets always have priority. Thus, in very active areas, murrelets will be counted first and other species will be approximated as time allows. Observers will be instructed not to focus on distant non-murrelets, or spend undue time observing other birds, in attempts to identify them to species, as they will likely miss murrelets near the boat. Unless a murrelet can be identified to species, it will be recorded as a *Brachyramphus* murrelet.

2. Estimate of breeding population.

A baseline survey of the AHY population will be done for each study site. Three surveys of each area will be conducted at each site between 1-15 June. During all surveys, birds in complete breeding (althernate) plumage will be the default plumage. Birds in transitional plumage will include birds with <25% white on their belly (code T2) and 25-75% white (code T3). Birds with >75% white belly, or black-and-white birds, will be examined the same as black-and-white birds observed in July/August surveys (see below).

3. Estimate of juvenile abundance and ratio to adults

Juvenile surveys in late summer must accommodate inter-annual changes in peak fledging dates, and higher day-to-day variability (Kuletz et al. 1996), therefore, each site will have 6 replicates. Thus, in PWS, there will be at least 9 surveys in June (3 sites x 3 replicates) and 18 surveys in July/August (3 sites x 6 replicates). More replicates will be obtained in July/August if weather and logistic arrangements permit.

Observers will be trained to score birds by plumage and behavioral characteristics (Carter and Stein 1995, Kuletz et al. 1996), using photos, study skins, drawings and on-sight training to standardize observers. When a black-and-white (B&W, or possible juvenile) murrelet is observed, the boat operator will enter the GPS location, note the time, water depth and approximate distance offshore of the bird. The survey will be interrupted until the black-and-white bird is identified, disappears, or 10 min elapses. During that time the boat may go off course to track the targeted bird. Once identification or termination is reached (and time noted), the boat will return to the original position and the transect will resume.

New B&W birds that appear during this identification effort will be recorded as well, and the crew will attempt to keep track of all birds. Even B&W birds that can not be followed will be recorded, and unless an identification is made quickly, will be entered as 'unknown'.

B&W birds will be classified as one of five possible categories:
(1) definite juvenile, (2) possible juvenile, (3) unknown, (4) possible adult, and (5) definite adult.

A data format will allow observers to check off siting of key identification characteristics (white above bill, neck band, speckling on breast, missing feathers, etc.), behavior of the bird (diving, flying, foraging), presence of and interaction with other birds, relative body size, and outcome (identification successful or unsuccessful, bird flys off, bird disappears).

Data analysis. -- We will test for differences in the absolute numbers and ratios of juveniles : adults among sites, using Z tests on the standard error of the ratios (Manley et al. 1993). The ratio of juveniles will also be calculated relative to total murrelets in June (presumably the local breeding population), and compared among sites with a Kendall *taub* correlation test. A non-parametric ranking test will be used to determine if relative prey abundance among sites is correlated with relative murrelet and juvenile murrelet density.

B. Diet

We will document murrelet prey species by visual observations of murrelets on the water holding fish in their bill. We will primarily target prey items destined for chicks and thus will concentrate prey observation surveys during the peak chick-rearing period. The beginning of chick-rearing will be based on first observation of birds holding fish on the water surface or an adult flying with a fish in its bill.

The main observation sessions will be conducted in between the at-sea surveys, late June to mid July. Opportunistic observation sessions will be made throughout the July/August juvenile surveys. We will attempt to obtain a minimum of 50 identified prey items per site at four sites: Naked Island and Jackpot/Dangerous Passage in PWS, and Glacier spit (inner bay) and Herring Islands area (outer bay) in Kachemak Bay.

Observation sessions will be conducted primarily after dawn and around sunset, to maximize observations of prey destined for chicks. A session should be timed to allow 2-3 hours of observation with enough light to identify prey (this will depend on changing sunrise/sunset time, cloud cover and weather). An observation session will be a minimum of 2 hours, conducted from a boat or a land-based position where feasible. Specific sites within the general areas can be altered, depending on where murrelets are foraging most frequently during twilight hours.

From a boat, 2 observers will operate from a small boat, cruising foraging areas and stopping to identify prey items of foraging birds. If a good forage site is identified, the observers can anchor in place or drift with the motor off. At the beginning of an observation session observers will record start and stop time, weather and sea conditions, water depth and distance from shore. For each observation of a bird with fish the observers will record time, location, plumage of the bird, prey to nearest taxon, size of prey relative to length of the head-to-bill tip, and outcome of the observation (swallowed by bird, bird flys off with fish, bird remains on water with fish etc.). Additional observations about diving behavior or handling time will be recorded.

To identify the prey, observers will use binoculars (from boats) and spotting scopes (from land). A field guide will be prepared prior to the season that will illustrate fish species and point out key features to look for. A field training session will also be done in June to familiarize the observers with fish common in the study areas. This will be done in association with concurrent trawl and seining operations of the APEX fish studies. Refresher training sessions will be done throughout the summer. If the observer can not identify the fish, but notices key features (such as adipose fin, tail shape, body shape), they will make notes and sketches and assign the prey item an id number.

C. Environmental & Habitat factors

Environmental data for the murrelet study areas will include spatial data from GIS bathymetric and terrestrial coverages as well as temporal data collected on-site. Each survey area will be divided into shoreline transects that are already digitized on USFWS Atlas/GIS files (Strategic Mapping, Inc. 1992). The survey areas currently have between 11-18 transects each. Temporal data will be collected prior to each transect.

Temporal data will include air and surface temperature and salinity, presence of glacial ice, water clarity (by Secchi disk), sea conditions, weather, time and observed feeding activity. We will calculate tide with a Paradox (Borland, Inc. 1992) script (Kuletz / FWS files). Shoreline and bathymetric features will be taken from GIS at the transect level, study site and regional level, depending on the scale of analysis.

Fish abundance and distribution. -- All study sites overlap with the APEX sites, either in PWS or Kachemak Bay, and relative prey abundance will be obtained independently by that project.

On-site data:

Water temperature - from boat's thermistor or thermometer held about 1-3 ft. below surface.
Air temperature - To nearest 0.1 C, from on-board thermometer out of the sun.

Wind speed and direction - from wind meter and direction estimated from boat's compass.

Salinity - From salinity meter, at 1-3 ft below surface.

Water clarity - to nearest 0.5 meter, using Secchi disk.

Ice - By visual estimate, as percent of water on transect, to nearest 5 %.

Sea conditions: to modified Beaufort scale.

Cloud cover - by visual estimate, percentage of sky with clouds, to nearest 10%.

Weather: 0 = <50% clouds, no precipitation, 1= >50% clouds, no rain, 2 = fog, 3 = light rain, 4 = moderate rain (w/ brief episodes of heavy rain), 5 = heavy rain (downpour/ continuous; difficult to see).

AT SEA SEABIRD DATA COLLECTION:

1997 CRUISE PROTOCOL

Pelagic Transects: Bird Data Collection

One observer will collect Seabird data at all times while pelagic transect sampling is underway. All birds and mammals observed within 100 m of the starboard side of the vessel (that side of the vessel which is being scanned by the side-viewing sonar) will be identified and recorded. If side-viewing sonar is not used then observations will be made to 50 m of both sides of the vessel. We will make bird observations by scanning ahead 100 m of the ship using binoculars. Recorded observations shall be those made prior to the ships presence influencing bird activities. We will attempt to record data when the ship is closest to the point at which the birds were first observed. When possible the perpendicular distance for each bird observed will be estimated to the nearest meter and recorded. Observers will calibrate their ability to estimate distances with laser range finding binoculars or equivalent means. Calibrations will be made frequently by comparing estimated distances to laser measurements. We will record bird behavior categorically as: (a) in the air, (b) on floating object, © on water, (d) following boat, and (e) foraging. Foraging (e) is defined as actual observation of foraging behavior such as diving for food or holding food in the bill. In PWS larid behavior will be categorized as (f) potential foraging when 1 or more birds are observed deviating from linear flight. We will directly enter data into a computer file using the Quick Basic program, *Birds* or DLOG. The data entry system will be programmed to record time and location of each observation. Our computer clock will be calibrated with the hydroacoustic's computer clock daily. Location will be recorded directly from BioSonics geographical positioning system. In PWS we will also collect data on all foraging flocks observed on either side of the vessel. Three foraging piscivorous seabirds shall be used as a threshold value. We will record estimated perpendicular distance to the flock, location, time of observation, and number of each species using the computer program, *Birds*. Flocks seen to the port side of the vessel will record as negative values.

Near Shore Transects: Bird Data Collection

Two observers will collect data for the near shore transects following the same protocol as the pelagic surveys with additional data collection requirements on foraging flocks. We will record a separate data file for each transect segment. G.P.S. data will be generated by a military instrument. Transect segments will be named by a manner that will allow easy identification of parallel segments. We will initiate block surveys alternately, nearshore and offshore. We anticipate that many more birds will be encountered in near shore habitats and that there will be occasions that data entry will be limited. We will give priority to recording locations of larids, alcids, cormorants, and loons. Data on other species will be recorded opportunistically.

Foraging Flock Observations: (PWS only)

Our goal will be to collect data on 10 foraging flocks in each study area. We will collect detailed data on not more than one foraging flocks for each near shore sampling block, if it appears that we will be unable to meet our objective sample size, we will collect data on all flocks seen in sampling blocks. If more than 1 flock is located at a time then the nearest flock will be monitored. Detailed data collection on foraging flocks will require interruption of transect data collection. After data have been obtained from foraging sites the transect will be resumed from the point of departure. For each sampled flock, conductivity, temperature and depth (CTD), hydroacoustic, GPS location, and behavioral data will be collected. We will collect behavioral data from a distance of 100m. Behavioral data collection will not continue longer than 30 minutes. We will also record appropriate header data as per the 1995 forage fish survey and the species composition of the flock every 10 minutes. One person will use the micro cassette to record all behaviors for a single kittiwake for a 2 minute period. Behaviors will include but may not be limited to type of foraging attempt and success if known (a swallowing movement is good enough to consider a foraging attempt successful even though no prey item is seen), aggressive interactions, and if the bird enters or leaves the flock. We will include all kleptoparasitic interactions as foraging attempts. This should be repeated for 4 or more different kittiwakes depending upon the duration of the flock. The observer will repeat the same for Glaucous-winged or other gulls present in the flock. The second observer may scan over a broader area for foraging jaegers or other interactions of interest over the same time period while recording changes in species composition every ten minutes. Video may be used by the secondary observer to gather other interesting data. If the flock is very small (< 5 birds), we may be able to record behaviors for all the birds at the same time as long as we can keep from getting them mixed up.

At foraging flocks feeding in a tight area (Type I) on a dense school of fish the video recording can be more useful. One person will video record for at least fifteen continuous minutes staying focussed on the center of the feeding flock for that time period. The other observer should collect all the appropriate header data, changes in species composition and any foraging success as best as possible by concentrating on one bird at a time.

After we have collected behavioral data and before the flock has broken up, we will collect hydroacoustic data on fish schools located beneath the birds. After we have collected sufficient hydroacoustic data we will fish the school by the most appropriate method available.

Pigeon guillemot Protocol for APEX Projects at Naked Island and Jackpot Island in Prince William Sound, and Kachemak Bay in Lower Cook Inlet, 1997.

Compiled by Kathy Kuletz, Ted Spencer, Dan Roby, and David Irons from protocols written by Lindsey Hayes, Dan Roby, Jill Anthony, and Pam Seiser.

Version 1.3: March 10, 1997

Note: All procedures will be learned and conducted by the entire field crew.

A. Colony Attendance, Resighting, and Nesting Attempts

1) Guillemots will be censused at each colony beginning in early June to ascertain colony attendance.
Boats, blinds, and strategic locations on land will be used to census the birds.

Counts will be made during these watches and later chick feeding watches at study colonies every 15 minutes to obtain maximum attendance.

Pairs and nest site associations will be noted during these watches and later at chick feeding watches.

2) During all nest checks, colony visits, and chick-feeding watches, the presence of all banded birds will be recorded.

The optimal time for resighting is early morning, high tide, and May to early June. The birds stay at the colonies for longer periods before the egg-laying/incubation period. Because of displays and pairing up, birds remain out of the water longer, therefore potential nests and bands are more easily discerned. These blind watches in June should be repeated 2-3 times at each colony and for 4-8 hours duration. Data from these watches will include colony attendance for some past and future comparisons, better resighting opportunities for banded birds, and an enhanced chances to identify new nests and nesting pairs.

B. Productivity

There are known, previously-occupied nest sites at all three study sites (Naked, Jackpot, and Kachemak). At each study area, all nest sites used in previous years will be checked. Active nests should be monitored from the egg stage through fledgling for productivity analyses. New nests can and should be added to the sample of nests in previously occupied sites, and these new nests will likely be found sometime after egg-laying. They should be monitored regularly with the other nests.

PIGEON GUILLEMOT PROTOCOL VERSION 1.3 3/10/97

1) At least 40 active and accessible nests will be located and marked at each study site prior to hatching. Active nests are considered to be any crevice containing at least one egg and where an adult was seen in that nest at least once. Starting out with >40 active and accessible nests will increase the chances that 30-40 nestlings can be measured until fledgling (10-15 each of alpha chicks, beta chicks, and singletons).

2) To increase the sample size of nests monitored during the nestlng-rearing period, and to replace nests that are lost during incubation, we will attempt to locate additional active nests after hatching by observing adults that are transporting fish in their bills. Although these additional nests will have chicks of an unknown age, we will use wing length to estimate age. These "unknown-age" chicks are still useful for assessing growth rates and nestling survival rates.

3) Monitor nests by checking a minimum of every 5 days to determine the fate of eggs or nestlings until nestlings fledged or the nesting attempt fails.

4) Parameters: Means for the following variables will be estimated as indicators of productivity:

Mean Clutch Size (eggs per nest with eggs)
Hatching Success (% of eggs laid that hatch)
Fledgling Success (% of chicks hatching that fledged)
Productivity (% of eggs laid that fledged chicks)
Nesting Success (% nests where at least 1 chick fledged)
Laying, Hatching, and Fledgling Dates (medians)
Predation (see attached predation protocol A)

C. Chick Growth Rates

Measure growth and development rates of nestlings every 5 days from 0-4 days post-hatch to fledgling (>day 30) for a minimum sample of 20 broods (30-40 chicks) each at Naked Island, Jackpot Island, and Kachemak Bay. Larger sample sizes should be feasible at Naked Island and Kachemak Bay.

1) Beginning late in the incubation period, check marked nests a minimum of every 5 days using flashlights or burrow probes to determine approximate hatching date. Extreme care should be taken not to cause attending adults to panic and potentially abandon the nest. If an adult is sitting tight on either eggs or hatchlings, do not attempt to dislodge the adult to determine if the eggs have hatched.

2) When chicks are first discovered in a nest site, every effort should be made to assign as accurate an age (days post-hatch, with day 0 as the hatch day) as possible, based on size, wing length, mass condition of plumage, and other appearance factors. Indicate the degree of certainty that you have in an assigned age (e.g., day 1=B1 1 day; day 13=B1 4 days).

3) In the case of two-chick broods, mark chicks soon after hatching (using a permanent marking pen on toe webbing) so that alpha and beta chicks can be distinguished during subsequent nest checks. When nestlings are old enough (as the tarsus gets longer and larger; see attached banding protocol B), first a FWS stainless steel band and later color cohort and individual color bands should be applied for easy identification.

4) Visit all active nests containing known-age chicks every 5 days during the nestling period to measure and record the following growth and development:

a. Wing Chord: the distance from the bend of the wing (wrist) to the tip of the longest primary (tip of the developing teleoptile). The wing is straightened and flattened for this measurement (see figure T).

b. Also the length of the outer (10th) primary (from emergence from skin to tip, down not included) will be measured. We will use the left wing and a ruler to the nearest millimeter for all wing and feather measurements (see figure U).

c. Body Mass: Birds will be weighed with Pesola™ spring scales (0-100g x 1g, 0-500g x 5g, and 0-1kg x 10g) using the scale with the greatest precision possible. If you are unable to catch nestlings on a particular nest visit, continue to try to capture them on subsequent nest check days.

5) Measure peak nestling body mass, wing length, and outer primary for a sample of 40 nests for a final minimum sample of 20 broods each at each site. It is desirable to measure chicks at about 30 days post-hatch, when chicks are at peak mass but before they are likely to fledged. All surviving known-age chicks will be weighed and measured at about 30 days. This will allow us to compare "peak" weight and measurements between colonies without having to control for the weight fluctuations typical of chicks shortly before fledgling.

6) Determine fledgling age (within 1 day) for a minimum sample of 20 broods. Try to visit all the active nests a minimum of every two days during the fledgling period (older that 30 days post-hatch) to visually determine fledgling age. If possible, those nests containing nests with fledglings 30+ days old should be checked every day to determine fledgling age and weighed and measured every 2 days to determine whether there is a pre-fledgling weight recession.

C. Adult Body Condition

Weigh, measure, band, and mark guillemot breeding adults captured at nests where nestling growth is being monitored or at active nests where chick meals are being collected. We will only attempt to trap adults at nests where chicks are older than 5 days, after they are normally capable of thermoregulation without adult assistance.

1) The best time to capture adult guillemots to collect weights and measurements is during chick-rearing, when chick meals need to be collected (see protocol for collecting PIGU chick meals below). At Naked Island, we found the best capture method used sections of mist net secured over the nest entrance and not visible to the adult. The net should be draped loosely so that the bird becomes entangled and not rebound off a tight net.

2) Measure weight, wing length, outer primary length, tarsus, and culmen of each adult. These morphometric variables will be used to derive a condition index for adults during chick-rearing, when parent seabirds are particularly taxed. The protocol for these measurements are:

a. Mass: Birds will be weighed with Pesola™ spring scales (0-500g x 5g, and 0-1kg x 10g) using the scale with the greatest precision possible.
b. Wing Chord: the distance from the bend of the wing (wrist) to the tip of the longest primary (tip of the developing teleoptile). The wing is straightened and flattened for this measurement (see figure T).
c. Also the length of the outer (10th) primary (from emergence from skin to tip) will be measured. We will use the left wing and a ruler to the nearest millimeter for all wing and feather measurements (see figure U).
c. Tarsus: (Right leg) the distance from the point of the joint between the tibia and metatarsus to the point of the joint at the base of the middle toe in front (achieved by bending the foot down and measuring the front side of the leg (see figure V).
d. Culmen: The distance from the tip of the mandible back to the anterior edge of the cere (see figure X).

3) Band adults with USFWS leg band and unique color combination of plastic leg bands (see attached banding protocol B). Plastic leg bands will permit determination of attendance of individual parents and can be used to measure feeding rates by individual parents. It is also helpful to mark adult white wing patch so as to be identifiable while sitting on the water.

4) Each adult pigeon guillemot captured will be swabbed for the ELLISA assay. The dorsal and ventral plumage will be swabbed with two 2x2gauze pads saturated with isopropanol. The treated pads will be wrapped in aluminum foil, labeled, and frozen. These frozen swabs will be sent to Larry Duffy's lab at UAF after the field season.

5) Any ticks (preferably live) found on chicks or in the nest substrate should will be collected and sent to Dr. Duffy in accordance with the attached tick protocol C (not furnished yet).

D. Chick Diet and Provisioning Rates

Throughout the nestling period, observations will be made at selected groups of guillemot nests to collect diet and provisioning rate data. Optimally, select four or five groups of guillemot nests where deliveries to each nest can be detected and prey items can be identified with binoculars or telescopes from blinds or boats. Try to select groups containing three or more nests. For provisioning rate data, the number of chicks in each nest and their age should be known, but this may not always be possible.

1) Determine delivery rates of chick meals (number of meals delivered per nest per day) by monitoring active nests throughout the daylight period. Conduct these dawn-dusk watches at least every 4-5 days so as to detect shifts in diet composition and feeding rates. If dawn to dusk watches are not feasible, then sample for 8-hour blocks beginning at 06:00 or 14:00. Sample each time block (morning or evening) equally, and try to sample morning and evening time blocks on consecutive days.

2) To record each feeding event, a standardized data sheet will be utilized (see attached data sheet).

a. The adult's arrival and departure times and flight directions will be recorded. Also recorded will be the estimated size and type of fish delivered and the time (and nest) it was delivered to. Hourly weather records will be kept and time of day will allow us to determine tidal stage later.

b A comment section will be used to explain other observations such as disturbances (by observers, boats, airplanes, or predators). Birds already present (with and without fish) upon arrival will be counted. Fish not delivered to a nest (still being held by adult upon observers departure or eaten by the adult) can still be counted in data on taxonomic composition of the diet, but not in meal delivery rates.

3) A minimum of three repetitions (nest days) should be obtained for each site with more if possible (Jackpot Island-2 sites, Naked Island-3 sites, and Kachemak Bay-4 sites). To obtain the most information possible, it may be necessary to use the shorter observation periods (8 hours) more frequently. Diet specialization by specific adults could be observed with more frequent observation periods.

4) Determine taxonomic composition of a minimum of 300 chick meals each on Naked and Jackpot Islands, and Kachemak Bay.

5) Information on prey species composition can be obtained by direct observation of active guillemot nests during chick-rearing. Chick meals will be identified to the lowest taxonomic group possible. Fishes like sand lance and crescent gunnels can be identified to species, but gadids and sculpins can rarely be identified past family. The minimum prey categories are:

a. blennies-BLE (gunnels[GUN],pricklebacks and eelblennies[LUM], shannies[SHA])
b. sculpins (SCU)
c. sand lance (SAN)
d. herring/capelin/smelt (H/S)
e. gadids (GAD)[pollock, tomcod, Pacific cod)
f. juvenile salmonid (SAL)
g.flatfish (FLA)
h.invertebrates (INV)[shrimp, euphausiids]
i.fish seen but not identified despite having a good look (NK=not known)
j.fish missed or not seen adequately to make an identification (NS=not seen)

6) Estimate length of each prey item delivered to nests by adults as a multiple of bill length to the nearest half bill length.

