19.02.03

FY 95 Detailed Project Descriptions

19.2.3

95001

RECEIVED
JUL 0 6 1995
EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL
ADMINISTRATIVE RECORD

95001

SFOS 95-156

PROPOSAL

RECEIVED
FEB 9 1995
EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL

TO: Exxon Valdez Oil Spill Trustee Council
645 G Street
Anchorage, AK, 99501

FROM: Institute of Marine Science
School of Fisheries and Ocean Sciences
P.O. Box 757220
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

TITLE: Recovery of harbor seals from EVOS: Condition and health status.

PRINCIPAL INVESTIGATORS: Dr. Michael Castellini
Associate Professor

NEW/CONTINUING: NEW

DURATION: 3 Years

PROPOSED START DATE: Jan 1, 1995 to Dec 31, 1997

AMOUNT REQUESTED: $375,720

[signature] 1/23/95
Dr.Michael Castellini /Date
Principal Investigator
(907)474-6825

[signature] 1-25-95
Joan Osterkamp /Date
Executive Officer
School of Fisheries and Ocean Sciences

[signature] 26 Jan 95
A. V. Tyler /Date
Associate Dean
School of Fisheries and Ocean Sciences

[signature] 25 Jan 95
Donald M. Schell /Date
Director
Institute of Marine Science

[signature] 1/23/95
Ted DeLaca /Date
Director, Office of Arctic Research
University of Alaska Fairbanks

DETAILED PROJECT DESCRIPTION
for
FY95 RESTORATION PROJECTS

PROJECT TITLE: Recovery of harbor seals from EVOS: Condition and health status.

PROJECT NUMBER:	95001
LEAD TRUSTEE AGENCY:	ADF&G
COOPERATING AGENCIES:	UAF
PROJECT START DATE:	January 1, 1995
PROJECT COMPLETION DATE:	December 31, 1995
EXPECTED DURATION:	3 Years
COST OF PROJECT:	$153,823 (FY95) $120,028 (FY96) $101,869 (FY97)
GEOGRAPHIC AREA:	Prince William Sound
PROJECT LEADER:	Dr. Michael Castellini
PROJECT MANAGER:	Dr. J. Sullivan

[signature] 1/25/95 [signature] 2/3/95

Dr. Michael Castellini /Date
Project Leader
(907) 474-6825
(907) 474-7204 (fax)

Dr. J. Sullivan /Date
Project Manager
ADF&G

A. INTRODUCTION

Harbor seal (*Phoca vitulina*) populations in Alaska show evidence of decline over portions of their range. Prior to the *Exxon Valdez* Oil Spill (EVOS), population declines of 85% had been reported from Tugidak Island (Pitcher 1990), and declines may also have occurred in the eastern Bering Sea and Aleutian Islands (Hoover-Miller 1994). Prince William Sound (PWS) harbor seal populations, further impacted by EVOS (Frost and Lowry 1994a), have essentially stabilized at decreased levels, but have shown no signs of population recovery (Frost and Lowry 1994b). Trend-site counts in PWS indicated that declines occurred both in pup and non-pup portions of the population (Frost and Lowry 1994b). Assessment and interpretation of harbor seal body condition and nutritional status data can help resolve multiple hypotheses proposed to explain these declines, and to help focus future studies. The premises and hypotheses of this project are simple: *either the EVOS-impacted animals are different in their health status compared to non-EVOS animals, or they are not.* If the PWS harbor seals are compromised, then we will know some of the directions that should be followed towards potential restoration. If they are not compromised, then we can focus our attention into other areas that may better explain their current recovery status.

Changes in ecosystems or in prey availability due to natural or anthropogenic causes can be reflected in the body condition or nutritional status of top trophic-level consumers, such as harbor seals. However, indices used to assess body condition may also vary with season, age, or sex (Pitcher 1986; Trites and Bigg 1992; Beck et al. 1993; Renouf et al. 1993) independent of foraging ability or prey availability. Therefore, normal ranges of body size, shape and blubber distribution must be quantified before useful interannual comparisons can be performed. Likewise, blood chemical and hematological parameters also change significantly in response to environmental or nutritional effects (Seal et al. 1975; Geraci et al. 1979; McConnell and Vaughan 1983; Kuiken 1985; Roletto 1993). Chemical profiles and complete blood counts can identify potential homeostatic imbalances in organ systems or metabolic pathways if the effects of non-health related variation can be quantified (Payne and Payne 1987; Kerr 1989; Castellini et al. 1993).