E. Chick Meal Size

Collect samples of chick meals in order to measure meal size (grams) and determine species identity at Naked and Jackpot islands, and Kachemak Bay.

1) Samples of chick meals are best obtained by intercepting adults with nets in front of or inside the nest entrance. These chick meals collected from adults are likely to be representative of chick diets. The best times to collect chick meals from adults are when prey delivery rates are highest (i.e., early morning and high tide). Fresh samples will be labeled as "collected from adult". In some cases adults may drop chick meals because they have been startled by the investigators activities around the nest. These chick meals are also considered "collected from adult." Try to avoid seriouslly disrupting parental feeding of nestlings during collection of chick meals. If an adult refuses to enter a nest for several hours, remove the netting and try another nest. Tryto avoid collecting an excessive number of chick meals from a particular nest, especially if the chick is being measured for growth rate. Collect at least 40 chick meals from adults at each of the three study sites.

2) Although not likely to be representative of chick diets, dropped or discarded chick meals that are found in or near the nests should also be collected and labeled "discarded". These samples of chick meals are less valuable than those collected from adults, but can provide supplemental data on taxonomic composition.

3) Both "collected from adult" and "discarded" chick meal samples will be used for positive identification of fish types and sizes delivered to guillemot chicks. The size, mass, sex, age class, reproductive status, and analyses of energy content will be determined for all prey fish samples obtained. Weigh all chick meals to the nearest 0.01 g on an Ohaus top-loading balance, and place the fish in separate Whirl-Paks and include an identification label in the bag (see attached sample) and mark on the outside of the bag the date, colony, PIGU, and type of sample (ADULT or DISCARDED).Freeze all samples in a propane freezer as soon after collection as possible. These samples will be shipped frozen to Kathy Turco in Alan Springer's lab at University of Alaska (UAF) at the end of the field season for processing. At Springer's lab, the samples will identified to species, sexed, aged, and measured prior to analysis of composition. It is crucial that samples remain frozen during shipment; if allowed to thaw it will be impossible to measure proximate composition and energy density. When shipping any frozen samples, pack the frozen samples tightly in a cooler surround samples with frozen "blue ice". The lid of the cooler should be tightly sealed with duct tape to avoid air leaks.

Food Availability

In addition to underwater transects completed by divers, each site will collect information on species diversity and abundance of benthic and schooling fish using minnow traps and beach seines in several areas near the colonies.

1) Minnow traps will be set at 4 locations near the pigeon guillemot colonies. The trapping locations will be chosen from areas where guillemots have been observed feeding. At each location, we will set eight traps, distributed in four pairs. One trap of each pair will be located 0.75 m above the anchor and the other 1.5 m above the anchor. We will check traps (daily for three days and rebait with the same material). We will identify and record the abundance of all organisms captured in each trap. Fish that are not collected for the APEX project will be released. Shrimp will be counted, samples of each species collected, and the approximate percentage recorded.

2) Beach seining will be conducted at various sites every 5-10 days at Naked I. And Jackpot I. Using sites established in 1996. Methods will follow protocol established by Martins Robard (see attached Beach Seine D protocol).

3) Fish samples retained from seining and fish traps will be processed with the same procedures as chick meals. We will weigh whole fish to the nearest 0.01 g on an Ohaus top-loading balance, and place the fish in separate Whirl-Paks which will be labeled with date, location, how captured, standard length, and sample weight. We will freeze all samples in a propane freezer as soon after collection as possible. These samples will be shipped frozen to Kathy Turco in Alan Springer's lab at University of Alaska (UAF) at the end of the field season for processing. At Springer's lab, the

samples will identified to species, sexed, aged, and measured prior to analysis of composition. It is crucial that samples remain frozen during shipment; if allowed to thaw it will be impossible to measure proximate composition and energy density. When shipping any frozen samples, we will first pack the frozen samples in a cooler, which will be surrounded with frozen "blue ice". The lid of the cooler will be tightly sealed with duct tape to avoid air leaks.

4) Some dedicated seine attempts will be done for Molly Sturdevant (see attached **seine** E protocol-not furnished yet).

H. Bio-sample Collections

We will collect blood from each adult that we handle. For each chick that is monitored for growth performance, we will attempt to draw blood from either the brachial or tarsal vein at approximately 20, 25, and 30 days of age. When practical, we will draw blood from birds that are exactly 20, 25 and 30 days of age. Otherwise we will draw the first blood sample as close to 20 days of age as possible and draw the other two blood samples 5 and 10 days later. For the samples at 20 and 25 days of age, we will draw only 1 cc of blood. For the sample at 30 days of age we will draw 2 cc of blood. We will label each sample with the bird's USFWS metal band number, nest identification, chick rank (alpha, beta or solo), colony name, and collection date. Each time blood is drawn, we will produce four blood products in the field:

(1) Two samples of whole blood will be transferred immediately from the syringe or puncture sight to micro-hematocrit tubes and refrigerated. These samples will be shipped to the commercial analysis lab as soon as possible. Do not tape hematocrit tubes together but place them in the small plastic slide box along with the blood smear. Each bird will have a separate shipping box.

(2) Two whole blood smears on glass slide will be created. One blood smears will be sent to the commercial analysis lab and another will be stored and forwarded to Purdue lab after the field season. Slide must be dry before storing in the slide boxes.

(3) The blood remaining in the syringe will be placed in a vacutainer containing heparin anticoagulant. The vacutainer will be centrifuged to separate serum and blood cells within two hours of collection. Serum will be distributed into two snap-top tubes. One of the snap-top tubes is for the commercial analysis lab and the other is for analyzes of haptoglobin and interleukin-6 at Larry Duffy's UAF lab. At least 200 micro liters are required for the latter analysis. Serum for the blood lab will be refrigerated and shipped as soon as possible and all other serum will be frozen and shipped at the end of the season to Duffy's lab.

(4) The red blood cells remaining in the vacutainer tubes will be frozen and shipped to UAF at the end of the season.

Each site will keep a record book of blood collection and shipping dates. Samples will be shipped to the Avian and Exotic Lab ASP. Many samples can be shipped together but for each bird a Aviann and Exotic Lab form will be filled out and bagged with a sampling box filled with one slide, two micro-hematocrit tubes and one vial of serum collected from that bird.

I. Foraging Areas

Foraging areas will be determined by following guillemots returning to forage after making a delivery at the colony.
1) This can be done during the feeding observations by using VHF radio communications between observers in blinds and others in boats stationed offshore or other points on land.

- a Arrival and departure flight time and direction will be recorded during chick feeding watches.
- b When possible, marked or unmarked mates of marked birds will be followed (dyed wing patches would facilitate this procedure).
- c If bird lands (splash-down) within sight of blind, direction and distance from blind will be recorded.
- d Note any feeding (self or for chicks) occurring near the colony. Also record direction of birds with fish leaving to other areas.

Observations of foraging guillemots and flight directions of guillemots (with and without fish) will be made from strategic locations to locate and assess the importance of other foraging areas to the guillemots.

A. Predation Protocol

Potential nest predators of guillemots include the river otter (*Lutra canadensis*), mink (*Mustela vison*), northwestern crow (*Corvus caurinus*), common raven (*Corvus corax*), Steller's jay (*Cyanocitta stelleri*), glaucous-winged gull (*Larus glaucescens*), and the black-billed magpie (*Pica pica*). Bald eagles (*Haliaeetus leucocephalus*), peregrine falcons (*Falco peregrinus*), and other raptors could be predatory on adult and fledgling guillemots.

1) We will assume that predation is the cause if eggs:
   a Disappear from nests between nest checks.
   b Disappear from nests between nest checks and shell fragments are found in or around the nest.

2) We will assume that predation is the cause if chicks:
   a Less than 30 days old (too young to fledge) disappear from nests between nest checks and we are reasonably certain that no chick is hidden somewhere in the nest.
   b Disappear and feathers, blood, bones, or other evidence is found in or near the nest.
   c Carcasses of chicks or adults are present in or near the nest with signs of trauma associated with them. These carcasses will be retained with labels describing date, nest, band #, nest status, and then frozen for possible further examination at a forensic lab.

3) After repeated visits, those nests missing chicks that we can not be certain are empty, the cause of failure will be listed as unknown.

4) **Plans for predation? Proactive-quick response Jackpot and Naked**

B. Banding Pigeon Guillemots

All captured adults will be banded on the left tarsus with a USFWS metal band on the bottom and a color plastic cohort band above. The right tarsus will be banded with a unique combination of two color plastic bands. In addition, the white wing patch will be dyed with various color combinations to facilitate field identification.

Newly hatched two-chicks broods will be marked on toe webbing with a permanent marking pen to distinguish between alpha and beta chicks. When chicks are large enough (100g +) they will be banded on the right tarsus with a USFWS metal band for easier identification. With further growth, a color plastic cohort band will be placed above the steel band. Then the left tarsus will be banded with a unique combination of two color plastic bands. Banding pliers will be utilized to affix the metal bands and super glue for the plastic bands.

As each bird is banded with a USFWS metal band, the band number, date, nest, and colony will be recorded with the unique color band sequence for that bird. The 1994 cohort plastic band was yellow, 1995-orange, 1996-white, and 1997-dark blue. The band sequence will always be recorded the same way to avoid confusion. Left leg top, left leg bottom/right leg top, right leg bottom. A typical 1994 banding sequence would appear as: adult= yellow, steel/dark green, orange (Y,S/DG,O), a chick= orange, yellow/yellow, steel (O,Y/Y,S).

D. Beach Seine Protocol

BLACK-LEGGED KITTIWAKE PROTOCOL FOR APEX PROJECT, 1997

Field camps include Shoup Bay, Eleanor Island, and North Icy Bay, PWS; and Gull Island, Chisik Island, and Barren Islands in Lower Cook Inlet.

Compiled by David Irons, Dan Roby, Rob Suryan, and Jill Anthony from protocols written by Vern Byrd, David Irons, Kirk Lenington, Dan Roby, Rob Suryan, and Jill Anthony.

Version 3.2: March 13, 1997

Note: All measurements should be learned and blind practices should be conducted by all people in the field crew.

A. Productivity Plots (n=10 to 20 plots with 10 to 50 nests each)

Productivity plots will provide data on several reproductive parameters. By observing the contents of the nests on a scheduled regime, data will be collected on egg laying date, hatching date, fledging date, clutch size, hatching success, brood size at hatching, fledging success, brood size at fledging, and predation.

Initially, plots should be systematically selected from the "viewable" population of possible plots, and the same set of plots should be used in subsequent years. If plots or observation points are lost due to erosion, new plots may be added.

After a location is determined for the particular productivity plot, a Polaroid photo is taken of that plot so as to include the largest number of nests without

ambiguity. The location from where you count the plot should be marked to ensure that counts are made from the same spot. Although it is best to take the photo from the top of the colony looking down into the nests, in some cases this may be not be feasible. Every effort should be made to minimize any confusion resulting from the perspective from which the photo was taken.

Every nest in each photo is assigned a number with that number being written on the corresponding nest in the photo. The numbering should be sequential throughout all the nests on all of the photos. That is, the numbering of the nests does not reset at 1 for each photo but continues sequentially for the entire set of productivity plots. After all the nests are numbered, the photos should be covered with acetate film to prevent numbers from wearing off, damage to photos, etc.

The contents of all the nests will be monitored every three days beginning no later than May 31 so as to catch any early eggs. All Productivity Plots should be monitored on the same day. The contents of each nest will be recorded as follows:

NN = no nest (the nest site in the photo has fallen away or been destroyed)

NNB = no nest bowl (although nest material is present, there is no impression or

enough of one, to hold eggs)

0 = no eggs (there is a well-defined nest bowl, but no eggs/chicks)
1E = one egg
2E = two eggs
3E = three eggs
0C = used for zero chicks in nest if chicks disappear before fledging
1C = one chick
2C = two chicks
3C = three chicks
1F = one chick fledged (used when a chick is absent from nest at about fledging age)
2F = two chicks fledged (ditto 1F)

and any combination of these required. Upper case (capital letters) should be used for eggs and chicks to eliminate the chance of confusion when transcribing data. A sample page from a data book is included.

The monitoring effort should continue until there are no more eggs/chicks present.

In subsequent years, the Productivity Plots should be in the same locations with new Polaroid photos taken from the same perspectives.

Survey Units: A sample plot is defined as a segment of cliff-nesting habitat which; (1) may be viewed from above so that the contents of nests can be clearly seen, (2) has readily identifiable boundaries, and (3) contains approximately 25-35 nesting pairs of seabirds.

Parameters: Means for one or more of the following variables could be estimated:

Mean Clutch Size (eggs per nest with eggs)
Laying Success (% of nest structures where $\geq$ 1 egg is laid
Hatching Success (% of eggs laid that hatch)
Fledging Success (% of chicks hatching that fledged)

Reproductive Success (% eggs laid that fledged chicks)
Productivity (chicks fledged per nest structure)
Nesting Success (% nests where at least 1 chick fledged)
Laying, Hatching, and Fledging Dates (medians)
Brood size at hatching
Brood size at fledging
Predation (probable or observed)

Sample Size: Ideally, a productivity monitoring system would include 10-20 plots, each with 10-50 nesting pairs of birds. The sample size is the number of plots; nests are subsamples for estimating the average success for each plot.

B. Chick Growth Rates (n=40 to 50 broods)

Growth Rate monitoring will provide data on growth and development ratės of chicks.

Three to six areas spread throughout the colony, with five to 10 nests each, will be designated as the Growth Rate areas. These areas will preferably be areas where other work, such as Productivity Plots or other experiments, is not taking place so as to minimize the amount of disturbance to these nests. The clutch sizes of nests in the growth rate areas should be similar to the clutch sizes in the Productivity Plots. The same areas should be used in subsequent years, if possible. Polaroid photos will be taken and accessible nests assigned numbers following the protocol for the Productivity Plots.

Nests should be checked for chicks beginning no later than June 30. Growth rates on both chicks (if two present) in each nest will be taken every 4 days. In nests with two chicks, mark chicks soon after hatching (using permanent marking pens to mark A and B chicks different colors on their breast feathers) so that alpha and beta chicks can be distinguished during subsequent nest checks. The A and B chicks should both be banded as soon as possible. At first, only a USFWS metal band will be able to be affixed. Then, as the tarsus gets longer and wider so there is no danger of slipping bands, colony, cohort, and individual color bands can be attached.

During the hatching period, check growth rate nests daily, if it is not too much disturbance, (using mirror poles, if necessary) to determine hatching date. That way known-age chicks can be weighed and measured and growth rates compared between colonies.

The following growth and development measurements will be taken for each nestling every four days:

Headbill: Measure the distance from the tip of the mandible in a straight line to the posterior edge of the cranium.

Tarsus: (right leg) Measure the distance from the point of the joint between the tibia and metatarsus to the point of the joint at the base of the middle toe in front (achieved by bending the foot down and measuring the front side of the leg).

Wing Chord: (right wing) Measure the distance from the bend of the wing (wrist) to the tip of the longest primary (tip of the developing teleoptile). The wing is flattened and straightened for this measurement.

10th Primary: (right wing) Measure the length of the outer (10th) primary (from emergence from skin to tip, down not included).

Mass: Use pesola scales that have been tiered, and record mass to the nearest gram. Put chick in a weighing cone or something else that does not get wet and change mass as you weigh chicks. Record the total weight of the chick and the weighing cone, and the mass of the cone (note: the mass of the cone can be subtracted later).

If the chick regurgitates before or during weighing, weigh the total mass of the regurgitation and record mass and whether it regurgitated before or after the chick mass was taken. Try to refeed the regurgitant once or for one minute or less. If the chick does not take it the regurgitant may be used a diet sample. At small colonies you may collect one regurgitant per chick for a diet sample (i.e., you do not have to try to refeed it), but try to collect diet samples from chicks 15-30 days old. If the regurgitation weighs less than 6 g, (if you have room in your freezer, freeze it rather than use alcohol) preserve it in isopropyl or ethyl alcohol for later determination of diet composition in the lab. If the regurgitation weighs more than 6 g, place it in a whirl-pak labeled with the date, time, colony, nest id number, fresh weight of diet sample (to nearest 0.01 g) and freeze it.

Fledging Wt.: Measure fledgling (day 30 post-hatch, ± 1 day) body weight, wing length, and outer (10th) primary for a minimum sample of 40 broods.

The name of the person taking the measurements should also be recorded. A sample page from a data book is enclosed.

If a chick is not present in it's nest, it should be recorded as gone. If a Growth Rate chick is found dead, it should be recorded as dead and any signs of injury noted (e.g., head pecks, neck chewed, etc.).

Measure growth and development rates of nestlings from hatching (day 0) to fledging age (day 30) for a sample of 40 broods.

C. Adult Body Condition (n=30 with chicks and n=15 without chicks)

Weigh, measure, and mark kittiwake 30 breeding adults captured with a noose pole for radio-tagging or some other purpose, during the incubation period, and a sample of 30 adults with chicks and 15 without chicks (if possible) between July 15 and July 30.

a) Measure headbill, tarsus, weight, and wing length as described in Chick Growth Rate section.

b) Band adults with USFWS leg band and unique color combination of plastic leg bands, according to Banding Protocol. Plastic leg bands will permit determination of attendance of individual parents at nests to be used for observations of chick feeding rates.

D. Delivery Rates

N = 30 to 50 nest days per colony sampled during 4 to 6 observation days spread over the chick-rearing period at separate plots with 4 to 8 nests each.

Delivery Rate monitoring will provide data on brood feeding frequency (# of food loads delivered to the nest by the 2 breeding adults per day). Measurements of Delivery Rate at each colony are crucial in order to understand differences in nestling growth and productivity among kittiwake colonies and to understand foraging choices made by parents (such as energy provisioned to the brood, foraging trip duration, etc.). Delivery Rates are measured in conjunction with Periodic Weighing of Chicks for Brood Meal Sizes (see below).

During the incubation period or early in the chick-rearing period, clusters of active and accessible nests throughout the colony will be selected for measurements of Delivery Rates. Please be sure to include a written description of the location of the regions, using permanent land marks for reference. The same sites should be considered in subsequent years; however, specific nests need not be included. Identify enough active nests to ensure having 8 nests near each other, preferably within a binocular field of view from the vantage point. Note nest contents in a field book and take Polaroid photos to assign nest numbers. In the second week in July, these nests should be checked briefly to record nest contents and wing chords of all chicks as an estimator of age.

On the day before a scheduled observation, it is important to select the site, identify the nests, mark the adults (at least one member of each pair), and mark the chicks. The chicks in nests under observation must be 10 to 32 days old on the day of the observation, because younger and older nestlings tend to have different feeding rates. Avoid choosing nests that contain chicks that are growing poorly. Try to select one and two chick broods in proportion to what is in the colony in that year. If neither of the adults at a nest under observation have been previously banded or marked, dye-mark at least one member of the pair (a super soaker squirt gun filled with straight red dye cut with a small amount of dish washing detergent works well to spray the adults while they are on the nest. The squirt gun has a range of only 8 to 10 ft spray, so approach the plot very slowly to get close and spray across a series of nests. Record the dye pattern on the adults once they return to the nest. For identification of individual nestlings in broods of two, mark the heads of the chicks in a mohawk pattern and the right toe webbing with specific colored Sharpies (e.g., red for alpha chicks and blue for beta chicks).

Observations should begin and end at the top of the hour for dawn to dusk watches. Observations should be continuous from daybreak to darkness. At the beginning of the observation period, record the date, colony, observers, weather, tidal cycle for the day, site (plot), and start time.

The goal of measuring Delivery Rates is to count the number of parental exchanges associated with the delivery of a food load ("meal") for each nest by monitoring active nests throughout the daylight period. A meal is one full esophagus of food brought back to the brood by a parent. This can be fed in one short feeding event or in several small boluses throughout that parent's attendance at the nest. Either way, it is considered only one meal. For a new meal to be delivered, the other parent will have to return to the nest and feed the chicks. Measuring Delivery rates takes more attention than one would think; exchanges occur quickly and are easily missed. This is why having at least one adult marked at each nest is so crucial. Each nest on average receives only about 3 to 6 chick meal deliveries per day, so a missed exchange seriously biases the estimate.

The following parameters will be recorded for each nest during dawn to dusk observations spread out over the chick-rearing period:

Parental Attendance: each event when an adult arrives at or departs from a nest under observation. This is recorded using the adult's "nickname" (based on how it is marked) followed by an A for arrival and D for depart.
Roll Call: Changes in parental attendance are occasionally missed (e.g., sometimes they occur immediately after a periodic weighing or unexpectedly). Record the parent attending each nest at the beginning and end of a day, before and after each periodic weighing, and regularly throughout the day to detect missed exchanges as soon as possible.
Exchange (E): an exchange of parental attendance accompanied by the feeding of a chick meal by the newly arrived parent. For example, a parent arrives at the nest, the other parent leaves, and the chicks are fed during the new parent's watch.

Feeding often occurs within 15 to 30 minutes of arrival of the new parent, but may occur later. When parents exchange nest duties, record an E followed by the adult's "nickname." Once you observe a feeding, circle the E.
Pseudo-Exchange (PE): an exchange of parental attendance without an accompanied feeding of chick meal by the newly arrived parent. If feeding is not observed before the parents exchange again, add a P to the uncircled E recorded upon that parent's arrival. Do not circle the PE.
Feeding (F): Food is observed being passed from the parent to the chick by regurgitation. A feeding event is recorded with an F followed by the identification of the chick (when there are two chicks in the brood) and the duration. Chicks are identified by their status in the nest as alpha, beta, theta, or singleton.
Nest Feed (NF): A rare type of chick feeding occurs when a parent regurgitates into a nest and the chick(s) feed out of the nest. This is considered a feeding, but the event must be directly observed and recorded with an NF followed by the chick's identification and duration.

Make a note to confirm it, as it is rare and can be confused with pecking at the nest bowl or consuming objects near the nest.
Pecking at the nest bowl (NB): Chicks often peck at the nest bowl looking for scraps or clearing away guano. This is recorded as NB followed by the identification of the chick.
Begging (B): nestling pecks at the parent's bill. Record begging with a B followed by the chick's identification and the intensity of begging during that one minute period (high/low).

E. Brood Meal Size

Brood Meal Size is another crucial measurement to obtain at each colony in order to understand differences in nestling growth and productivity among kittiwake colonies and to understand foraging choices made by parents (such as energy provisioned to the brood, foraging trip duration, etc.). Like Delivery Rates, we know that Brood Meal Size varies among colonies and among years, and is one indication of parental investment in provisioning young. Brood Meal Size can be measured using Periodic Weighing of Chicks in conjunction with measuring Delivery Rates (see above). Two other methods will be used to obtain measurements of Chick Meal Size: Whole Regurgitation Brood Meals, and Random Regurgitation Brood Meals.

1. Periodic Weighing of Chicks

N = 15 to 25 nest days per colony sampled during 4 to 6 observation days spread over the chick-rearing period at separate plots with 4 to 8 nests each.

Periodic Weighing of Chicks to measure Brood Meal Sizes is done in conjunction with measuring Delivery Rates. The periodic weighing of chicks requires relatively accessible nests containing young that are between 10 and 30 days old. Each chick involved in periodic weighing must be weighed every 2 hours over an 8-hour period (each chick is weighed 5 times). Each chick must be weighed regardless of whether it was fed or not during the intervening 2 hours.

We recommend weighing the chicks in half the nests observed for Delivery Rates for the first 8 hours of the all-day watch, and weighing the chicks in the remaining nests the second 8 hours to reduce the stress imposed on chicks by weighing them every 2 hours all day long. Begin periodic weighing at prearranged times on the 2-hour mark (e.g., 04:00, 06:00, or 08:00 so that time blocks are the same from one day to the next and to avoid partial coverage of time blocks at the beginning or end of the day.

Please record the mass of the chick and the weighing cone together, using a Pesola scale. Then, record the mass of the weighing cone separately. If the chick regurgitates, it is not necessary to refeed, but it is important to record the weight of the chick both before and after it regurgitated. Record whether the regurgitation occurred before or after weighing. Reweigh the chick(s) for a starting mass for the next 2-hour session.

Whole Regurgitations and Random Regurgitations may be collected from Periodic Weighing chicks, if the periodic weighing coincides with completion of a chick feeding. To ensure a complete brood meal has been obtained, stroke the neck of the chick(s) and apply gentle pressure with your pinkie or a soft object to the inside back of their throat to induce the gag reflex. If there are two chicks in the brood, both chicks need to be encouraged to regurgitate, even if you did not observe both being fed. Weigh the regurgitation(s). It will be considered a Whole Regurgitation if the exchange occurred 15 to 30 minutes before the periodic weighing session and the chick(s) were fed. Otherwise, it will be considered a Random Regurgitation. Place the regurgitation in a whirl-pak labeled with the date, colony, BLKI, and RANDOM or WHOLE and place an identification label in the bag. Record the sample in the proper field book. Store the regurgitation in a cooler and freeze it as soon as possible after weighing it again with the Ohaus top-loading balance back at camp.

2. Whole Regurgitation Brood Meals

N = 50 whole regurgitations (weighing more than 6 grams) per colony

All active and accessible nests at the colony are appropriate for these samples, other than those used for Growth Rates. Avoid choosing nests that contain chicks that are obviously aberrant and growing poorly, but sometimes many of the chicks will be growing poorly.

A regular sampling of 10 whole regurgitations per week for 6 to 7 weeks will provide data over the entire chick-rearing period, when diets can vary. Two sampling sessions a week is preferred, with one as a minimum. Chicks must be at least 10 days old, however, the best samples are obtained from chicks that are 18 to 30 days post-hatch and likely to be fed the entire meal at once. Be sure to obtain samples from both 1-chick and 2-chick broods each week.

Whole Regurgitation Brood Meals are the best indicators of meal size and also are less digested than Random Regurgitations, so they are extremely valuable samples. During peak feeding times at the colony, observe a large group of accessible nests for adults returning from foraging trips with food for chicks (an exchange of parental attendance). It works best to scan with the naked eye and confirm feeding with binoculars. Once feeding has occurred, wait about 10 minutes or so to be certain that the adult has transferred all or most of its stomach contents to the chick(s). It is best to observe the exchange of parental attendance and to note it. However, it is acceptable to collect the sample as a Whole Regurgitation if you observe substantial feeding, but did not see the exchange.

After the waiting period, approach the nest and handle the chick(s) in the brood until the recently fed food is regurgitated. To ensure a complete meal has been obtained, stroke the neck of the chick(s) and apply gentle pressure with your pinkie or a soft object to the inside back of their throat to induce the gag reflex. Both chicks in a two chick brood need to be encouraged to regurgitate, even if you did not observe both being fed.

Place the regurgitation in a whirl-pak labeled with the date, colony, BLKI, and WHOLE and place an identification label in the bag (see attached example). It is very important to indicate the brood size (one or two chicks). Evaluate whether the sample is complete or incomplete. A complete sample means the chick(s) in a brood were encouraged to regurgitate the entire brood meal and you are satisfied that the sample contains the entire meal. An incomplete sample means one of the chicks in a brood of two was not encouraged to regurgitated, or the chick was not encouraged to regurgitate the entire meal, so you are not certain if the meal is complete. Record the sample in the Whole Regurgitation field book. Store the regurgitation in a cooler and freeze it as soon as possible after weighing it again on the Ohaus top-loading balance back at camp.

Follow shipping instructions outlined in Brood Diets (below).

3. Random Regurgitation Brood Meals ("haphazard", actually)

N = 80 to 240 complete random regurgitations (weighing more than 6 grams) per colony

All active and accessible nests at the colony are appropriate for these samples.

An attempt should be made to avoid Growth Rate nests, however, a complete regurgitation may be obtained on the last day when the nestlings are weighed. Avoid choosing nests that contain chicks that are growing poorly. These regurgitations can easily be obtained while collecting other data at the colony.

A regular sampling of 10 to 30 Random Regurgitations per week for 7 to 8 weeks will provide information regarding diet changes over the chick-rearing period. Two sampling sessions a week is preferred, with one as a minimum. Be sure to sample both one chick and two chick broods each week. Samples are best when they weigh more than 6 grams, but those smaller are valuable too, especially when chicks are less than 10 days old (an age when nestling diets are otherwise under represented).

Random Regurgitation Brood Meals are an index to meal size. The mass of these randomly collected regurgitations will be used as an index to chick meal size at

colonies where periodic weighing is impractical and collection of whole chick meals is more difficult. This index will be calibrated using Whole Regurgitations obtained from the same colony and with Periodic Weighing and Whole Regurgitations measured at Shoup Bay and Eleanor Island, where they are more easily obtained.

To ensure a complete Random Regurgitation has been obtained, stroke the neck of the chick(s) and apply gentle pressure with your pinkie or a soft object to the inside back of their throat to induce the gag reflex. Both chicks in a two- chick brood need to be encouraged to regurgitate to get a Random Regurgitation Brood Meal. This is an easy way to collect diet samples to determine taxonomic composition of the diet, but rarely provides whole, freshly delivered meals that can be used to directly infer Brood Meal Size.

Place the Random Regurgitation in a whirl-pak labeled with the date, colony, BLKI, and RANDOM and place an identification label in the bag (see attached example). Evaluate the sample with a freshness index (1 is fresh, 2 is unsure, and 3 is not fresh) and as complete or incomplete. A complete sample means the chick(s) in a brood were encouraged to regurgitate the entire contents of their stomach(s) and you are satisfied that the sample contains close to the entire contents of the stomach(s). An incomplete sample means one of the chicks in a brood of two was not induced to regurgitate, so you are not certain if the meal is complete. Record the sample in the Random Regurgitation field book. Store the regurgitation in a cooler and freeze it as soon as possible after weighing it again on the Ohaus top loading balance back at camp.

Follow shipping instructions outlined in Brood Diets (below).

F. Brood Diets

N = 50 complete Whole Regurgitations (greater than 6 grams) per colony and
80 to 240 complete Random Regurgitations (greater than 6 grams) per colony

Back in the laboratory, we will determine taxonomic composition, proximate composition, and energy density of all complete Whole Regurgitations and Random Regurgitations that were frozen in the field. We understand that conditions differ between colonies, but the closer we can get to these sample sizes of Regurgitations from each colony, the better.

Either in the course of the summer or at the end, arrange to ship these frozen samples by Alaska Airlines Goldstreak to Kathy Turco (University of Alaska Fairbanks). THIS MUST BE ARRANGED IN ADVANCE. Please do not ship frozen samples to Kathy unless you know that she is in town and is expecting them (she's in and out of town all summer). Her telephone number is (907) 455-4286.

It is critical that samples remain frozen during shipment. If allowed to thaw, it will be impossible to measure the energy content of these samples. The samples must be wrapped tightly and packed in frozen "blue ice" in a cooler or sturdy box lined with crinkled newspaper. To avoid air leaks, seal the cooler or box with duct tape. Always have coolers stored in a freezer whenever possible during transport. Samples should not be in transit for more than 12 hours, unless the cooler can be placed in a freezer in route.

Regurgitations will be sorted for determination of fish prey species and size, followed by analyses of proximate composition and energy density at Dan Roby's lab at OSU.

Regurgitations that weigh less than 6 grams are less valuable for proximate analysis than those greater than 6 grams, but should be collected to provide information on taxonomic composition of prey.

G. Adult Diets

N = 0 to 100 Adult Regurgitations from each colony

This technique should be used to obtain samples similar to Whole Regurgitation Brood Meals. Complete Adult Regurgitations yield the best data on diet composition and meal size. Every attempt should be made to collect an Adult Regurgitation whenever an adult is in hand during the chick-rearing period (Radio-tagging Adults, Adult Body Condition, Banding Adults for Delivery Rates).

Collect Adult Regurgitations by capturing adults soon after they return from a foraging trip using a noose pole or foot noose. To ensure a complete meal has been obtained, stroke the neck and apply gentle pressure with your pinkie or a soft object to the inside back of their throat to induce the gag reflex. Adults may also be tipped upside down and light pressure applied to the abdominal region.

Place the Adult Regurgitation in a whirl-pak labeled with the date, colony, BLKI, and ADULT and place an identification label in the bag (see attached example). It is very important to indicate the brood size (one or two chicks).

Evaluate the sample as complete or incomplete. A complete sample means the adult was encouraged to regurgitate the entire brood meal and you are satisfied that the sample contains the entire meal. Record the sample in the Adult Regurgitation field book. Store the regurgitation in a cooler and freeze it as soon as possible after weighing it again on the Ohaus top-loading balance back at camp.

Follow shipping instructions outlined in Brood Diets.

H. Glossary of Terms

Brood Size: Number of chicks per nest

Clutch Size: Number of eggs per nest

Delivery Rate: the number of parental exchanges associated with the delivery of

a meal observed throughout the daylight period. (previously known as Chick Provisioning Rate)

Exchange: an exchange of parental attendance accompanied by the feeding of a chick meal by the newly arrived parent. For example, a parent arrives at the nest, the other parent leaves, and the chicks are fed during the new parent's watch.

Fledgling: Chick that is beginning to fly. In the final stage of chick- rearing, before leaving the nest permanently, a chick will temporarily fly from the nest, but return for meals and a safe space to rest.

Headbill: the distance from the tip of the mandible in a straight line to the posterior edge of the cranium. You can feel a ledge at the back of the head.

Chick Mass: the total weight of the chick. The weight of the chick with the weighing cone are recorded, then record the weight of the weighing cone separately.

Meal: one esophagus and stomach full of food brought back to the brood by a parent. This can be fed in one short feeding event or in several small boluses throughout that parent's attendance. Either way, it is considered one meal.

Nesting Success: % nests where at least 1 chick fledged

Pipping: First evidence of the chick breaking the egg shell from within during hatching

Productivity: Number of chicks fledged per nest

Pseudo-Exchange: an exchange of parental attendance without an accompanied feeding of a chick meal by the newly arrived parent.

Tarsus: the distance from the point of the joint between the tibia and the metatarsus to the point at the joint at the base of the middle toe in front. Bend the foot down and measure the front side of the main leg bone.

Tenth Primary: Outer (and in kittiwakes the longest) primary feather. Measure from its emergence from the skin to the tip. Do not include the down.

Wing chord: the distance from the bend of the right wing (the wrist) to the tip of the longest primary (or the tip of the developing teleoptile in younger birds). Straighten and flatten the wing for this measurement.

Visitor Use Data - Shoup Bay only

As part of our permit with State Parks we are required to collect data on visitor use an provide State Parks with a report. When a visitor is seen (on foot, boat, plane, or helicopter) record: date, time, vessel description (e.g., aluminum jet boat, Glacier Angler Charters or helicopter 9159EH), purpose (tour, fly-by visit, egging, hunting), number of people if known, and comments (estimated duration of visit).

K=BLKI, P=PIGU, M=MURRE, G=GWGU, T=TUPU, H=HOPU, C=PECO, R=RFCO, D=DCCO

PARAMETER	SAMPLE SIZE	N. PWS	C. PWS	S. PWS	CHISIK	KACH	BARRENS
Productivity plots	200 nests						
clutch size		K,G	K,P,G	K,P	G	K,P,G	K,M,G
lay dates and success		K	K,P	K,P			
hatch dates and success		K,G	K,P,G	K,P	K,M,G,H	K,P,M,G	K,M,G,T
fledge dates and success		K	K,P	K,P	K,M,H	K,P,M,C	K,M,T,C
nestling survival		K	K,P	K,P	K,M,H	K,P,M,C	K,M,T,C
brood reduction		K	K,P	K,P	K	K,P	K
brood size at fledging		K	K,P	K,P	K	K,P	K
fledgling age		K	K,P	P			K,M
overall productivity index		K,G	K,P,G	K,P	K,M,H,G	K,P,M,G,C	K,M,G,T,C
Chick growth rates	30 nests	K	K,P	K,P	K,M,H	K,P,M	K,M,T
fledgling mass & condition		K	K,P	P			
Adult activity budgets (radio)	30 Birds						
forage trip duration		K	K	K			
time both parents present		K	K	K			
Adult activity budgets (visual)	20 nest days						
forage trip duration		K	K,P	P	K,M	K,M,P	K,M
time both parents present					M	M,P	M
chick provisioning rates	30 nest days	K	K,P	P	K,M	K,M,P	K,M
Chick meal size							
a. periodic chick weighing	40 nests	K	K,P	P			
b. Weigh regurgitate	all	K	K	K	K	K	K
Chick diets	50chicks	K	K,P	K,P	K,M,H	K,P,M	K,M,T
Seasonal chick diets	20/wk	K,G	G		K,M,H,G	K,P,M,G	K,MT,G
Adult diet	50 adults				K,M,G,H,C	K,P,M,G,T,C	K,M,G,T,C
Seasonal adult diets	20/wk	G	G		K,M,H,G	K,M,G	K,M,T,G
Adult census		K,G	K,P,G	K,P	K,P,M,G,H,D	K,P,M,G,T,C	K,M,G,T,C
Adult survival rates		K				K?	
Adult condition	45 adults	K	K,P	K,P	K,M,H	K,M	K,M,T

Follow Birds	20 Birds	
Foraging location		
Foraging distance		
Foraging trip duration		
Time Budgets		
Foraging effort		
HaBitat selection		
Ind vs forag flock		
Dist from shore		
Water depth		
Water temp and sal		
Tidal stage		

PARAMETER	SAMPLE SIZE	START DATE	FREQ	END DATE	EFFORT (People days)	SHARE W/	CULM EFFORT (People days)
Nest check	100 nests	6/1	1/3day	8/15	1/2day/3day	none	2day/3day
Productivity plots (clutch size, lay, hatch and fledge dates and success)	200 nests	6/1	1/3day	8/15	1/4day/3day	none	1/4day/3day
Growth rates	60 nests	hatching	1/4days	8/15	2day/4day	none	4 1/4day/3day
Chick provision rate (Feeding freq)	30 nest days	1 week after hatch	1/nest	4 weeks after hatch	1day/3day	feed freq	5 1/4day/3day
Chick meal size (periodic weighing)	30 nests	1 week after hatch	1/nest	4 weeks after hatch	1day/3day	provis rate	5 1/4day/3day
R Chick diets	50 chicks	hatching	1/nest	fledging	1/2day/3day	adult diet	5 3/4day/3day
R&I Adult diet	50 adults	hatching	1/Bird	fledging	1/2day/3day	chick diet	6 1/4day/3day
I chick diets	200 chicks	hatching	1/nest	fledging	1/4day/3day	none	6 1/2day/3day
DC C							
DCC maint.		6/15	1/week	8/15	1/2day/3day	none	7day/3day
Trip duration							
Tidal stage							
Follow Birds	20 Birds	6/15	1Bird/3/4day	8/15	4 1/2day/3day	none	11 1/2day/3day
Foraging location							
Foraging distance							
Foraging trip duration							
Time Budgets							
Foraging effort							
HaBitat selection							
Ind vs forag flock							
Dist from shore							
Water depth							
Water temp and sal							
Tidal stage							

Mark adults for survival and exchanges	100 Birds	6/15		hatching	4day/3day	none	XXX
Predation obs		6/1	daily	?	as aKle	none	XXX
Survival rates	500 Birds						

PARAMETER	SAMPLE SIZE	N. PWS	C. PWS	S. PWS	CHISIK	KACH	BARRENS
K=BLKI, P=PIGU, M=MURRE, G=GWGU, T=TUPU, H=HOPU, C=PECO, R=RFCO, D=DCCO							
Productivity plots	200 nests						
clutch size		K,G	K,P,G	K,P	G	K,P,G	K,M,G
lay dates and success		K	K,P	K,P			
hatch dates and success		K,G	K,P,G	K,P	K,M,G,H	K,P,M,G	K,M,G,T
fledge dates and success		K	K,P	K,P	K,M,H	K,P,M,C	K,M,T,C
nestling survival		K	K,P	K,P	K,M,H	K,P,M,C	K,M,T,C
brood reduction		K	K,P	K,P	K	K,P	K
brood size at fledging		K	K,P	K,P	K	K,P	K
fledgling age		K	K,P	P			K,M
overall productivity index		K,G	K,P,G	K,P	K,M,H,G	K,P,M,G,C	K,M,G,T,C
Chick growth rates	30 nests	K	K,P	K,P	K,M,H	K,P,M	K,M,T
fledgling mass & condition		K	K,P	P			
Adult activity budgets (radio)	30 Birds						
forage trip duration		K	K	K			
time both parents present		K	K	K			
Adult activity budgets (visual)	20 nest days						
forage trip duration		K	K,P	P	K,M	K,M,P	K,M
time both parents present					M	M,P	M
chick provisioning rates	30 nest days	K	K,P	P	K,M	K,M,P	K,M
Chick meal size							
a. periodic chick weighing	40 nests	K	K,P	P			
b. Weigh regurgitate	all	K	K	K	K	K	K
Chick diets	50chicks	K	K,P	K,P	K,M,H	K,P,M	K,M,T
Seasonal chick diets	20/wk	K,G	G		K,M,H,G	K,P,M,G	K,MT,G
Adult diet	50 adults				K,M,G,H,C	K,P,M,G,T,C	K,M,G,T,C
Seasonal adult diets	20/wk	G	G		K,M,H,G	K,M,G	K,M,T,G
Adult census		K,G	K,P,G	K,P	K,P,M,G,H,D	K,P,M,G,T,C	K,M,G,T,C
Adult survival rates		K				K?	
Adult condition	45 adults	K	K,P	K,P	K,M,H	K,M	K,M,T

Follow Birds 20 Birds

Foraging location
Foraging distance
Foraging trip duration
Time Budgets
Foraging effort

HaBitat selection
- Ind vs forag flock
- Dist from shore
- Water depth
- Water temp and sal
- Tidal stage

PARAMETER	SAMPLE SIZE	START DATE	FREQ	END DATE	EFFORT (People days)	SHARE W/	CULM EFFORT (People days)
Nest check	100 nests	6/1	1/3day	8/15	1/2day/3day	none	2day/3day
Productivity plots (clutch size, lay, hatch and fledge dates and success)	200 nests	6/1	1/3day	8/15	1/4day/3day	none	1/4day/3day
Growth rates	60 nests	hatching	1/4days	8/15	2day/4day	none	4 1/4day/3day
Chick provision rate (Feeding freq)	30 nest days	1 week after hatch	1/nest	4 weeks after hatch	1day/3day	feed freq	5 1/4day/3day
Chick meal size (periodic weighing)	30 nests	1 week after hatch	1/nest	4 weeks after hatch	1day/3day	provis rate	5 1/4day/3day
R Chick diets	50 chicks	hatching	1/nest	fledging	1/2day/3day	adult diet	5 3/4day/3day
R&I Adult diet	50 adults	hatching	1/Bird	fledging	1/2day/3day	chick diet	6 1/4day/3day
I chick diets	200 chicks	hatching	1/nest	fledging	1/4day/3day	none	6 1/2day/3day
DC C							
DCC maint.		6/15	1/week	8/15	1/2day/3day	none	7day/3day
Trip duration							
Tidal stage							
Follow Birds	20 Birds	6/15	1Bird/3/4day	8/15	4 1/2day/3day	none	11 1/2day/3day
Foraging location							
Foraging distance							
Foraging trip duration							
Time Budgets							
Foraging effort							
HaBitat selection							
Ind vs forag flock							
Dist from shore							
Water depth							
Water temp and sal							
Tidal stage							

Mark adults for survival and exchanges	100 Birds	6/15		hatching	4day/3day	none	XXX
Predation obs		6/1	daily	?	as aKle	none	XXX
Survival rates	500 Birds						

PARAMETER	#NESTS/ BIRDS	CULM NESTS	CULM CHICKS	CULM ADULTS	TOTAL EFFORT 7/15-8/5 120 PERSON DAYS
Nest check	100 Birds			500	10 person days
Productivity plots (pred plots) clutch size,lay, hatch and fledge dates and success	200 nests	200			10
Growth rates	60 nests	260	120		20
Chick provision rate (Feeding Freq)	30+nest days	290	180		10 @6 nest/day
Chick meal size (Periodic weighing)	60 (30nests)	290	180		see above
R Chick diets	50 chicks	340	230		10
R&I Adult diet	50 adults			550	see above
I chick diets	200 chicks	540	430		5
DCC maint.					8
Follow Birds	20 Birds	560		550	30
Mark adults exchanges	100 Birds			650	10
Predation obs					as able
TOTAL		570	430	650	

G=Greg Golet, R=Dan Roby, I=David Irons

Protocol for APEX Common Murre Studies

Barren Islands
Gull Island
Chisik Island

Arthur Kettle and John Piatt
11 March 1997

Productivity and Hatch Dates

Murre productivity and hatch dates are calculated from data recorded during regular observations of nest sites grouped into plots.

Field work: Generally, clusters of 20-40 nests on one cliff face or section of flat-topped offshore rock are considered plots. At least 7 plots are subjectively selected (to include different habitat types) at each study location (E. Amatuli, Gull, Duck).

If possible the same plots will be used each year and nest site numbers should be retained among years. Observations of each plot will be made from a marked point that is used each year. Plot boundaries will be clearly marked on photographs taken from the observation point, and on hand-drawn maps that show recognizable features of the terrain.

Nests should be observed about every 3 days from before eggs are laid until ultimate nest fates can be determined. Before eggs are laid, a "nest site" is a site attended by an adult. During each check, codes will be used to describe the status of birds at the site and the nest contents if visible. Since it is often difficult to see underneath a murre to determine whether an egg or chick is present, distinctive adult postures will also be used to indicate eggs or chicks. Codes for these data follow:

Adult codes

S Standing and not in incubation or brooding posture.

L Laying down and not in incubation or brooding posture.

IP Incubation posture. A distinct posture assumed by most murres when incubating eggs. Adult sits forward with back humped, tail held down, and wings slightly dropped with tips uncrossed.

BP Brooding posture. A distinct posture assumed by most murres when brooding chicks. Characterized by wing-mantling--the wing sheltering the chick is dropped.

P Adult present. Can't classify posture as any of the above.

N No adult present.

Example: "2S" means that 2 adults were standing

Nest content codes

E An egg is seen

C A chick is seen

O There is no egg or chick

U Undetermined nest content

Examples: "SLO" means that one adult stood, another lay, and there was no egg or chick.

"NC" is an unattended chick

"NO" is an empty nest site

Data analysis: For each plot we calculate productivity (chicks fledged per egg), hatching success (chicks hatched per egg), fledging success (chicks fledged per chick), and median hatch date. The mean and standard deviations of plot values provide the best point estimates for a study location for each year.

Because laying and hatching of eggs and fledging of chicks are rarely observed during plot checks, the date that a nest site changed status (i.e., "no egg" to "egg", "egg" to "chick", or "chick" to "no chick") is estimated to be the midpoint between the closest pre- and post-event observation dates. Two methods are used to improve precision during data analysis. First, each nest site with a "data gap" of more than seven days between pre- and post-event observations for both laying and hatching is excluded from the data set. Second, if the data gap for laying is smaller than the gap for hatching, we calculate the hatch date by adding 32 days (the incubation period) to the laying date (see Byrd 1986, 1989; Roseneau et al. 1995).

Chicks last seen at age 15 or older are considered fledged (Hatch and Hatch, 1990).

Plots estimates (n ~ 7 per site) will be used to compare among sites and years
with ANOVA and Tukey pairwise mean comparison. Trends among years will be tested with Kendall's tau rank corellation analysis.

Chick Growth

Gull and Chisik islands

Field work: On Gull and Chisik islands, fifteen to thirty unmarked murre chicks of unknown age will be weighed and measured three times. Personnel will visit the colonies at dawn or after sunset during early, mid, and late chick-rearing periods and attempt to measure a sample that represents chicks of varying ages. Data recorded will be mass (to 1 g), flattened wing chord (to 1 mm), and culmen (to 0.1 mm). Personnel time in the colony will be limited to 30 min.

Data analysis: Mean mass as a function of wing length will be plotted for all data, and the linear phase of mass increase will be determined. For all measurments within this linear phase, mass will be divided by wing length to derive an index of body condition. These values will then be averaged for each island; differences will be compared with t-tests.

East Amatuli Island

Field work: At East Amatuli Island, if sea conditions allow it (as they did in 1996), fledglings will be weighed and measured just after they jump from the nesting cliffs. Fledglings will be scooped from the water, weighed, measured, and released one at a time. A dip net is used to capture the chicks. Wing chord is measured to 1 mm, culmen to 0.1 mm, and mass to 1 g. Wing chord is measured on a flattened wing. If the weighing platform is a boat, a 500-g Pesola scale, rather than a 300-g scale, will be used to minimize bounce. To maintain boating safety and precision of weights, this parameter will be measured only in very calm sea conditions. For safety, a full moon is desirable.

Data analysis: Mean mass, wing chord, and culmen will be averaged as annual indices. Differences among years will be tested with ANOVA.

In 1997, personnel at Gull and Chisik will assess the feasibility of measuring murre fledging size, and the crew at East Amatuli Island will assess the feasibility of measuring more pre-fledging samples (one sample of 33 chicks was measured late in the nestling period in 1996).

Chick Food Types

Field work: We will identify prey items brought to chicks by observing with binoculars adults as they return to the nest. Identification will be based on color and shape of the item's body, and of the caudal, anal, adipose fins of fish. "A field guide to common murre bill loads (John Piatt)" and other keys will be used to identify prey.

Observation periods may occur at any time of day and be of any specified length of time, but the time must be set aside specifically for this purpose. We do not want to include fish haphazardly observed during productivity checks, for example; this practice may skew observations toward large fish. We will obtain at least 50 positive identifications each week throughout the nestling period. When possible, we will synchronize days of observations among Gull, Chisik, and East Amatuli islands. We will record only fish returns that were followed by a feeding (we won't include fish brought back for display to a mate or potential mate). Each observation will be recorded as one of the following three categories: (1) "Not Seen" (a feeding occurred but no identification was possible, because the return was too fast or was obscured), (2) "Unknown" (a view sufficient for identification was obtained, but positive identification was not made, or not enough of the fish was visible for identification), or (3) the fish will be identified to the lowest practical taxonomic level.

When nest sites are visited for chick measurements, the area will be searched for dropped prey items; any found will be collected.

Data analysis: We will calculate percentage of occurrence for each category of prey, including "unknown."

Adult Time Budgets
Chick Provisioning Frequency
Nest Attendance by Adults
Foraging Trip Duration

Field work: Adult time budgets will be calculated from day-long observations of a plot of 10 nest sites at each study location. So that variation among nest sites and among days can be calculated, the same nest sites should be used for all observation-days, if possible. The observation post must allow the observation of chick feeding for each nest site. The time of all adult arrivals, deliveries of prey to chicks, exchanges of incubation or brooding duty, and adult departures will be recorded. Each observation-day will begin as close to first light as possible and end as close to dark as possible. Because at East Amatuli Island a commute by boat is necessary, early-morning and late-night observations will be recorded by video and later analyzed at camp. At least three observation-days will occur during incubation, and three during the nestling period. The observations should occur early, middle, and late in the incubation and nestling periods. When possible we will coordinate days of observation among colonies.

We will attempt to color-mark adults with a squirt gun and dye.

Data analysis: Nest attendance will be measured as bird-minutes per nest per hour (a nest with one bird attending for a full hour and a second bird attending for half of the hour will have 90 bird-minutes that hour). Adult provisioning frequency will be measured as feedings per nest per hour. Adult duty exchange frequency will be exchanges per nest per hour. Duration of trips from the nest will begin when an adult leaves the nest and end when it returns. We will calculate values for trips made during incubation, trips during the nestling period, and trips that ended with chick provisioning. Only complete trips will be counted--not trips that were in progress when the observation period started or ended.

We will calculate separately nest attendance during incubation and during the nestling period.

To calculate differences among nests, the nest-day will be the sample.

For example, to test whether there was a significant difference in provisioning frequency among the ten nests, the number of feedings for nest 1 on the first, second, and third observation-day would be compared with the three values for nest 2, etc.

[To calculate differences among days, the nest-day will be the sample. The values for each of the ten nests for one day will be compared with the valuse for another day.]

To obtain an index for the year, the sample will be the daily mean for all the nests. For example, the mean provisioning frequency (feedings / nest / hour) for all ten nests for the first, second, and third observation-days would be compared with those from another year or another site.

Among-nest, -day, and -year, and -site comparisons will be tested with ANOVA and Tukey pairwise mean comparison; trends among years will be tested with Kendall's tau rank corellation test.

Population Counts

Field work: Murres will be counted on all productivity plots whenever plots are checked. On Chisik and Gull islands, an additional set of larger attendance plots will be counted 5-10 times during the season; on East Amatuli Island (and Nord I.) in 1977, this will be part of Project 97144.

Data analysis: The sample for obtaining the annual mean for each type of plot set will be the daily total count of all the plots. The annual index for comparing population size among years will be the average of the daily total counts for all days between the peak of hatching and the start of fledging. If plots are added or subtracted, we will maintain a sample of plots for which counts can be compared among all the years of the study.

Differences among years and sites will be tested with ANOVA followed by Tukey pairwise mean comparison. Trends will be tested with Kendall's tau rank corellation analysis.

Literature Cited

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Protocol for Collecting and Processing Samples
APEX Forage Fish Diet Investigations (97163C)

M. V. Sturdevant, Principal Investigator

Auke Bay Laboratory, National Marine Fisheries Service

March, 1997

List of Appendices

Appendix A. Checklist of field supplies for collecting, processing, preserving, labeling and shipping forage fish and prey samples for APEX forage fish diet studies.

Appendix B. Forage fish species codes used in the identification of specimens collected for APEX studies. Priority species indicated with **. Codes provided courtesy of SEA Program.

Appendix C. APEX fish diet study sample log for forage fish , zooplankton and epibenthic prey samples. Gear codes are indicated at bottom of page.

Appendix D. Miscellaneous information used in the APEX forage fish diet study. Database codes are indicated next to the data field in parentheses..

Appendix E. APEX sample labels for use with fish, zooplankton, and epibenthic samples collected for diet studies.

Appendix F. Stomach content data sheet for APEX diet studies. Species codes are given in Appendix G.

Appendix G. List of prey codes, taxonomic names, size groups, summary taxonomic categories, mean weights (mg), and literature sources for prey weights used in APEX 97163C forage fish diet studies.

Appendix H. Zooplankton and epibenthic sample data sheet for use in APEX diet studies. Species codes are given in Appendix G.

Introduction

"Diet Overlap of Forage Fish Species" focuses on the trophic interactions of forage fish in Prince William Sound (PWS) and the Gulf of Alaska (GOA). The study is one component of the Alaska Predator Ecosystem Experiment (APEX), a multi-disciplinary, multi-year study designed to examine the PWS food web and its effects on species injured by the *Exxon Valdez* Oil Spill (EVOS). The diet study is conducted under the APEX hypothesis that "planktivory is the factor determining abundance of the preferred forage species of seabirds." This hypothesis suggests that, if carrying capacity limits the production of forage fish species, then utilization of prey resources by some planktivores will shift in response to the changing abundance and distribution of other planktivores; such shifts will be reflected in forage fish diets through competition for food. Evidence supporting the alternative hypothesis, that forage fish diets are similar and remain unchanged when the distributions of abundant species overlap, would suggest that food is not limiting. These hypotheses are being tested by examining the food habits, diet overlap and prey selection of several species of forage fish in different areas of PWS and in different geographical regions. This protocol outlines the objectives of the diet study, describes the methods used in field collection of samples, sample preservation, and laboratory processing of forage fish and prey resource samples, and describes basic data summary methods to achieve the study objectives. Appendices A-H contain data sheets, field supply lists and other details necessary to carry out these methods.

Objectives

The diet study has the following long-term objectives: (1) to characterize the food habits of forage fish species and size groups in PWS and the GOA from spring through fall seasons by analyzing fish stomach contents; (2) to investigate forage fish prey selection by analyzing zooplankton samples collected at the same stations and approximate times as fish; (3) to determine whether forage fish diets shift in the presence of potential competitors by comparing diets of fish collected from mixed species schools to those from monospecific schools in the same area; (4) to determine whether prey resources are partitioned by time of day, to determine times of peak feeding of species/size groups, and to assess changes in utilization of local prey resources by fish over the period of a day by analyzing stomach contents from fish collected on a diel cycle (every 4-6 hours over a 24-hour period) in two ways: (a) from the same schools of fish tracked acoustically and (b) from the same location; and (5) to determine field evacuation rates of forage fish for use in studies of the bioenergetics of competition.

To date, most samples for diet studies were collected opportunistically during APEX surveys along offshore or nearshore transects in 1994-1996. The identifications of fish detected hydro acoustically were verified by trawling or fishable beaches were seined blindly (Haldorsen et al 1996; Haldorsen and Shirley 1996); diet samples were retained whenever possible. Analysis of the 1994-1995 diet samples has resulted in significant progress toward objectives 1-3, above. When samples collected in 1996 have been completely processed, additional information on how fish diet and trophic relationships vary geographically, interannually, seasonally and with species composition will be available. In the three remaining field seasons (1997-1999), food competition among forage fish species will be studied via directed sampling efforts to meet objectives 4 and 5.

Field Methods

Sample Collection

APEX Project 97163C (APEX/Fish Diet Overlap) will primarily depend on Projects 97163A (APEX/Forage Fish Assessment; Haldorsen and Shirley 1996) and 97163M (APEX/Responses of Seabirds to Forage Fish Density; Piatt 1996) to obtain biological samples for diet and zooplankton analyses. Additional samples will be provided from beach seine operations conducted at Naked Island by the pigeon guillemot foraging studies (97163F) and in the Barrens Islands for the nesting study (97163J). Forage fish may include pelagic schooling species in the offshore region of PWS as well as demersal nearshore species. The size range in forklength (FL) of forage fish for diet analyses will encompass specimens from approximately late larval size (>20 mm) to juveniles (<200 mm). Priority species include Pacific sandlance (*Ammodytes hexapterus*), Pacific herring (*Clupea harengus pallasi*), walleye pollock (*Theragra chalcogramma*), tomcod (*Microgadus proximus*), Pacific cod (*Gadus macrocephalus*), capelin (*Mallotus villosus*), eulachon (*Thaleichthys pacificus*), northern smoothtongue (*Leuroglossus schmidti*), and juvenile salmonids (*Oncorhynchus* spp.; pink, chum, sockeye and coho). Other species, particularly intertidal fish of importance to the birds, such as Pacific snake pricklebacks (*Lumpenus sagitta*) and daubed shanny (*L. maculatus*), are also of interest. Samples of unusual species, such as sandfish (*Trichodon trichodon*), saffron cod (*Eleginus gracilis*) or prowfish (*Zaprora silenus*), will be retained for diet analyses, to take advantage of the opportunity to contribute new data to the limited information available on the food habits of such species.

Fish collected for the "special cases" of diel feeding and gut evacuation rate studies will be handled in the same manner as described below. As these investigations depend on directed sampling efforts, they will be conducted at an opportune time to fit in with other activities scheduled (Haldorsen et al. 1996). Diel studies will be conducted during discreet time intervals of 00:01-06:00 hours (Time I), 06:01-12:00 hours (Time II), 12:01-18:00 hours (Time III), and 18:01-24:00 hours (Time IV). The gut evacuation study will be accomplished by collecting 80-100 specimens of a fish group from one site at the time of peak feeding (determined from diel studies). Fish will be maintained at ambient temperature in an aquarium on board the vessel during the starvation period following capture. Stomach content evacuation will be monitored by sacrificing 10 specimens every hour for a period of 8 hours. Only the data from the specimens preserved immediately after catching will be included in food habits analyses other than the evacuation study.

Sample Processing

Sampling supply kits containing all materials necessary for shipboard processing and subsequent shipment of preserved samples as air cargo to Auke Bay Laboratory will be provided (Appendix A). Materials and general methods of preparing samples for shipment to the lab are described below.

1. Fish samples. Forage fish collected for diet studies will initially be processed following the protocols established for APEX Projects 97163A and 97163M (above). All catch and size data will be recorded by personnel on these projects. Samples will be sorted to species (see Appendix B), and up to 200 randomly subsampled specimens of each species and size class will be measured to the nearest mm FL to generate length frequency data.

Fish showing signs of regurgitation in the net (gaping mouths) will not be used for diet studies. If fish are living when the catch is retrieved (e.g., during beach seining versus trawling operations), samples will be anaesthetized with MS-222 (tricaine methonosulfate) in a container of seawater. Small fish will be rendered inactive in a solution of approximately 1 teaspoon MS-222 per 5 gallon bucket of saltwater; add more anaesthetic as necessary. This will minimize the possibility of regurgitation of fish stomach contents in formalin solutions.

Fish larger than approximately 50 mm will be identified in the field. Identifications will later be confirmed in the laboratory, particularly to distinguish similar species (e.g., salmonidae) or larval specimens. The abdomens of fish longer than approximately 100 mm FL will be slit to allow formalin to penetrate the body cavity and fix stomach contents. This is done by inserting the tip of the dissecting scissors or the scalpel into the vent and slitting the ventral side of the specimen forward to the heart, without puncturing the stomach wall. Same-species fish differing by at least 25 mm in FL will be considered different size/age classes for the purposes of diet studies. At least 10 specimens in each species-size group will be selected and preserved from these subsamples for diet analyses. The preferred method of preservation is to fix samples in a solution of 10% formalin buffered in seawater (see below). When possible, 2-5 additional fish per species-size class will be preserved to allow for loss due to damaged specimens. The stomachs of 10 fish per species-size group will be analyzed microscopically in the laboratory for statistical purposes. Fish of the same species-size group collected in different hauls at the same station in close temporal proximity (within one hour) may be pooled to obtain the needed sample size. Smaller numbers of rare or unusual species may be preserved for diet analyses.

When limited samples are available for multiple APEX projects, some of which require frozen specimens, those reserved for diet analyses may be shared by exercising one of two procedural options: a) removal and preservation of stomachs only in the field so that carcasses can be frozen to accomodate others' use, or b) initially freezing whole fish, with removal of stomachs later when analyses requiring frozen tissue are conducted. The first method is preferred for two reasons: 1) digestion of stomach contents continues during the freezing process, and 2) microscopic prey specimens are more difficult to identify because freezing further damages their tissues. Dissecting tools, microscope, light, etc., will be provided on the vessel (Appendix A) to facilitate at-sea processing of samples under the first procedural option. In addition, unique specimen numbers will be assigned in the field to dissected specimens. All records and bottles, vials, baggies, etc. containing tissues from a dissected fish will be labelled with its unique number so that researchers can access complementary data describing a specimen. If the second procedural option is exercised, a record of the frozen specimens will be written into the stomach sample log as a reminder of their availability from the 97163A,C Principal Investigators.

2. Prey resource samples. Prey resource samples (two replicates) will be collected whenever diet samples are successfully collected, including when specimens are frozen for multiple project use rather than preserved (see above). Offshore diet samples, such as fish collected by trawling, will be complemented by zooplankton samples; nearshore samples, such as those collected by beach seining, will be complemented by both zooplankton and epibenthic prey samples. Zooplankton samples collected offshore will be sampled with a 0.5 m diameter, 243-_ mesh ring net towed vertically from the depth where fish are sampled to the surface. In addition, macroinvertebrates collected in the 0.5 mm mesh cod end of the midwater trawl or the NIO net will be preserved from Project 95163A to compare to prey resources utilized by the fish; although non-quantitative, these samples can provide information about the relative composition of prey resources not sampled by the plankton nets. Zooplankton samples collected nearshore will be sampled using the same type of net within approximately 100 m of the fish sampling site or beach (e.g., when beach seined); the plankton net will be towed to a standard, maximum depth of up to 20 m depending on bottom depth at that distance from shore (Hauser 1987; Celewycz and Wertheimer 1996). Epibenthic samples will be collected using an epibenthic sled with an attached 0.3-m-diameter, 243-_-mesh net hauled along a 10-m horizontal area at approximately 0.5-m depth adjacent to the seine location. The sled is designed to be towed 11-cm above the substrate, thus collecting both epibenthic and planktonic organisms across the integrated microhabitats near the bottom. Zooplankton and epibenthic samples will be handled similarly on board the vessel. Replicate samples will be separately concentrated into the cod end of the nets by washing them down from outside of the net with the deck hose, then using a squirt bottle and sieves having mesh < 243-_ to further reduce sample volume as necessary (Hauser 1987) .

Labelling and logging samples

Adequate labelling and sample collection records are crucial elements of field research. Labels and sample log sheets printed on write-in-the-rain paper will be provided for diet samples by project 97163C (Appendices B and C, respectively). These labels and log sheets will be designed to accomodate records of both the fish and prey samples collected and should be written on with pencil or indelible marker, not pen. They will include only essential information pertaining to the subset of samples preserved for diet studies because basic catch and identifying information (eg., station latitude and longitude, bottom depth, etc.) will be available for reference in the ship's and project cruise logs.

The following data is required for labels and sample logs: set number (haul number), gear type, date, time, species, bottle number, number of specimens in the sample, and location. APEX 97163A or B numbering conventions will generally be followed for identifying samples. This number is of the form "97-01-001-T", indicating the year, cruise number within the year, station, and gear type. The letter codes designating gear type are printed on the bottom of the sample log sheet. A 3-digit code will be used to identify fish species (Appendix C), following the SEA Program convention. Sample bottles will be identified by a separate number using the indelible markers provided. Fish sample bottle numbers will be of the form "001F"; zooplankton and epibenthic sample bottle numbers will be of the form "001P" and "001E". The bottle number will be recorded on the sample log with the sample number and identifying information as samples are preserved. Bottle numbers are used to facilitate the inventory process; particular fish or prey resource samples can be more easily located by comparing bottle numbers against sample logs, rather than searching all the labels on all the bottles for the one sample desired. Location will be recorded as a place name or area of the sound. Accessory descriptions and information should be recorded in the diet study field notebook; details such as weather, habitat descriptions, tidal stage, and personally meaningful landmarks for the sample site, etc., should be included.

Sample Preservation

Formalin for preserving fish and prey samples will be made as a 1:10 (10%) or 1:20 (5%) solution of formaldehyde concentrate:water, respectively. Formaldehyde concentrate (37.5%; hereafter referred to as "formaldehyde") will be supplied in jugs (1- gallon or 4-liter) or spigotted containers (5-gallon or 20-liter). Fish will be preserved in 1000 ml (1-liter) and 4000 ml (4-liter) plastic bottles in 10% saltwater-buffered formalin solution. Zooplankton and epibenthic sample replicates will be separately preserved in 5% saltwater-buffered formalin solution in 500 ml sample bottles after concentration.

Sample bottles may be marked in advance of field collections with lines indicating the correct volumes of formaldehyde and seawater. Plastic beakers and graduated cylinders will be provided to measure formaldehyde and water. The volume requirements of formaldehyde and seawater for different sample bottle sizes and formalin concentrations are given in Appendix D. Fish sample bottles should be prefilled with no more than 75% volume of formalin solution to allow 25% volume for fish biomass. Prey samples should not be poured directly into the formaldehyde, as this can rupture zooplankters due to osmotic shock. A small amount of filtered seawater should be added to the formaldehyde before the sample is poured in, then the bottle should be topped off with additional filtered seawater.

Fish up to approximately 100 mm in length can be put whole into bottles or into sample bags which go in bottles. To conserve space, two sizes of Tyvek, perforated "soil sample bags" will be included for small fish: 3 _ x 5 "and 5 x 7 ". The bags have a label sewn into the seam. Sample bags containing fish should be submerged so the formalin can percolate through the perforations into the bag; check that the bags don't simply float on the surface of the solution. Larger fish should be placed loose in one or more 1-gallon bottles with at least enough formalin to cover them. Lab gloves and large forceps wll be provided should one need to reach into the solution.

A label for each sample included in a bottle should be placed on the sample bag or with loose fish IN the bottle; a duplicate label should be taped with wide scotch tape ON the outside of the bottle (Appendix E; see also labelling section below). Multiple labels can be taped to the outside of the bottle. Use pencil or marker on the bag label OR put a standard, preprinted label on the inside of the bag; to facilitate later sorting,, write the number of specimens and species code contained in the bag on the bag itself with indelible marker (e.g., "12 pollock (270)"; see also Appendix C). If samples are pooled from different hauls into one bottle, it is imperative that each sample be uniquely labelled. If individual, dissected stomachs are preserved in bags or bottles, they must be labelled with unique specimen numbers and length-weight data recorded with other sample information.

Shipping samples in formalin

When packing formalin-preserved samples to be returned to Auke Bay Lab, all Internation Air Transportation Association (IATA) and Code of Federal Regulations 49 (CFR49) should be adhered to. All sample bottles should go inside plastic garbage bags to contain any leaks. Stand the bottles up inside one or more garbage bags inside the tote. Pack vermiculite around the bottles inside the bags, to absorb any potential spills and keep them in place. Tie up the bag, latch the lid and wrap duct tape completely around the labelled totes for shipping. The required forms and packing labels and an example of the codes to fill in on the HAZMAT Declaration of Dangerous Goods form for samples in 10% formalin will be included (see also Appendix F). Please contact Molly Sturdevant or Mary Auburn with APEX (789-6041 or 6057), or Mike Murphy, the Safety Officer (789-6036), at ABL for questions about HAZMAT packaging.

Laboratory Methods

Forage fish stomach samples and prey samples will be analyzed at the NMFS Auke Bay Laboratory. Laboratory processing will include transfer of fish to isopropyl alcohol, measuring and dissecting specimens, and stomach content and prey sample analysis. The following methods are consistent with laboratory protocols developed during research preceding the APEX Project, including SEA Program 94163C (Forage Fish Diet Overlap).

1. Fish Samples. After arriving at the laboratory, whole fish samples will be stored as returned from the field in 10% buffered formaldehyde for a minimum total of six weeks to allow shrinkage to stabilize. They will then be rinsed and transferred to 50% isopropanol (isopropyl alcohol) for preservation for a minimum of 10 days before analysis. When ready for processing, ten specimens per species-size class will be randomly selected from each haul. Whole fish will be blotted dry, weighed to the nearest 0.01 g and measured to the nearest mm standard fork length (FL). Fish stomachs, including the region from the pharynx immediately behind the gills to the pylorus, will be excised from the body cavity. The foregut will be blotted dry and weighed full to an accuracy of 1.0 mg, the contents removed, and the empty stomach blotted and weighed again. Total stomach contents wet weight will be estimated by subtraction. Stomach fullness and prey digestion will be visually assessed and semiquantitative index values (Appendix F) recorded. Fullness index will be recorded as: 1=empty, 2= trace, 3=25%, 4=50%, 5=75%, 6=100% full, and 7=distended. The fullness code provides an index of the amount of food consumed relative to the fish's stomach size. The state of digestion will be recorded as: 0=fresh, 1=partially digested, 2=mostly digested, 3=stomach empty. These codes provide indications of how recently the fish ate as well as general prey condition, which reflects the level of identification possible. All measurements on fish specimens will be recorded on individual data record sheets (Appendix F.)

Prey items in the gut will be completely teased apart, identified to the lowest possible taxonomic level and enumerated. Standard subsampling techniques (Folsom splitter, Stempel pipette) will be employed when stomachs are so large and/or full that counting every prey item is not practical (Kask and Sibert 1976). Prey identification efforts will be concentrated on identifying copepods and other taxa to species, sex, size and life history stages to examine prey selection within these categories. Quality assessment-quality control (QAQC) measures will consist of dividing each set of samples for analysis between at least two technicians and cross-checking identifications among the three technicians analyzing the samples. Resident and non-resident taxonomic experts will be consulted when a consensus identification cannot be reached. Where possible, partially digested large copepods which can not be completely identified will be distinguished as pristane-manufacturing species (*Neocalanus* spp., *Calanus* spp.) or non-pristane-manufacturing species (e.g.., *Metridia* spp., *Epilabidocera longipedata*). Raw counts of prey taxa, the fraction split examined, and expanded total numbers will be recorded on the same data record sheets as other fish measurements (Appendix F).

Prey categories and taxa are described in the prey code list (Appendix G) developed for use in the APEX and related ecosystem studies. This dynamic list includes taxa encountered in stomach content, zooplankton and epibenthic samples. Prey categories and weight data are constantly being expanded and refined as new prey are encountered and reference collections improved. This prey list, as well as other appendicized data record forms, mimics the database structure used to manage the APEX diet data. Further documentation for the database, currently stored in RBASE 4.5++, is available at ABL. The prey list will be supported by a voucher collection of prey taxa. After samples have been processed, gut contents will be saved in a labeled vial in 50% isopropanol and prey samples will be reconstituted and archived in the original bottles. Stomach and prey samples may be disposed of when the data is published and no longer needs to be available for reference.

2. <u>Prey Resources</u>. The composition of available prey resources will be estimated from laboratory analyses of ring net samples. A Folsom plankton splitter or Hensen-stempel pipette will be used to split or subsample (1, 5, or 10 ml capacity) each sample. Samples will be diluted to achieve a minimum total count of 500 animals or 200 of the dominant taxon. Zooplankton and epibenthic invertebrates will be identified to the lowest practical taxon and enumerated in each subsample in a manner similar to the analysis of stomach content samples. These data will be recorded on individual sample data sheets (Appendix H). Raw numbers of taxa in either stomach or prey samples will be expanded by multiplying the count by the appropriate volume or fraction split enumerated. Since the proportion of the sample analyzed varies with its condition, stomach and prey resource data sheets provide a field to record raw numbers and sample splits for verification of expanded numbers.

Data Summary and Statistical Methods

Mean preserved fork lengths (FL) for each group of fish used in diet studies will be calculated to distinguish between intraspecific size/age groups. Literature values for size-at-age will be relied upon since fish will not be aged. The lengths and weights of any frozen fish analyzed will be converted to the sizes of formalin-preserved fish using fresh-preserved size relationships obtained from regression analyses.

The semi-quantitative stomach fullness index of fish groups will be summarized as < 25% full (empty or trace contents), 25-50% full and > 75% full. After summing total weight of all prey taxa in the gut, stomach fullness as mean prey percent body weight (%BW) will be computed:

$$\%BW = [\_x(i)*(w_i)/(BW- \_x(i)*(w_i))]*100$$, for i = 1 to n prey taxa,

where w_i = the mean weight of each prey taxon in mg, and BW = the fish body weight in mg.

The percent number of fish in a species or size group having each level of stomach fullness will be computed. Mean fullness at time of day will be analyzed to determine principal diel feeding periods; discreet time intervals rather than continuous times will be used from diel feeding periodicity studies are conducted. Gut evacuation rate will be determined by modelling the hourly decline in %BW, prey number and fullness index and (Persson 1986).

The percentage composition and mean abundance of prey taxa in zooplankton and epibenthic samples will be summarized to characterize the general resources available to planktivores in the northeast, central and southwest areas of PWS. Total biomass in each taxonomic group will be estimated as the product of average body blotted-dry weight and abundance. Literature values for average blotted-dry wet weight of each species or developmental stage will be used when available. When literature values are not available, mean blotted-dry wet weight will be determined by weighing a sample (n_ 50) of intact specimens (Appendix G). The abundance of available epibenthic and planktonic prey will be standardized to a 1 m^2 surface area or 1 m^3 water volume.

Overall food habits of forage fish species will be summarized for the northeast, central and southwest areas of PWS by pooling the specific prey taxa identified into summary prey categories (Appendix F) presented as percent total biomass (calculated as for prey resources, above), percent prey numbers and percent frequency of occurrence. Index of Relative Importance diagrams (Pinkas 1971) will be constructed from these values to characterize diets.

The Schoener Index of Overlap, also known as the Percent Similarity Index (PSI), will be used as the principal measure of diet overlap (Wieser, 1960; Schoener 1974; Boesch, 1977; Hurlbert 1978; Krebs 1989). The PSI is computed by summing the minimum percentage of all prey taxa shared between two species of forage fish :

$$PSI_{jk} = \_min(p_{ij}, p_{ik}) = 1-0.5(\_ |p_{ij} - p_{ik}|),$$

where p is the biomass proportion of the i^{th} prey taxon in n taxonomic categories consumed by fish species j and k. The PSI is a simple and conservative estimator of diet overlap, yet, in this case, is based on the finest resolution identifications available. It will be used to compare general food habits of fish among different regions of PWS and to compare specific diets of forage fish collected sympatrically in the same hauls.

Strauss Linear Selection Index will be used as the principal measure of prey selection. This measure compares the numbers of prey taxa consumed by fish to the numbers available in prey resource sample (Ivlev 1961; Krebs 1989; Manly 1986; Strauss 1979). The index is computed by calculating the difference in the mean numerical proportion of a taxon consumed by fish and the mean numerical proportion available in the environment:

$$L_i = (p_i - e_i)*100, \text{ for } i = 1 \text{ to n prey taxa,}$$

where p_i is the numerical proportion consumed and e_i is the numerical proportion in the prey resource sample. Selection values will be calculated only for fish whose stomach contents can be compared to zooplankton or epibenthic samples collected at the same station. Selection values will be calculated for all taxa observed in either the stomachs or the prey samples. Negative values indicate avoidance, positive values indicate selection, and values near zero indicate predation at a rate proportional to the availability of the taxon.

Competition will be investigated through diet shifts by comparing prey selection values for forage fish species occurring in the allopatric condition with those for the same species in the sympatric condition. The relative frequency of selection or avoidance of available taxa will be used to indicate whether fish diets shift in the presence of potential competitors.

Other statistical analyses used will vary according to the final sample design, but will include standard parametric and non-parametric Analysis of Variance (ANOVA), Linear Regression, Chi Square (2) tests of frequency, tests comparing mean values, and others (Conover 1980; Elliot 1979; Kleinbaum, Kupper, and Muller 1988; Krebs 1989; Manly 1986; and Winer 1971).

Independent variables used in these analyses will include year, season, calendar day, time, tidal stage, sampling area within PWS or Cook Inlet, location (eg., Port Fidalgo), station, depth caught, fish density, gear type, species, and size group.

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Forage Fish Field Collection Protocol for APEX Projects, 1997

Compiled by Jill Anthony, Kathy Turco, and Dan Roby

The objective is to determine the range of quality in forage fish available to seabirds in Prince William Sound and Lower Cook Inlet. Additional samples are required to complete this objective, specifically to determine energy densities for rarely sampled species and to evaluate intraspecific, interannual, and regional differences in commonly consumed species. It is important to obtain samples from the northern, central, and southern divisions of PWS and from LCI to determine regional differences in energy densities.

After catching the fish, please store it in a cooler and freeze as soon as possible. Record these variables for each fish:

Sample number (###)	Sequentially throughout each season
Species	Please refer to the fish prey identification manual provided by Kathy Turco and/or Martin Robards and fish vouchers
Date	Month/Day/Year
Method	ex. Beach seine, trawling, cast net
General location	ex. Kachemak, Naked
Specific location	ex. Salmon Bay, NE Herring Bay
Standard length (mm)	Lay fish out on smooth surface. Measure from tip of nose to end of vertebral column (where flesh ends and tail begins)
Field Mass (g)	Use a paper towel to pat the fish dry a few times to remove excess water. Weigh to the nearest 0.01g. Place in whirl-pak. If you must weigh the fish in the whirl-pak, weigh the whirl-pak first to get the actual weight of the fish.

Record the data in the proper field book for a duplicate record. Place the identification label with the above information in the whirl-pak. Label the outside of the whirl-pak with the Sample number, Species, Date, and General location (ex. Kachemak). Store the fish in a cooler and freeze it as soon as possible.

Either in the course of the summer or at the end, arrange to ship these frozen samples by Alaska Airlines Goldstreak to Kathy Turco (University of Alaska Fairbanks). THIS MUST BE ARRANGED IN ADVANCE. Please do not ship frozen samples to Kathy unless you know that she is in town and is expecting them (she's in and out of town all summer). Her telephone number is (907) 455-4286.

It is critical that samples remain frozen during shipment. If allowed to thaw, it will be impossible to measure the energy content of these samples. Samples must be wrapped tightly and packed in frozen "blue ice" in a cooler or sturdy box lined with crinkled newspaper. To avoid air leaks, seal the cooler or box with duct tape. Always have coolers stored in a freezer whenever possible during transport. Samples should not be in transit for more than 12 hours, unless the cooler can be placed in a freezer in route.

WISH LIST

for Lower Cook Inlet and Prince William Sound (Northern, Central, and Southern, separately)

Walleye Pollock (*Theragra chalcogramma*)

Age 0+ (60-100 mm)	about 100 individuals from each area
Age 1+ (120-150 mm)	about 25 individuals from each area
Age 2+ (151-190 mm)	about 15 individuals from each area

Capelin (*Mallotus villosus*)

Adult males: pre-spawning (90-150 mm)	about 25 individuals from each area
Adult males: post-spawning (90-150 mm)	about 25 individuals from each area
Adult females: pre-spawning, gravid (90-150 mm)	about 25 individuals from each area
Adult females: post-spawning (90-150 mm)	about 25 individuals from each area

Pacific Herring (*Clupea pallassii*)

Age 0+ (60-90 mm)	about 100 individuals from each area
Age 1+ (91-145 mm)	about 25 individuals from each area
Age 2+ (150-190 mm)	about 15 individuals from each area

Pacific Sandlance (*Ammodytes hexapterus*)

Age 0+ (60-90 mm)	about 100 individuals from each area
Age 1+ (110-139 mm)	about 25 individuals from each area
Adult males (140-180 mm)	about 25 individuals from each area
Adult females (140-180 mm)	about 25 individuals from each area

Eulachon (*Thaleichthys pacificus*)

Any age, size, gender, or reproductive class (preferably adults)	25 or more individuals from each area

Diet Taxonomic Composition Protocol for APEX Projects, 1997

Compiled by Jill Anthony, Kathy Turco, and Dan Roby

Forage Fishes

- Analytical balance is calibrated each time it is turned on.

- Balance is tared between each measurement.

- Designate the sample type on the data sheet. "FOFI" represents a forage fish sample.

- Assign a lab sample number to each fish in the format of
  Year+Location+Field Sample Number.

For example, "96S266" represents a sample from Shoup Bay. Standard location codes are attached. Codes for new locations will be added, as necessary.

- Record field data on lab data sheet from the information tag in the whirl-pak.

- Partially thaw sample, until whole fish can be removed from the whirl-pak without tearing open the bag (about 1 hour, depending on the size).

- Denote the condition of the fish (ex. good, mangled).

- Determine lab wet mass of the sample (aka individual lab mass) to ± 0.01 g.

- Key out the species of the fish using reference books and vouchers. Record the species on the data sheet according to the standard species code (see attachment). For example, "PAHE" represents Pacific herring. Clearly indicate and define new codes.

- Measure the standard length of the fish (from the tip of nose to the end of vertebral column, where flesh ends and tail begins).

- Measure the fork length of the fish (from the tip of nose to the place where the tail begins to fork, not to the very end of the fish tail).

- Whenever possible or relevant, determine the gender and reproductive state of the fish.

- In representative fish, remove the otolith and indicate that this has been done on the data sheet.

- Record any comments about the fish, replace it in the original whirl-pak, and refreeze.

• Arrange to ship frozen samples by Alaska Airlines Goldstreak to Jill Anthony (Oregon State University). THIS MUST BE ARRANGED WITH JILL IN ADVANCE. It is critical that samples remain frozen during shipment. If allowed to thaw, it will be impossible to measure the energy content of these samples. Samples must be wrapped tightly and packed in frozen "blue ice" in a cooler or sturdy box lined with crinkled newspaper. To avoid air leaks, seal the cooler or box with duct tape. Always have coolers stored in a freezer whenever possible during transport. Samples should not be in transit for more than 12 hours, unless the cooler can be placed in a freezer in route.

Pigeon Guillemot Chick Meals

• Follow the protocol for forage fishes above.

• Designate the sample type on the data sheet. "PIGU" represents a pigeon guillemot chick meal sample.

Black-legged Kittiwake Regurgitations

• Analytical balance is calibrated each time it is turned on.

• Balance is tared between each measurement.

• When handling solvents, work under a hood with no open flame or spark source. Although hexane is not a known carcinogen, it is moderately toxic if you expose yourself to breathing the vapors for a prolonged period.

• Prepare the 7:2 (v:v) mixture of hexane and isopropyl alcohol (2-propanol) in a clean, empty glass container (ex. 4 liters). Be sure to mix the solvents well. Transfer some to a Nalgene squirt bottle for use.

NOTE: Hexane ranges in purity. It is cost effective to use "Practical" grade hexane, 85% by GC for about $52.45 per 4-liter container. Paying much more than this may mean that you are using a grade that is unnecessarily pure (ex. extremely high grade capillary GC/GC-MS solvent). It is all right to use n-Hexane, if it's available at your stockroom. Isopropyl alcohol (IPA) is the chemical reagent "2-Propanol", $CH_3CH(OH)CH_3$. Water content should be a maximum of 0.5%. This is relatively inexpensive: a 4-liter container of this grade of IPA goes for $19.67 in the latest VWR catalog, so if you are paying much more than $5.00 per liter you are probably using too high a grade.

• Designate the sample type on the data sheet. "BLKI" represents a black-legged kittiwake regurgitation sample.

• Assign a lab sample number to each fish in the format of
Year+Location+Field Sample Number.
For example, "96S266" represents a sample from Shoup Bay. Standard location codes are attached. Codes for new locations will be added, as necessary.

- Samples will be organized by brood meal, such that regurgitations from a two-chick nest should be combined. Maintain the sample number (ex. 96I025/026).

- Record field data on lab data sheet from the information tag in the whirl-pak. Be very careful to keep ADULT, WHOLE, and RANDOM regurgitation samples separate.

- Label a wide-mouthed glass sample jar with the colony, sample type (BLKI), sample collection (Adult, Whole, Random), and sample number. Avoid cheap glass sample jars with flimsy cardboard cap-liners. They tend to dissolve into the solvent.

- Partially thaw sample, until entire regurgitation can be removed from the whirl-pak without tearing open the bag (about 1 hour, depending on the size).

- Weigh sample bag and contents ± 0.1 g, preferably ±0.01 g. Wipe outside of bag prior to weighing to remove any condensed moisture.

- Place contents of bag in sorting pan, preferably while in a semi-frozen state (like soft ice cream). Rinse the whirl-pak with a few mls of hexane:IPA, swirling or shaking to coat inner surface of bag with solvent, and pour solvent into labeled sample jar.

- Open rinsed whirl-pak by cutting at the seams and place in drying oven (about 60 degrees C). Evaporate residual solvent and water and reweigh to determine fresh sample weight by subtraction. Remember that hexane is highly flammable, so don't place a bag with a lot of solvent on it directly in a hot drying oven. If in doubt, let the bag sit under the hood for a few minutes until the hexane is gone.

- Record the quality of the sample on a scale of 1 (fresh) to 5 (highly digested).

- Estimate the percent volume of solid material in each taxonomic group. It is very helpful to use graduated cylinders to check your estimates. Remember that otoliths and other slowly digested material may accumulate in the gizzard from previous meals and could be regurgitated, although the contents of the gizzard is normally not regurgitated when a chick regurgitates. Sparingly add water as needed to suspend otoliths, heads, and other identifiable material.

- Estimate the length of individual fish and the number. It is helpful to weigh the portions of individual fish.

- Record comments about the sample (ex. flesh and skin, all bones, etc.) and whether otoliths were removed.

- After sorting is complete, pour contents of sorting tray into sample jar, use squirt bottle to sparingly rinse down the sorting tray and dissolve any lipid adhering to sides and bottom of tray. Pour solvent into labeled sample jar.

• Leave sample jar uncapped under the hood in order to evaporate most of the hexane. If you have used solvent sparingly this should not take long, because hexane is volatile and should be sitting at the top of the jar. Hexane is so flammable that it would be advisable to evaporate it before you seal up the sample jar and store it in the freezer. Otherwise hexane vapor could conceivably build up inside the freezer and if there was a spark source, look out. Also, you don't want to be shipping glass jars containing hexane if you can avoid it.

• Screw the sample jar cap down securely, wrap electrical tape around seam between lid and jar to guard against leaks, and refreeze.

• Arrange to ship frozen samples by Alaska Airlines Goldstreak to Jill Anthony (Oregon State University). THIS MUST BE ARRANGED WITH JILL IN ADVANCE. It is critical that samples remain frozen during shipment. If allowed to thaw, it will be impossible to measure the energy content of these samples. Samples must be wrapped tightly and packed in frozen "blue ice" in a cooler or sturdy box lined with crinkled newspaper. To avoid air leaks, seal the cooler or box with duct tape. Always have coolers stored in a freezer whenever possible during transport. Samples should not be in transit for more than 12 hours, unless the cooler can be placed in a freezer in route.

APEX STUDY SITES

A	=	Barren Islands
B	=	Block Island
C	=	Chenega Island
Ch	=	Chisik Island
D	=	Duck Island
E	=	Eleanor Island
F		
G	=	Gull Island
H	=	Haldorson (unknown location)
I	=	North Icy Bay
J	=	Jackpot Island
K	=	Kachemak Bay
L	=	Lynn Canal
M	=	Malcolm (unknown location)
N	=	Naked Island
O		
P		
Q		
R	=	Robards (unknown location)
S	=	Shoup Bay
T		
U		
V	=	Valdez Arm
W, X, Y, Z		

APEX Forage Fish Codes

SPECIES	CODE	SCIENTIFIC NAME
Arctic shanny	ARSH	*Stichaeus punctatus*
Armorhead sculpin	AHSC	*Gymnocanthus galeatus*
Black prickleback	BLPR	*Xiphister atropurpureus*
Capelin	CAPE	*Mallotus villosus*
Chum salmon	CHSA	*Onchorhynchusketa*
Crescent gunnel	CRGU	*Pholis laeta*
Crested sculpin	CRSC	*Blepsias bilobus*
Cutthroat trout	CUTR	*Salmo clarki*
Daubed shanny	DASH	*Lumpenus maculatus*
Dover sole	DOSO	*Microstomus pacificus*
Eulachon	EULA	*Thaleichthys pacificus*
Flatfish	FLAT	
Great sculpin	GRSC	*Myoxocephalus polyacanthocephalus*
Horned sculpin	HOSC	
High cockscomb	HICO	
Kelp greenling	KEGR	*Hexagrammos decagrammus*
King salmon	KISA	*Onchorhynchus*
Lingcod	LICO	*Ophiodon elongatus*
Myctophid	MYCT	Myctophidae
Northern ronquil	NORO	*Ronquilus jordani*
Octopus	OCTO	*Octopus* spp.
Pacific cod	PACO	*Gadus macrocephalus*
Pacific herring	PAHE	*Clupea harengus pallasii*
Pacific herring - eggs	HEEG	*Clupea harengus pallasii*
Pacific sandfish	SAND	*Trichodon trichodon*
Pacific sand lance	PASA	*Ammodytes hexapterus*
Pacific tomcod	PATO	*Microgadus proximus*
Padded sculpin	PASC	*Artedius fenestralis*
Pink salmon	PISA	*Onchorhynchus gorbuscha*
Plain sculpin	PLSC	*Myoxocephalus jaok*
Prowfish	PROW	*Zaprora silenus*
Rainbow smelt	RASM	*Osmerus mordax*
Red Irish Lord	RILO	*Hemilepidotus hemilepidotus*
Rex sole	RESO	*Glyptocephalus zachirus*
Ribbed sculpin	RISC	*Triglops pingeli*
Rockfish	ROCK	
Rock greenling	ROGR	*Hexagrammos lagocephalus*
Roughspine sculpin	RSSC	*Triglops macellus*
Sablefish	SABL	*Anoplopoma fimbria*
Shrimp	SHRI	*Pandalus* spp
Silver salmon	SISA	*Onchorhynchus kisutch*
Silverspotted sculpin	SISC	*Blepsias cirrhosus*
Slender eelblenny	SLEE	*Lumpenus fabricii*

Slim sculpin	SLSC	*Radulinus asprellus*
Snake prickleback	SNPR	*Lumpenus sagitta*
Sockeye salmon	SOSA	*Onchorhynchus nerka*
Surf smelt	SUSM	*Hypomesus pretiosus*
Squid	SQUI	
Tidepool sculpin	TISC	*Oligocottus maculosus*
Unidentified	UNID	
Unknown sole	UNSO	
Walleye pollock	WAPO	*Theragra chalcogramma*
Four horned sculpin	FHSC	*Myoxocephalus quadricornis*
Worm	WORM	

FISH PROXIMATE ANALYSIS PROTOCOL

- Gloves are worn throughout the process.
- **Analytical balance is calibrated each time it is turned on.**
- **Balance is tared between each measurement.**
- **Solvents are handled under a ventilation hood.**

Determination of Dry Mass

- Temperature of drying oven is set at 60° C (ovens are normally set and left on).

- Partially thaw Sample is partially thawed, until whole fish or regurgitation can be removed from the Whirlpak without tearing open the bag (about 1 hour, depending on the size of the sample).

- Aluminum weighing pan is labeled with species of fish and sample number using a pencil.

- Aluminum pan is pre-weighed to ± 0.1 mg, and mass is recorded on the bottom of the pan.

- Sample is placed in aluminum pan and mass of wet sample in pan is recorded to ± 0.1 mg. Any sample residue is removed from whirl-pak. For regurgitations, whirlpak is rinsed with a few mls solvent before pouring sample into pan. Weighing pan is allowed to sit under the hood for a few minutes to evaporate the solvent before weighing.

- Sample is placed in drying oven at 60° C, recording the time in the lab data book. Small samples are weighed in 3 days and then every 24 hours until mass is constant (± 1 mg). Large samples are weighed in 6 days and then every 24 hours until mass is constant (± 2 mg).

- At time of re-weighing, sample is allowed to cool in desiccator for a few minutes and weighed in aluminum pan to ± 0.1 mg. If mass is constant compared to previous weighing, time and dry mass of sample and pan are recorded, and "sample dry mass" and "water content of sample" are calculated by subtraction. Percent water content of sample is calculated.

Preparation for Lipid Extraction

- A solvent mixture of 7 hexane: 2 isopropyl alcohol is prepared in a 4-liter brown glass bottle with a secure cap, making sure it is well-mixed. A squirt bottle is filled with 150 ml and stored under the hood.

- Sample is thoroughly ground using mortar and pestle, pulverizing bones and homogenizing sample. All of ground sample is tranferred from mortar back into aluminum pan.

- The mortar and pestle are sparingly rinsed with 7:2 hexane : isopropyl alcohol (v:v) mixture from squirt bottle. Solvent is poured into original aluminum pan with sample. Solvent is evaporated from sample pan under the hood. Sample is placed back in drying oven overnight (or for at least 4 hours) to drive off residual isopropyl alcohol.

- Each extraction thimble is labeled using a pencil with sample number and species. Empty thimbles are placed in drying oven for at least 4 hours.

- After drying, the aluminum pan is placed with ground sample in desiccator to cool, sample is weighed again to ± 0.1 mg and mass recorded as "ground dry sample."

• Thimbles from drying oven are placed in desiccator to cool, each thimble is pre-weighed (± 0.1 mg), and mass recorded as "dry thimble."

• Sample is transferred from aluminum pan into pre-weighed thimble, attempting to remove complete sample using spatula without tearing the pan. Thimbles are used that are large enough for the entire sample to be extracted in no more than 3 thimbles. Thimble + sample are placed in drying oven or desiccator while processing subsequent samples.

• Leaned cotton balls are prepared by placing one ball in a small funnel stemming from a small beaker. The 100% cotton balls are rinsed with 7:2 hexane : isopropyl alcohol (v:v) solution from a squirt bottle. Cotton balls are placed in hood to evaporate solvent (1-3 hours). When dry, cotton balls are stored in a sealed glass jar under the hood.

• Thimble + sample are removed from drying oven, placed in desiccator to cool, weighed to ± 0.1 mg, and recorded as "dry thimble and sample." "Dry sample mass" is determined by subtraction of "dry thimble." While weighing other thimbles in a batch, previously weighed thimbles are stored in desiccator to avoid sample hydration by ambient air.

• Previously leaned and dried cotton ball is placed in the top of the thimble as a stopper. Thimble + sample + cotton plug are weighed to ± 0.1 mg, and recorded as "total dry sample mass."

Lipid Extraction

• Soxhlet apparatus is placed under the hood and cold water source attached to the low inflow of the first condenser unit.

• Six boiling stones are added to each 500 ml soxhlet flask. Each flask is filled with 400 ml of 7:2 solvent. Each flask is then placed on one of the electrothermal units.

• Long forceps are used to place prepared thimble in extraction tube of each soxhlet apparatus.

• Extraction tubes are fitted into each condenser tube and flask and clamped into place.

• Multi-heating unit is plugged in, master power switch of the electrothermal unit turned on, and temperature controls adjusted.

• Soxhlet apparatus is monitored for a minimum of one hour to be sure it is operating properly. Each flask is maintained at an even, moderate boil.

• Once boiling, the time is recorded in the lab data book as the start time of extraction.

• After 10 hours of extraction, each temperature control on the multi-heating unit is turned off.

• End time of extraction is recorded in the lab data book.

• Thimbles are removed from each extraction tube and placed out of the way to evaporate solvent.

• Solvent is allowed to evaporate from the thimbles before placing them in the drying oven for 4-hours or overnight.

• Thimbles with leaned sample are removed from drying oven with tweezers and placed in desiccator to cool for a few minutes. Samples are weighed to nearest 0.1 mg and mass recorded as "lean sample + thimble". Sample lipid content is calculated by subtracting "total leaned sample mass" from "total dry sample mass." Thimble with leaned sample and cotton is placed in desiccator while preparing for ashing.

Preparation for Ashing

- One glass scintillation vial is labeled with a sample number for each leaned sample, the empty vial is weighed without the lid to ± 0.1 mg, and recorded as "vial mass."

- The cotton ball is carefully removed from top of thimble, any adhering sample removed and placed in the scintillation vial, and cotton discarded. Entire sample is emptied from thimble into vial, using a spatula to gently scrape sample into vial. Thimbles are retained for cleaning and reuse. Vial + leaned sample are reweighed and recorded as "pre-ash mass". Sample mass is calculated for ashing (lean dry mass) by subtracting "vial mass."

- The cap of the scintillation vial is secured tightly. Samples that have been leaned and dried are stored until there are a sufficient number of vials to fire up the muffle furnace.

Determination of Ash Mass and Ash-free Lean Dry (Protein) Mass

- Samples are placed in glass scintillation vials in muffle furnace and set at 600 °C. Samples are ashed for 12 hours or until all ash samples are white or pale gray.

- Vials with ashed samples are cooled in desiccator, reweighed with ashed sample to ± 0.1 mg, and recorded as "vial and ash mass."

- Ash mass of sample is determined by subtracting "vial mass" from "vial and ash mass." "Ash-free lean dry mass" is calculated by subtracting "vial and ash mass" from "pre-ash mass."

APEX BUDGET (updated 4/7/97)

Project No.	Title	Investigator(s) (Agency)	FY95 Budget	FY96 Budget	FY97 Budget	FY98 Budget Request	Approved FY98 Budget	FY98 vs FY97
97163 A	Forage Fish Assessment	Lew Haldorson and Tom Shirley (UAF)	482.5	421.5	406.5	389.7		-16.8
97163 B	Bird/Fish Interaction	Bill Ostrand (USFWS)	83.3	125.3	118.4	89.9		-28.5
97163 C	Fish Diet Overlap	Molly Sturdevant (NOAA)	NOAA 21.0 ADFG 34.5 total 55.5	NOAA 21.2 ADFG 55.7 total 76.9	88.3	40.0		-48.3
97163 D	Puffins as Samplers	John Piatt (NBS)	41.5	12.0	0.0	0.0		0.0
97163 E	Black-legged Kittiwakes	Dave Irons and Rob Suryan (USFWS)	105.7	178.2	170.0	179.4		+9.4
97163 F	Pigeon Guillemots	Lindsey Hayes (USFWS)	127.2	141.4	134.5	111.1		-23.4
97163 G	Energetics	Dan Roby and Jill Anthony (OSU)	158.8	175.0	171.0	221.3		+50.3
97163 H	Proximate Composition	Graham Worthy (TA&M)	0.0	0.0	29.3	0.0		-29.3
97163 I	Project Leader	Dave Duffy (UAA)	58.2	186.1	139.2	160.6		+21.4
97163 J	Barren Is. Murres and Kittiwakes	Dave Roseneau and Art Kettle (USFWS)	36.1	104.0	107.0	113.3		+ 6.3
97163 K	Fish as Samplers	Dave Roseneau (USFWS)	15.1	4.7	9.2	9.6		+0.4

97163 L	Historical Data Review	Paul Anderson (NOAA) John Piatt (NBS) Jim Blackburn (F&G) Bill Becktol (F&G)	NBS 28.8 NOAA 7.1 ADFG 19.1 total 55.0	NBS 20.0 NOAA 45.1 ADFG 32.3 total 97.4	NBS 19.3 NOAA 43.3 ADFG 28.8 total 91.4	NBS 19.3 NOAA 43.3 ADFG 28.8 total 91.4		0.0
97163 M	Lower Cook Inlet	John Piatt (NBS)	-------	214.0	214.0	267.7		+53.7
97163 N	Kittiwake Feeding Exp.	Marc Romano and John Piatt (NBS)	-------	21.5	30.0	30.0		0.0
97163 O	Statistical Review	Lyman McDonald (WET)	-------	21.4	21.4	21.4		0.0
97163 P	Sand Lance HC Exposure	Jack Anderson (CAS)	-------	21.4	0.0	0.0		0.0
97163 Q was 97253	APEX Modeling	Dave Ainley (HTH&A) Glenn Ford (ECI) Dave Schneider (MUN)	-------	-------	69.8	69.8		0.0
97163R was 97231	Marbled Murrelets	Kathy Kuletz (FWS)	-------	-------	118.5	118.5		0.0
97163S	Jellies	Jenny Purcell	-------	-------	-------	110.7		+110.7
TOTALS	19		$1,160.5K	$1,800.8K	$1,918.5K	$2,024.4K		$+105.9K

1998 EXXON VALDEZ TRUST OUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998	PROPOSED FFY 1997 TRUSTEE AGENCIES TOTALS					
			ADEC	ADF&G	ADNR	USFS	DOI	NOAA
			$0.0	$35.0	$0.0	$0.0	$944.3	$1,045.1
Personnel	$560.1	$589.7						
Travel	$55.6	$41.4						
Contractual	$1,031.1	$1,093.2						
Commodities	$89.6	$129.0						
Equipment	$32.3	$12.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$1,768.7	$1,865.3	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
General Administration	$149.8	$159.1	FFY 1999	FFY 2000	FFY 2001	FFY 2002	FFY 2003	FFY 2004
Project Total	$1,918.5	$2,024.4	$1,934.1	$967.1	$226.7	$0.0	$0.0	$0.0
Full-time Equivalents (FTE)	16.4	16.8						
	Dollar amounts are shown in thousands of dollars.							
Other Resources	$250.0	$250.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0

Comments: The primary objective of the 1994 Forage Fish Study was to test techniques and collect data in PWS to aid in designing sampling methods for subsequent years. In 1995 the Apex Predator Ecosystem Experiment (APEX) conducted simultaneous seabird and hydroacoustic surveys in conjunction with collections of seabird productivity and energetics data. The 1996 APEX project will include related monitoring and research of seabirds and their forage fish prey. Additional components of APEX will continue analysis of historic Gulf of Alaska trawl data, ecosystem modeling, and investigating continued exposure of sand lance to Exxon Valdez oil. The FY97 APEX study incorporates marbled murrelet (163R) investigations. The FY98 APEX study incorporates jellyfish (163S) investigations.

163D, Puffins as Samplers, was closed out in FY96.

1998

Project Number: 98163A-P
Project Title: APEX
Lead Agency:

FORM 2A PROJECT DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$3.4	$3.4						
Contractual	$382.9	$366.5						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$386.3	$369.9	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$20.2	$19.8						
Project Total	$406.5	$389.7	$382.0	$100.0				
Full-time Equivalents (FTE)	0.2	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This project was first funded as a component of the Forage Fish Ecosystem Study (94163) then as the APEX project (95163A , 96163A, and 97163A).

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

Personnel Costs:			GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		0.0	0	0	
						Personnel Total	$0.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
	Juneau to Anchorage (APEX planning and review meetings)	444	3	9	225	3.4
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$3.4

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
printing of APEX annaul report, DPD, and detailed budgets (100 copies each)	6.0
Forage Fish Assessment Contract	360.5
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$366.5

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Agency: NOAA

FORM 3B
Contractual
& Commodities
DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Agency: NOAA

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$92.8	$90.6						
Travel	$15.5	$20.9						
Contractual	$158.8	$123.1						
Commodities	$4.4	$4.8						
Equipment	$6.9	$12.4	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$278.4	$251.8	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
Indirect (50.0%)	$101.6	$108.7						
Project Total	$380.0	$360.5	$360.0	$90.0				
Full-time Equivalents (FTE)	2.8	2.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This project was first funded as a component of the Forage Fish Ecosystem Study (94163) then as the APEX project (95163A, 96163A, and 97163A). The primary objective of this project is to collect hydroacoustic and net sampling data and to analyze these data. Indirect costs as a UAF contract are 50.0% of total except equipment and student tuition.

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Name: University of Alaska Fairbanks

FORM 4A
Non-Trustee
DETAIL

1998 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:

Name	Position Description	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
L. Haldorson	PI	2.0	8,555	0	17.1
T. Shirley	fish biologist	2.0	7,328	0	14.7
K. Coyle	fish biologist	4.0	5,250	0	21.0
	technician	2.0	3,455	0	6.9
	M.S. student	9.0	1,096	0	9.9
	MS student	9.0	1,096	0	9.9
	tuition (4 semesters @ $2770/semester)				11.1
					0.0
					0.0
					0.0
					0.0
					0.0
	Subtotal	28.0	26,780	0	
				Personnel Total	$90.6

Travel Costs:

Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
Fairbanks to Cordova	454	8	16	103	5.3
Juneau to Cordova	352	8	16	103	4.5
Juneau to Seattle	752	1	8	113	1.7
Fairbanks to Seattle	1,248	2	6	113	3.2
Juneau to Anchorage	444	4	12	170	3.8
Fairbanks to Anchorage	218	3	10	170	2.4
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$20.9

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Name: University of Alaska Fairbanks

FORM 4B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
communications	0.5
vessel charters: acoustic vessel @ 1,200/day for 21 days (July cruise)	25.2
seine vessel @ 1,050/day for 21 days (July cruise)	22.1
Pandalas @ 1,350/day for 24 days (spring process cruise)	32.4
process vessel @ 1,350/day for 24 days (fall cruise)	32.4
Biosonics field contract and equipment maintenance	10.0
shipping	0.5
Contractual Total	$123.1

Commodities Costs:	Proposed
Description	FFY 1998
calorimeter supplies	0.5
chemicals (formalin STF substitute, formalin, and gasses)	0.9
office supplies	0.2
sample bottles and jars	1.5
computer supplies	1.2
shipping containers (20 @ $22.50 ea.)	0.5
Commodities Total	$4.8

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Name: University of Alaska Fairbanks

FORM 4B Contractual & Commodities DETAIL

1998 EXXON VALDEZ TRUST OUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
gillnets (2 @ $250 ea.)	2	250	0.5
Kodiak trawl	1	1,500	1.5
micro-bomb calorimeter	1	6,400	6.4
color video camera	1	1,500	1.5
mid-water trawl	1	2,500	2.5
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$12.4

Existing Equipment Usage: Description	Number of Units	

1998

Project Number: 98163A
Project Title: APEX/Forage Fish Assessment
Name: University of Alaska Fairbanks

FORM 4B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$85.7	$76.0						
Travel	$9.2	$1.2						
Contractual	$5.7	$1.0						
Commodities	$0.7	$0.2						
Equipment	$3.8	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$105.1	$78.4	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$13.3	$11.5						
Project Total	$118.4	$89.9	$89.9	$0.0				
Full-time Equivalents (FTE)	1.8	1.5						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: Collect seabird activity data while simultaneously monitoring fish abundance to determine seabirds' relationship to forage resources, how seabird's foraging behavior responds to change in the forage resource, and if forage availability is limiting population recovery. By collecting long term data on seabird activity while simultaneously monitoring forage fish abundance and distribution this project will determine relationship to forage resources, how seabirds' foraging behavior responds to change in the forage resource, and if forage availability is limiting population recovery. In FY98 limit field collections and concentrate on data analysis.

1998

Project Number: 98163B
Project Title: APEX/Seabird Interactions
Agency: DOI

FORM 3A AGENCY PROJECT DETAIL

4/7/97

1998 EXXON VALDEZ TRUS' :OUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
B. Ostrand	PI	GS11-3	12.0	5,133		61.6
	Research Assistant	GS5	6.0	2,400		14.4
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		18.0	7,533	0	
					Personnel Total	$76.0

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
Anchorage to Cordova (& field work in PWS)	200	1	10	3	0.2
meeting/conference					1.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$1.2

1998

Project Number: 98163B
Project Title: APEX/Seabird Interactions
Agency: DOI

FORM 3B
Personnel
& Travel
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
telephone services in field and office, postage and freight, publication page charges, film processing	1.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$1.0

Commodities Costs:	Proposed
Description	FFY 1998
scientific supplies (film, waterproof notebooks, charts)	0.1
rain gear, rubber boots, and gloves	0.1
Commodities Total	$0.2

1998

Project Number: 98163B
Project Title: APEX/Seabird Interactions
Agency: DOI

FORM 3B
Contractual
& Commodit
ies
DETAIL

4/7/97

New Equipment Purchases:	Number	Unit	Proposed
Description	of Units	Price	FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage:	Number	Inventory
Description	of Units	Agency

1998

Project Number: 98163B
Project Title: APEX/Seabird Interactions
Agency: DOI

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$5.5	$32.8						
Travel	$8.6	$2.2						
Contractual	$64.8	$0.0						
Commodities	$4.0	$0.1						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$82.9	$35.1	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$5.4	$4.9						
Project Total	$88.3	$40.0	$0.0	$0.0				
Full-time Equivalents (FTE)	0.1	0.7						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This project is designed to understand diet overlap of forage fish species in Prince William Sound. This project is scheduled for either closeout in FY98 or it may continue as a service project probably to 163A.

1998

Project Number: 98163C
Project Title: APEX/Fish Diet Overlap
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
M. Sturdevant	PI	GS11/3	1.0	5,500		5.5
M. Auburn		GS7/1	2.5	3,651		9.1
L. Hulbert		GS7/1	2.5	3,651		9.1
A. Brase		GS7/1	2.5	3,651		9.1
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		8.5	16,453	0	
					Personnel Total	$32.8

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
Juneau to Anchorage	444	2	6	225	2.2
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$2.2

1998

Project Number: 98163C
Project Title: APEX/Fish Diet Overlap
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

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1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed
Description	FFY 1998
sample bottles, formalin, and microscope work supplies	0.1
Commodities Total	$0.1

1998

Project Number: 98163C
Project Title: APEX/Fish Diet Overlap
Agency: NOAA

FORM 3B
Contractual
& Commodities
DETAIL

4/7/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency
binocular dissecting microscope (Trustee Council equipment)	1	NOAA
microscopes NOAA)	3	NOAA
computer (NOAA)	3	NOAA
electronic balances (NOAA)	3	NOAA
mici		

1998

Project Number: 98163C
Project Title: APEX/Fish Diet Overlap
Agency: NOAA

FORM 3B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$94.1	$110.5						
Travel	$8.7	$6.7						
Contractual	$18.1	$13.0						
Commodities	$22.0	$22.0						
Equipment	$11.7	$9.7	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$154.6	$161.9	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$15.4	$17.5						
Project Total	$170.0	$179.4	$181.6	$0.0				
Full-time Equivalents (FTE)	2.3	2.8						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This component will collect information on kittiwake foraging and reproductive parameters that indicate food stress. The cost of this project is being shared by the EVOS Trustee Council and the US Fish and Wildlife Service (FWS). The FWS is providing funding for most of the data collection at the Shoup Bay colony. This includes salaries for the camp leader, and two biotechnicians, travel cost and cost associated with running the field camp. The FWS is also providing funding for population size and productivity surveys of all 26 PWS kittiwake colonies. The APEX budget will provide funding for one Shoup Bay biotech.

1998

Project Number: 98163 E
Project Title: APEX/Kittiwakes
Agency: DOI

FORM 3A
AGENCY
PROJECT
DETAIL

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1998 EXXON VALDEZ TRUST COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
R. Suryan	co-PI	GS11	12.0	4,800		57.6
D. Irons	co-PI	GS12/5	0.5	6,800		3.4
	biotech. (Eleanor Is.)	GS5	10.0	2,500		25.0
	biotech. (Eleanor Is.)	GS5	5.0	2,500		12.5
	graduate student		6.0	2,000		12.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		33.5	18,600	0	
					Personnel Total	$110.5

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
Anchorage to Whittier: transport boat, 2 trips @ $1,200/round trip plus	1200	2	360	3	3.5
Anchorage to Whittier	100	12			1.2
float plane trips to study site	250	4			1.0
travel to scientific meetings to present study results					1.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$6.7

1998

Project Number: 98163E
Project Title: APEX/Kittiwakes
Agency: DOI

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
delivery of equipment and supplies to study site (split w/163 F and 163R)	1.3
delivery of fuel to study site (split with 163F and 163R)	0.6
maintenance and cleaning of radio telemetry equipment	2.0
boat maintenance and repair (Whalers and solid-hull boats)	5.0
telephone services in offices and in field	0.7
computer, printer, and network repair and maintenance	0.5
film processing, postage and freight	0.6
publication page charges	0.5
maintenance and cleaning of camping equipment for 3 people @ $200/person	0.6
maintenance and cleaning of 2 inflatable boats ($400/boat) and 2 motors ($400/motor)	0.6
maintenance and cleaning of binoculars, spotting scope, and camera	0.6
	0.0
	0.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$13.0

Commodities Costs:	Proposed
Description	FFY 1998
food for 3 people for 120 days @ $12/day	4.3
boat fuel: 150 gal/day for 60 days @ $1.50/gal.	13.5
camp supplies (stove and lantern fuel, mantles, head nets, bug spray, batteries, and cleaning materials)	0.4
scientific supplies (batteries for radios, film, waterproof notebooks, sample bags, scales, calipers, rulers)	1.2
rain gear, rubber boots, and gloves for 3 people @ $200/person	0.6
lines, anchors, and propellers for boats	1.5
software updates for computers	0.4
first aid kits	0.1
Commodities Total	$22.0

1998

Project Number: 98163E
Project Title: APEX/Kittiwakes
Agency: DOI

FORM 3B
Contractual
& Commodities
DETAIL

1998 EXXON VALDEZ TRUST OUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
radio tags			8.5
camp equipment (stoves, lanterns, tents, tools, batteries, dishes)			1.2
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$9.7

Existing Equipment Usage: Description	Number of Units	Inventory Agency
FWS lending telemetry equipment		USFWS

1998

Project Number: 98163E
Project Title: APEX/Kittiwakes
Agency: DOI

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$84.2	$72.2						
Travel	$7.6	$6.2						
Contractual	$13.7	$7.9						
Commodities	$12.1	$12.1						
Equipment	$3.3	$1.3	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$120.9	$99.7	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$13.6	$11.4						
Project Total	$134.5	$111.1	$113.3	$0.0				
Full-time Equivalents (FTE)	1.8	2.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This study will monitor the feeding and breeding ecology of pigeon guillemots on Naked Island in Prince William Sound and census their population there and at other designated study areas.

1998

Project Number: 98163F
Project Title: APEX/Guillemots
Agency: DOI

FORM 3A AGENCY PROJECT DETAIL

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1998 EXXON VALDEZ TRUST OUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Personnel Costs:			GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
	Name	Position Description					
	T. Spencer	biotech.	GS9	12.0	3,100		37.2
		biotech.	GS5	5.0	2,500		12.5
		biotech.	GS5	5.0	2,500		12.5
		grad. student		5.0	2,000		10.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		27.0	10,100	0	
						Personnel Total	$72.2

Travel Costs:		Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
	Description					
	Anchorage to Whittier to transport boat	1200	2			2.4
	Anchorage to Whittier for 4 people	100	16			1.6
	field per diem: 4 people, 100 days @ $3/day					1.2
	travel to scientific meeting					1.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$6.2

1998

Project Number: 98163F
Project Title: APEX/Guillemots
Agency: DOI

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
delivery of equipment and supplies to study site, $4.0K (spilt w/163E and 163R)	1.3
delivery of fuel to study site (spilt w/163E and 163R)	0.6
maintenance and repair of camping equipment for 2 people @ $200/person	0.4
boat maintenance and repair (Whaler or other solid-hull boat)	3.0
telephone services in office and in field	0.5
computer, printer, network repair and maintenance	0.5
film processing, postage and freight	0.4
publication page charges	0.2
maintenance and repair of 3 inflatable boats ($400/boat) and 2 motors ($400/motor)	0.7
maintenance and repair of binoculars, spotting scope, and cameras	0.3
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$7.9

Commodities Costs:	Proposed
Description	FFY 1998
food for 4 people for 100 days @ $12/day	4.8
boat fuel: 100g/day for 30 days @ $1.50/gal.	4.5
camp supplies (stove/lantern fuel, bug spray, batteries, tarps)	0.5
lumber, canvas, and hardware for tent floors and observation blinds	0.4
scientific supplies (batteries for radios, waterproof notebooks, sample bags, dial calipers, rulers)	0.5
rain gear, gloves and boots for 2 people @ $200/person	0.4
lines, anchors, propellers for boats	0.5
software updates for computers	0.4
first aid kits	0.1
Commodities Total	$12.1

1998

Project Number: 98163F
Project Title: APEX/Guillemots
Agency: DOI

FORM 3B
Contractual
& Commodities
DETAIL

4/7/97

1998 EXXON VALDEZ TRUS⁻ ;OUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
tools for boat and camp			0.3
materials for nest boxes			1.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$1.3

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163F
Project Title: APEX/Guillemots
Agency: DOI

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$0.0	$0.0						
Contractual	$159.8	$206.8						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$159.8	$206.8	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$11.2	$14.5						
Project Total	$171.0	$221.3	$180.0	$100.0				
Full-time Equivalents (FTE)	0.0	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

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Personnel Costs:			GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		0.0	0	0	
						Personnel Total	$0.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs: Description	Proposed FFY 1998
Contract with Oregon University Cooperative Research Unit.	206.8
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$206.8

Commodities Costs: Description	Proposed FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Agency: NOAA

FORM 3B
Contractual & Commodities
DETAIL

4/7/97

1998 EXXON VALDEZ TRUS' COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Agency: NOAA

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$48.3	$71.5						
Travel	$9.9	$10.9						
Contractual	$27.5	$36.6						
Commodities	$33.9	$40.5						
Equipment	$7.2	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$126.8	$159.5	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Indirect (26% or 42.5%)	$33.0	$47.3	FFY 1999	FFY 2000	FFY 2001	FFY 2002	FFY 2003	FFY 2004
Project Total	$159.8	$206.8	$160.0	$80.0				
Full-time Equivalents (FTE)	1.9	3.1						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: Assess the taxonomic and biochemical composition of seabird diets and determine the relationship of diet to nestling provisioning rates, chick growth energetics, and the reproductive success of seabirds in the EVOS area. For FY98 increased effort by doing doubley labeled water experiments.

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Name: Oregon State University

FORM 4A
Non-Trustee
DETAIL

1998 EXXON VALDEZ TRUST COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Personnel Costs:

Name	Position Description		Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
	graduate student, Ph.D.		12.0	1,358		16.3
	research assistant, field		1.5	1,907		2.9
	research assistant, field		1.5	1,907		2.9
	research assistant, field		1.5	1,907		2.9
	research assistant, field		3.0	1,907		5.7
	research assistant, field		3.0	1,907		5.7
	research assistant, field		3.0	1,907		5.3
	research assistant, field		3.0	1,907		5.7
	research assistant, field		3.0	1,907		5.7
	research assistant, field		3.0	1,907		5.7
	research assistant, lab.		3.0	2,420		7.3
	student tuition					5.4
	Subtotal		37.5	20,941	0	
					Personnel Total	$71.5

Travel Costs:

Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
presentation at national meetings	1,000	2			2.0
Anchorage to Cordova to field station	700	8	14	130	7.4
airfare OSU to Alaska for 6 week field assistants	500	3			1.5
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$10.9

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Name: Oregon State University

FORM 4B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
lab analysis o f blood samples for doubley-labeled water experiment	14.0
personal services contract to FALCO for fish ID and processing	10.0
duplication/computer fees	1.5
publication: page charges, reports, visual aids	1.5
transportation in Alaska for field personnel	1.5
vehicle rental 6 each (Anch. to Whittier)	0.7
maintenance of field equipment	0.8
shipping for samples	0.5
maintenance of laboratory equipment	1.5
barge charter to study sites	2.0
telephone services (long distance)	2.0
maintenance of propane freezer and accessories	0.6
	0.0
Contractual Total	$36.6

Commodities Costs:	Proposed
Description	FFY 1998
drying oven	2.0
doubly-labeled water, 100 injections @ $50 ea.	5.0
doubly-labeled water field supplies	1.5
Pesols spring scales (5 @ $40 each)	0.2
binoculars (10X40, Steiner low light, 4 each)	1.5
camp & field supplies (food, sleeping bags, pads & cots, propane heaters, MSR Waterwork filtration system, rite-in rain supplie	15.3
boat fuel (50 gallons/day @ 2.10/gallon for 87 days)	8.7
tent (VE25 Northface)	0.9
float coats and mustang suits (3 ea.)	3.5
lab. supplies, chemicals, extraction thimbles, and sample bags	1.9
Commodities Total	$40.5

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Name: Oregon State University

FORM 4B
Contractual
& Commodit
ies
DETAIL

4/7/97

1998 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	

1998

Project Number: 98163G
Project Title: APEX/Seabird Energetics
Name: Oregon State University

FORM 4B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$0.0	$0.0						
Contractual	$27.4	$0.0						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$27.4	$0.0	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
General Administration	$1.9	$0.0	FFY 1999	FFY 2000	FFY 2001	FFY 2002	FFY 2003	FFY 2004
Project Total	$29.3	$0.0	$0.0	$0.0				
Full-time Equivalents (FTE)	0.0	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This project of the APEX investigation will determine the proximate composition and energetic content of selected forage fish species in the EVOS study area. The intent is for this project to be managed within the APEX framework but to draw funding from several different sources. This is a proposal submitted under the Broad Agency Announcement. This project was not funded in FY95 or FY96. This project was funded in FY97 but the PI pulled out of the APEX project, and the funds are scheduled for reallocation within APEX to support PIGU colony work.

1998

Project Number: 98163H
Project Title: APEX/Proximate Composition of Forage Fish
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - Se ber 30, 1998

Personnel Costs:			GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		0.0	0	0	
						Personnel Total	$0.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163H
Project Title: Proximate Composition of Forage Fish
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
	0.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163H
Project Title: APEX/Proximate Composition of Forage Fish
Agency: NOAA

FORM 3B
Contractual
& Commodities
DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163H
Project Title: APEX/Proximate Composition of Forage Fish
Agency: NOAA

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$8.1	$0.0						
Travel	$4.9	$0.0						
Contractual	$0.0	$0.0						
Commodities	$5.9	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$18.9	$0.0	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
Indirect (45%)	$8.5	$0.0						
Project Total	$27.4	$0.0	$0.0	$0.0				
Full-time Equivalents (FTE)	0.2	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This project of the APEX investigation will determine the proximate composition and energetic content of selected forage fish species in the EVOS study area. This is a proposal issued submitted under the Broad Agency Announcement. This project/contract not funded in FY95 or FY96. The intent of this project is to be managed within the APEX framework but to draw funding from several different sources (SEA and NVP). This project was funded in FY97 but the PI pulled out of the APEX project, and the funds are scheduled for reallocation within APEX to support PIGU colony work.

1998

Project Number: 98163H
Project Title: APEX/Proximate Composition of Forage Fish
Name: Texas A&M University

FORM 4A
Non-Trustee
DETAIL

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - Se...ber 30, 1998

Personnel Costs:						
Name	Position Description		Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		0.0	0	0	
					Personnel Total	$0.0

Travel Costs:					
Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$0.0

1998

Project Number: 98163H
Project Title: APEX/Proximate Composition of Forage Fish
Name: Texas A&M University

FORM 4B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
Contractual Total	$0.0

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163H
Project Title: APEX/Proximate Composition of Forage Fish
Name: Texas A&M University

FORM 4B Contractual & Commodities DETAIL

4/7/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	

1998

Project Number: 98163H
Project Title: APEX/Proximate Composition of Forage Fish
Name: Texas A&M University

FORM 4B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$0.0	$0.0						
Contractual	$130.1	$150.1						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$130.1	$150.1	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$9.1	$10.5						
Project Total	$139.2	$160.6	$160.0	$160.0	$155.0			
Full-time Equivalents (FTE)	1.7	1.7						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This component of the APEX project will provide scientific oversight, coordination, performance tracking, and integration of results. The project management will have elements that have been used effectively in other large, multidisciplinary programs for ecosystem assessment. This is a proposal submitted under the Broad Agency Announcement.

1998

Project Number: 98163I
Project Title: APEX/Project Management
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

1998 EXXON VALDEZ TRUSTEE JNCIL PROJECT BUDGET
October 1, 1997 - S nber 30, 1998

Personnel Costs:			GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		0.0	0	0	
						Personnel Total	$0.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163I
Project Title: APEX/Project Management
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
contract to University of Alaska Anchorage (BAA)	150.1
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$150.1

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163I
Project Title: APEX/Project Management
Agency: NOAA

FORM 3B
Contractual & Commodities
DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163I
Project Title: APEX/Project Management
Agency: NOAA

FORM 3B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$83.8	$88.7						
Travel	$7.0	$4.3						
Contractual	$2.6	$15.0						
Commodities	$6.0	$5.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$99.4	$113.0	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
Indirect (32.9%)	$30.7	$37.1						
Project Total	$130.1	$150.1	$150.0	$140.0	$140.0			
Full-time Equivalents (FTE)	1.4	1.8						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This component of the APEX project will provide scientific oversight, coordination, performance tracking, and integration of results. The program management employed will have elements that have been used effectively in other large, multidisciplinary programs for ecosystem assessment. This is a proposal submitted under the Broad Agency Announcement.

1998

Project Number: 98163I
Project Title: APEX/Project Management
Name: University of Alaska Anchorage

FORM 4A
Non-
Trustee
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE INCIL PROJECT BUDGET
October 1, 1997 - S nber 30, 1998

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FFY 1998
D. Duffy	PI		6.0	8,158		48.9
Michaelson	data manager for GIS		3.0	5,913		17.7
	student assistant		12.0	1,842		22.1
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		21.0	15,913	0	
					Personnel Total	$88.7

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
conference (Monterey PSG)	800	1	4	250	1.8
Anchorage to Juneau	444	2	7	225	2.5
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$4.3

1998

Project Number: 98163I
Project Title: APEX/Project Management
Name: University of Alaska Anchorage

FORM 4B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
support of Pacific Seabird Conference	15.0
Contractual Total	$15.0

Commodities Costs:	Proposed
Description	FFY 1998
computer software and associated GIS supplies	4.5
field equipment for site visits	0.5
Commodities Total	$5.0

1998

Project Number: 98163I
Project Title: APEX/Project Management
Name: University of Alaska Anchorage

FORM 4B
Contractual & Commodities
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - S ıber 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	
computers	2	

1998

Project Number: 98163I
Project Title: APEX/Project Management
Name: University of Alaska Anchorage

FORM 4B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$71.7	$73.8						
Travel	$6.9	$7.5						
Contractual	$7.6	$7.8						
Commodities	$9.5	$12.6						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$95.7	$101.7	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$11.3	$11.6						
Project Total	$107.0	$113.3	$113.0	$100.0				
Full-time Equivalents (FTE)	1.8	1.8						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This component is designed to collect data on common murres, kittiwakes, and puffins on the Barren Islands (which is in the EVOS area) that will be used in a multi-species analysis of seabird productivity and energetics.

1998

Project Number: 98163J
Project Title: APEX/Barren Islands Seabird Studies
Agency: DOI

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE INCIL PROJECT BUDGET
October 1, 1997 - S_,_ nber 30, 1998

Personnel Costs:		GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
Name	Position Description					
D. Roseneau	PI	GS11/5	8.0	4,500		36.0
A. Kettle	camp leader/bio. tech.	GS7/1	8.0	3,100		24.8
S. Zuniga	bio. tech..	GS5/1	5.0	2,600		13.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		21.0	10,200	0	
					Personnel Total	$73.8

Travel Costs:	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
Description					
Homer to Anchorage	150	4	4	225	1.5
per diem @ $3/day x 200 days					0.6
2 vessel charter days @$2.2/day					4.4
travel to Pacific Seabird Conference					1.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$7.5

1998

Project Number: 98163J
Project Title: APEX/Barren Islands Seabird Studies
Agency: DOI

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

Contractual Costs: Description	Proposed FFY 1998
2 SCA volunteer in Homer, 3 months @ $3.9 each	7.8
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$7.8

Commodities Costs: Description	Proposed FFY 1998
gas, oil, Blazo, propane	3.4
field, climbing, and camping gear	0.7
replace climbing ropes, pitons, carabiners, chokes, webbing	0.5
boating supplies	0.4
camping supplies	0.4
replacement boots, rain gear and sleeping bags	1.0
food habits sample analysis (75 samples @ $18/each)	1.4
upgrade and purchase of computer software	0.4
posters at public meetings (4 posters @ $.2 each)	0.8
notebooks and film	0.3
cleaning, repair, and service of outboard motors, boats, radios, tents, binoculars, spotting scopes, time-lapse video cameras	3.3
Commodities Total	$12.6

1998

Project Number: 98163J
Project Title: APEX/Barren Islands Seabird Studies
Agency: DOI

FORM 3B Contractual & Commodities DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163J
Project Title: APEX/Barren Islands Seabird Studies
Agency: DOI

FORM 3B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$4.4	$4.5						
Travel	$0.5	$0.5						
Contractual	$1.5	$2.5						
Commodities	$2.0	$1.2						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$8.4	$8.7	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$0.8	$0.9						
Project Total	$9.2	$9.6	$10.0	$5.0				
Full-time Equivalents (FTE)	0.1	0.1						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: Forage fish will be obtained from the stomachs of sport caught large fish predators to test the feasibility and effectiveness of obtaining low cost, spatial and relative abundance data on forage fish in the Gulf of Alaska. This study will concentrate on Lower Cook Inlet. Based on peer review and Chief Scientist recommendations, this project was discontinued for FY96.

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/USFWS

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - S[illegible]ber 30, 1998

Personnel Costs:		GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
Name	Position Description					
D Roseneau	PI	GS11/5	1.0	4,500		4.5
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		1.0	4,500	0	
Those costs associated with program management should be indicated by placement of an *.					**Personnel Total**	$4.5

Travel Costs:	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
Description					
Homer to Seward	275	1	1	225	0.5
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$0.5

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/USFWS

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
1 SCA volunteer in Homer for 3.5 months	2.5
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$2.5

Commodities Costs:	Proposed
Description	FFY 1998
sampling supplies and freight	1.2
Commodities Total	$1.2

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/USFWS

FORM 3B
Contractual & Commodities
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - Sc[illegible]ber 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		New Equipment Total	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/USFWS

FORM 3B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$0.0	$0.0						
Contractual	$0.0	$0.0						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$0.0	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$0.0	$0.0						
Project Total	$0.0	$0.0	$0.0	$0.0				
Full-time Equivalents (FTE)	0.0	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: The PWS portion of this study is not continued in FY97, or FY98.

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/NPS

FORM 3A
AGENCY
PROJECT
DETAIL

1998 EXXON VALDEZ TRUSTEE INCIL PROJECT BUDGET
October 1, 1997 - S nber 30, 1998

	Personnel Costs:		GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		0.0	0	0	
						Personnel Total	$0.0

	Travel Costs:	Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/NPS

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/NPS

FORM 3B
Contractual & Commodities
DETAIL

4/7/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163K
Project Title: APEX/Large Fish as Samplers
Agency: DOI/NPS

FORM 3B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$16.8	$21.6						
Travel	$0.0	$0.0						
Contractual	$0.0	$0.0						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$16.8	$21.6	Estimated FFY 1998	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$2.5	$3.2						
Project Total	$19.3	$24.8	$25.0	$25.0				
Full-time Equivalents (FTE)	0.4	0.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This component will also coordinate the continuation of the historic review of the ecosystem structure in the Prince William Sound/Gulf of Alaska complex. Included in this review will be obtaining and synthesizing several forage fish data sets.

1998

Project Number: 98163L
Project Title: APEX Historic Review
Agency: DOI

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE (ICIL PROJECT BUDGET
October 1, 1997 - Se...ber 30, 1998

Personnel Costs:			GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
	J. Piatt	PI	GS13/6	2.0	7,300		14.6
	B. Johnson	tech.		2.0	3,500		7.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		4.0	10,800	0	
						Personnel Total	$21.6

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163L
Project Title: APEX Historic Review
Agency: DOI

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
	0.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed
Description	FFY 1998
	0.0
Commodities Total	$0.0

1998

Project Number: 98163L
Project Title: APEX Historic Review
Agency: DOI

FORM 3B
Contractual & Commodities
DETAIL

4/7/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		New Equipment Total	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163L
Project Title: APEX Historic Review
Agency: DOI

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$6.3	$17.6						
Travel	$2.8	$1.6						
Contractual	$19.9	$8.7						
Commodities	$0.0	$0.5						
Equipment	$12.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$41.0	$28.4	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
General Administration	$2.3	$3.2	FFY 1999	FFY 2000	FFY 2001	FFY 2002	FFY 2003	FFY 2004
Project Total	$43.3	$31.6	$32.0	$32.0				
Full-time Equivalents (FTE)	0.3	0.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This component will continue the historic review of the ecosystem structure in the Prince William Sound/Gulf of Alaska complex. Included in this review will be obtaining and synthesizing several forage fish data sets.

1998

Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
P. Anderson	biologist	GS12/4	3.0	5,866		17.6
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		3.0	5,866	0	
					Personnel Total	$17.6

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
Kodiak to Anchorage	250	1	6	225	1.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$1.6

1998

Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
electronic distributed database design	4.0
research associate for analysis	4.7
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$8.7

Commodities Costs:	Proposed
Description	FFY 1998
software upgrades	0.5
Commodities Total	$0.5

1998

Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: NOAA

FORM 3B
Contractual
& Commodities
DETAIL

4/7/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		New Equipment Total	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency
GIS equipment and software	1	NOAA

1998

Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: NOAA

FORM 3B
Equipment
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$25.0	$28.2						
Travel	$0.0	$2.6						
Contractual	$0.0	$0.0						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$25.0	$30.8	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$3.8	$4.2						
Project Total	$28.8	$35.0	$35.0	$35.0				
Full-time Equivalents (FTE)	0.5	0.4						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This component will continue the historic review of the ecosystem structure in the Prince William Sound/Gulf of Alaska complex. Included in this review will be obtaining and synthesizing several forage fish data sets.

1998

Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: ADF&G

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE (ICIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:		GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
Name	Position Description					
J. Blackburn	biologist III (Kodiak)	18	2.0	7,200		14.4
B. Bechtol	biologist II (Homer)	16	2.5	5,500		13.8
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		4.5	12,700	0	
					Personnel Total	$28.2

Travel Costs:	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
Description					
Kodiak to Anchorage	250	1	5	225	1.4
Homer to Anchorage	100	1	5	225	1.2
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$2.6

1998

Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: ADF&G

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: ADF&G

FORM 3B Contractual & Commodities DETAIL

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - Sep...ber 30, 1998

New Equipment Purchases: Description		Number of Units	Unit Price	Proposed FFY 1998
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.			**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

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Project Number: 98163L
Project Title: APEX/Historic Review of Forage Fish Data
Agency: ADF&G

FORM 3B
Equipment
DETAIL

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1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$67.0	$51.9						
Travel	$0.0	$0.0						
Contractual	$101.8	$130.0						
Commodities	$28.0	$68.9						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$196.8	$250.8	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$17.2	$16.9						
Project Total	$214.0	$267.7	$268.0	$180.0				
Full-time Equivalents (FTE)	2.7	1.7						
	Dollar amounts are shown in thousands of dollars.							
Other Resources	$250.0	$370.0	$370.0	$110.0				

This study is designed to measure the foraging (functional) and population (numerical) responses of six seabird species to fluctuating forage fish densities at three colonies in Cook Inlet.

Funding for this project is from three major sources: EVOS Trustee Council, Minerals Management Service ,and National Biological Service .

1998

Project Number: 98163M
Project Title: Response of Seabirds to Forage Fish Density
Agency: NBS

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:			GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
	G. Drew	Wildlife Biologist	GS11	4.0	5,031		20.1
	S. Zador	Wildlife Biologist	GS5	8.0	1,983		15.9
	M. Litzow	Wildlife Biologist	GS5	8.0	1,983		15.9
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		20.0	8,997	0	
						Personnel Total	**$51.9**

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163M
Project Title: Response of Seabirds to Forage Fish Density
Agency: NBS

FORM 3B
Personnel
& Travel
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs: Description	Proposed FFY 1998
M/V Pandalus (ADF&G research vessel)	43.2
Research Work Order, UC Irvine	26.8
University of Alaska, Kasitina Bay Lab.	35.0
FALCO, prey id and stomach analysis	25.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$130.0

Commodities Costs: Description	Proposed FFY 1998
food, camp, and field supplies for Chisik Is. field camp	25.0
food, camp, and field supplies for Kastina Is. field camp	25.0
satellite imagery	5.0
fuel (gas, diesel, and Blazo)	8.0
Whaler operations (repair and maintenance)	1.9
Kulak Clipper operations	4.0
Commodities Total	$68.9

1998

Project Number: 98163M
Project Title: Response of Seabirds to Forage Fish Density
Agency: NBS

FORM 3B Contractual & Commodities DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
Those purchases associated with replacement equipment should be indicated by placement of an R.		New Equipment Total	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163M
Project Title: Response of Seabirds to Forage Fish Density
Agency: NBS

FORM 3B
Equipment
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
			LONG RANGE FUNDING REQUIREMENTS					
Personnel	$18.4	$19.6						
Travel	$2.5	$4.1						
Contractual	$3.9	$1.5						
Commodities	$1.7	$1.8						
Equipment	$0.5	$0.0						
Subtotal	$27.0	$27.0	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$3.0	$3.0						
Project Total	$30.0	$30.0	$0.0	$0.0				
Full-time Equivalents (FTE)	1.0	1.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

This study will help determine: 1) Which parameters of breeding performance are most sensitive to food supply?
2) At what stage or stages of the breeding season are the effects of food limitation most evident?
3) Is food limiting the productivity of kittiwakes on Middleton Island?

FY98 is the closeout and final report preparation year.

1998

Project Number: 98163N
Project Title: Black-Legged Kittiwake Controlled Feeding Experiment
Agency: NBS

FORM 3A
AGENCY
PROJECT
DETAIL

4/7/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - Se...ber 30, 1998

Personnel Costs:						
Name	Position Description	GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
M. Romano	graduate research assistant		12.0	1,100		13.2
	lab. tech.		3.0	1,500		4.5
	tuition for graduate research assistant, $1,850/spring term					1.9
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		15.0	2,600	0	
					Personnel Total	$19.6

Travel Costs:					
Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
Oregon to Anchorage	750	2	8	120	2.5
Pacific Seabird Group conference					1.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$4.1

1998

Project Number: 98163N
Project Title: Black-Legged Kittiwake Controlled Feeding Experiment
Agency: NBS

FORM 3B
Personnel
& Travel
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
page charges, telecommunications, visual aids	1.5
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$1.5

Commodities Costs:	Proposed
Description	FFY 1998
solvents, thimbles, and other lab. supplies	1.6
misc. supplies	0.2
Commodities Total	$1.8

1998

Project Number: 98163N
Project Title: Black-Legged Kittiwake Controlled Feeding Experiment
Agency: NBS

FORM 3B
Contractual
& Commodities
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		New Equipment Total	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163N
Project Title: Black-Legged Kittiwake Controlled Feeding Experiment
Agency: NBS

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$0.0	$0.0						
Contractual	$20.0	$20.0						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$20.0	$20.0	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$1.4	$1.4						
Project Total	$21.4	$21.4	$37.5	$0.0	$0.0			
Full-time Equivalents (FTE)	0.0	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

This project will provide guidance on study design, insure appropriate statistical inferences, and assistance during statistical analysis of data and in report preparation.

The total FY96 budget for this project increased by $10,000 to accommodate additional projected project statistical review. The $10,000 was transferred from 96163I. These additional costs will be reflected in personnel and travel.

1998

Project Number: 98163O
Project Title: APEX: Statistical Review
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - Se... ber 30, 1998

Personnel Costs:							
	Name	Position Description	GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		0.0	0	0	
						Personnel Total	$0.0

Travel Costs:						
	Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163O
Project Title: APEX: Statistical Review
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
Statistical review contract	20.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$20.0

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163O
Project Title: APEX: Statistical Review
Agency: NOAA

FORM 3B Contractual & Commodities DETAIL

1998 EXXON VALDEZ TRUSTEE   ICIL PROJECT BUDGET
October 1, 1997 - Se...ber 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163O
Project Title: APEX: Statistical Review
Agency: NOAA

FORM 3B
Equipment
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$16.1	$15.3						
Travel	$3.2	$3.6						
Contractual	$0.0	$0.0						
Commodities	$0.7	$1.1						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$20.0	$20.0	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
Indirect	$0.0	$0.0						
Project Total	$20.0	$20.0	$35.0	$0.0	$0.0			
Full-time Equivalents (FTE)	0.1	0.1						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

This project will provide guidance on study design, insure appropriate statistical inferences, and assistance during statistical analysis of data and in report preparation. The PI is a member of the Nearshore Vertebrate Predator project and will coordinate nearshore sampling in so far as possible.

The total FY96 budget for this project was increase by $10,000 to accommodate additional projected project statistical review (start-up costs). The $10,000 was transferred from 96163I. These additional costs were reflected in personnel and travel. .

1998

Project Number: 98163O
Project Title: APEX: Statistical Review
Agency: Western EcoSystems Technology

FORM 4A
Non-Trustee
DETAIL

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FFY 1998
L. McDonald	Senior Biometrician		0.7	14,400		10.1
	Biometrician II		0.5	10,400		5.2
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		1.2	24,800	0	
					Personnel Total	$15.3

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
DIA to Anchorage	900	2			1.8
meal per diem			10	45	0.4
hotel per diem (winter)			5	75	0.4
hotel per diem (summer)			5	110	0.6
car rental			10	40	0.4
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$3.6

1998

Project Number: 98163O
Project Title: APEX: Statistical Review
Agency: Western EcoSystems Technology

FORM 4B
Personnel
& Travel
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
Contractual Total	$0.0

Commodities Costs:	Proposed
Description	FFY 1998
long distance telephone	0.6
shipping, postage, supplies	0.5
Commodities Total	$1.1

1998

Project Number: 98163O
Project Title: APEX: Statistical Review
Agency: Western EcoSystems Technology

FORM 4B
Contractual
& Commodities
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE INCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	

1998	Project Number: 98163O Project Title: APEX: Statistical Review Agency: Western EcoSystems Technology	FORM 4B Equipment DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$0.0	$0.0						
Contractual	$65.2	$65.2						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$65.2	$65.2	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$4.6	$4.6						
Project Total	$69.8	$69.8	$70.0	$70.0				
Full-time Equivalents (FTE)	0.0	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

A contract for a project designed to develop models of foraging effort and success as it relates to breeding productivity. Results will test the degree to which food limitation is affecting recovery, indicate the mechanisms by which this could come about, and identify the scale at which interactions are occurring between food availability and the colonies being studied by APEX.

1998

Project Number: 98163Q
Project Title: APEX Modeling
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE INCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:						
Name	Position Description	GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		0.0	0	0	
					Personnel Total	$0.0

Travel Costs:					
Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$0.0

1998

Project Number: 98163Q
Project Title: APEX Modeling
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
contract to H.T. Harvey and Associates for modeling	65.2
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$65.2

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163Q
Project Title: APEX Modeling
Agency: NOAA

FORM 3B Contractual & Commodities DETAIL

4/8/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		New Equipment Total	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163Q
Project Title: APEX Modeling
Agency: NOAA

FORM 3B
Equipment
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$29.5	$16.2						
Travel	$5.5	$6.8						
Contractual	$29.3	$40.6						
Commodities	$0.0	$1.6						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$65.2	$65.2	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
Indirect (0%)	$0.0	$0.0						
Project Total	$65.2	$65.2	$65.0	$65.0				
Full-time Equivalents (FTE)	0.2	0.1						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

This project will develop models of foraging effort and success as it relates to breeding productivity. Results will test the degree to which food limitation is affecting recovery, indicate the mechanisms by which this could come about, and identify the scale at which interactions are occurring between food availability and the colonies being studied by APEX.

1998

Project Number: 98163Q
Project Title: APEX Modeling
Agency: H.T. Harvey & Associates

FORM 4A
Non-Trustee
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FFY 1998
D. Ainley	Co-PI		0.9	15,120		13.6
S. Terrill	Co-PI		0.1	20,160		2.0
	admin. support		0.1	6,000		0.6
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		1.1	41,280	0	
					Personnel Total	$16.2

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
SFO-Anchorage (one trip for science workshop)	800	1	5	150	1.6
SFO Portland	800	2	8	150	2.8
St. Johns, NFLD to Anchorage	1,000	1	5	150	1.8
conference	250	1	3	110	0.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$6.8

1998

Project Number: 98163Q
Project Title: APEX Modeling
Agency: H.T. Harvey & Associates

FORM 4B
Personnel
& Travel
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
subcontract: ECI (Glenn Ford) 2.5 months @ $12,747/mo. = $18060	31.9
GIS tech., 0.4 month @ $9460/mo. = $4,730	3.8
Memorial Univ., D.C., Schneider, .4mo. @ $12,747/mo.	4.9
Contractual Total	$40.6

Commodities Costs:	Proposed
Description	FFY 1998
report printing costs	1.6
Commodities Total	$1.6

1998

Project Number: 98163Q
Project Title: APEX Modeling
Agency: H.T. Harvey & Associates

FORM 4B
Contractual
& Commodities
DETAIL

4/8/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	

1998	Project Number: 98163Q Project Title: APEX Modeling Agency: H.T. Harvey & Associates	FORM 4B Equipment DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$81.0	$81.0						
Travel	$5.4	$5.4						
Contractual	$8.7	$8.7						
Commodities	$9.6	$9.6						
Equipment	$1.0	$1.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$105.7	$105.7	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$12.8	$12.8						
Project Total	$118.5	$118.5	$118.5	$85.0				
Full-time Equivalents (FTE)	1.7	1.7						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

This project will continue to refine the Marbled Murrelet productivity index developed in FY95-FY96.

1998

Project Number: 98163R
Project Title: Marbled Murrelet Productivity
Agency: USFWS

FORM 3A
AGENCY
PROJECT
DETAIL

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
K. Kuletz	PI	GS 11/5	11.0	5,000		55.0
Kendall	GIS/Biologist	GS 9/4	4.0	4,000	1,600	17.6
	bio. tech.	GS 5	2.0	2,200	1,000	5.4
	volunteer		3.0	1,000		3.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		20.0	12,200	2,600	
					Personnel Total	$81.0

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FFY 1998
train, truck, and boat, Anchorage to Whittier	0.6	1			0.6
train, 3 people, Anchorage to Whittier (driver+vehicle @$123 ea.	0.1	12			1.2
field per diem for boat surveys ($3/day/person 3 people @40 days)					0.4
per diem for diet studies ($3/day/person people @20 days)					0.1
per diem (travel Rate), 3 people, 3 d training, 4 d summer					1.5
lodging, 3 people, 6 nights (Valdez)					0.6
conference (Murrelet At-Sea Workshop)					1.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$5.4

1998

Project Number: 98163R
Project Title: Marbled Murrelet Productivity
Agency: USFWS

FORM 3B
Personnel
& Travel
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
delivery of equipment and supplies to PWS study site: ($4.0K split with 163E and 163F)	1.3
delivery of fule to PWS study site ($2.0K split w/163E and 163F)	0.6
safety training for two new people @ $830/person, includes travlel and per diem to Whittier	1.6
boat maintenance and repair	3.0
telephone services in office and in the field	0.3
film processing	0.1
publication page charges	0.5
maintenance and cleaning of camp equipment for 4 people @ $200/person	0.8
maintenance and cleaning of binoculars, scopes, and cameras	0.5
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$8.7

Commodities Costs:	Proposed
Description	FFY 1998
food: 4 people, 176 people days @ $10/day (during boat surveys)	1.8
food: 2 peole, 20 days during diet study @ $10/day	0.4
boat fuel: 100 gal/day for 35 survey and travel days, i boat in PWS @ $1.50/gal, plus oil (2 gal/day) @ $12/gal	6.0
camp supplies (stove and lantern fuel, mantles, head nets, bug spray, batteries, cleaning materials)	0.4
scientific supplies (batteries for radios, film, waterproof notebooks, sample bags, preservatives, scales, calipers)	0.5
lines, anchors, propellers for boats	0.5
Commodities Total	$9.6

1998

Project Number: 98163R
Project Title: Marbled Murrelet Productivity
Agency: USFWS

FORM 3B
Contractual & Commodities
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE NCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
camp equipment (stoves, laterns, tents, tools, batteries, dishes)			1.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		New Equipment Total	$1.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency
survival suits	5	USFWS
mustang suits	5	USFWS

1998

Project Number: 98163R
Project Title: Marbled Murrelet Productivity
Agency: USFWS

FORM 3B
Equipment
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$0.0						
Travel	$0.0	$0.0						
Contractual	$0.0	$103.5						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$103.5	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
General Administration	$0.0	$7.2						
Project Total	$0.0	$110.7	$118.3	$75.1	$71.7			
Full-time Equivalents (FTE)	0.0	0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: This project will investigate Jellyfish as competitors and predators of fishes in Prince William Sound.

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Agency: NOAA

FORM 3A
AGENCY
PROJECT
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE (ICIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Personnel Costs:			GS/Range/	Months	Monthly		Proposed
	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1998
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		0.0	0	0	
						Personnel Total	$0.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FFY 1998
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
jelly fish as competitors and predators contract with Horn Point Environmental Laboratory	103.5
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$103.5

Commodities Costs:	Proposed
Description	FFY 1998
Commodities Total	$0.0

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Agency: NOAA

FORM 3B
Contractual
& Commodit
ies
DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Agency: NOAA

FORM 3B
Equipment
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Budget Category:	Authorized FFY 1997	Proposed FFY 1998						
Personnel	$0.0	$51.9						
Travel	$0.0	$13.4						
Contractual	$0.0	$4.6						
Commodities	$0.0	$2.5						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$72.4	Estimated FFY 1999	Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004
Indirect (43%)	$0.0	$31.1						
Project Total	$0.0	$103.5	$110.6	$70.2	$67.0			
Full-time Equivalents (FTE)	0.0	1.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

This project will investigate Jellyfish as competitors and predators of fishes in Prince William Sound.

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Name: Horn Point Environmental Laboratory

FORM 4A
Non-Trustee
DETAIL

4/8/97

1998 EXXON VALDEZ TRUSTEE (ICIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Personnel Costs:						
Name	Position Description		Months Budgeted	Monthly Costs	Overtime	Proposed FFY 1998
J. Purcell	PI		3.0	6,500		19.5
	technician		12.0	2,700		32.4
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		1.3	9,200	0	
					Personnel Total	$51.9

Travel Costs:					
Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FFY 1998
University of Maryland to Juneau or Anchorage (RT)	900	7	57	100	12.0
University of Maryland to Juneau or Anchorage (RT) (Restoration Wor	900	1	5	100	1.4
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$13.4

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Name: Horn Point Environmental Laboratory

FORM 4B
Personnel
& Travel
DETAIL

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

Contractual Costs:	Proposed
Description	FFY 1998
photocopying	0.1
shipping	0.7
communications	0.3
computer services	0.5
housing in Juneau	3.0
Contractual Total	$4.6

Commodities Costs:	Proposed
Description	FFY 1998
laboratory supplies	2.5
Commodities Total	$2.5

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Name: Horn Point Environmental Laboratory

FORM 4B
Contractual & Commodities
DETAIL

4/8/97

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1998
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	
scuba dry suit	1	
laptop computer	1	

1998

Project Number: 98163S
Project Title: Jellyfish as Competitors and Predators of Fishes
Name: Horn Point Environmental Laboratory

FORM 4B
Equipment
DETAIL