Interpretation of blood chemistry and body condition data collected from harbor seals during EVOS and subsequent studies can be improved by quantifying non-health related effects and by establishing normal values for free-ranging animals. Additionally, few studies have critically examined the assumptions used in assessing body condition from morphometric measurements in harbor seals. This project will continue work performed by our laboratory in association with Alaska Department of Fish and Game (ADFG) harbor seal monitoring programs.

B. PROJECT DESCRIPTION

1. Resources and Associated Services

The focus of this study is the harbor seal (*Phoca vitulina*). The results of this study, in conjunction with our blubber-quality study (Project Number 95117-BAA), will help elucidate the nature of harbor seal population decline and non-recovery in Prince William Sound. This information will be critical for developing species restoration or management plans.

2. Relation to Other Damage Assessment Work

This project continues nutritional status and body condition work performed by our laboratory in association with ADFG harbor seal Project Number 93064, 'Habitat use, behavior, and monitoring of harbor seals in Prince William Sound'. Our study of blubber quality (Project Number 95117-BAA, 'Harbor seals and EVOS: blubber and lipids as indices of food limitation') utilizes samples obtained from the seals used in this project to provide a complete picture of blubber energy stores available to these seals. To move towards the restoration of marine mammals, a multi-disciplinary, integrative approach is critical given the scope of the problem. Because this study is being performed in conjunction with past (Project No. 93064) and present (Project No. 95064, 'Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound) studies, it presents an unparalleled opportunity for interdisciplinary research into aspects of habitat use, trophic level interactions, population dynamics, and nutritional status of harbor seals. The results from this study will also be interpreted in light of results generated from stable isotope research into dietary changes of harbor seals (Project No. 95320I, 'Isotope tracers-food web dependencies in PWS (fish, marine mammals and birds)').

3. Objectives

1. Collect additional hematological data to establish reference ranges of blood chemistries and hematologies of PWS harbor seals and determine variation attributable to sampling technique, age, sex, or season and location of capture.

2. Estimate our ability to detect changes in body condition using morphometric measurements.

3. Assess body condition using morphometric measures of body shape, density and fat content, and determine the effects of age, sex, season and location.

4. Compare blood and morphological indices of health and condition in light of the above to examine interannual changes, potential EVOS-related impacts, and to help interpret changes in population status.

Seals will be captured during Spring and Fall of 1995. Laboratory analyses and statistical analysis will be conducted throughout the remainder of the year.

4. Methods

Field Techniques
Harbor seals will be live-captured by net entanglement, in conjunction with EVOS Project Number 95064, using methods previously described by Frost and Lowry (1994b). Once captured, seals will be transported to shore or ship, anesthetized if required (using Ketamine and Diazapam), weighed with an electronic hanging scale, and morphometric measurements gathered. Blood will be drawn from the extradural vein into Vacutainer® blood collection tubes.

Body Condition

Linear and curvilinear length, a series of girths at 7 locations, and mass will be collected from each animal. Blubber depths at 2-3 sites at each girth ring will be measured using a portable ultrasound unit (Scanoprobe II, Model 7310, Scanco, Inc.). These measurements are quickly and easily carried out in the field. In the laboratory, the data will be fit into models of how length, girth and mass are related for harbor seals and will be used to evaluate body condition. Ultrasonic measurements of blubber depth will provide data on the spatial variablility of blubber stores, and also estimation of total body fat (Worthy et al. 1992). Condition indices will be compared using a database of morphometric measurements and corresponding body and sculp masses collected during 1972-1978 by Alaska Department of Fish and Game, and previously presented in Pitcher and Calkins (1979) and Pitcher (1986).

Hematology

Samples will be transported to the ship/lab and examined microscopically to determine red and white cell counts. Blood hematocrit (% red blood cells by volume) will be measured in the field using a portable centrifuge. Samples of whole blood will be pipetted into Drabkin's reagent for hemoglobin analysis. Subsamples of blood will be centrifuged to prepare plasma and plasma, serum and whole blood samples will be frozen in liquid nitrogen for later laboratory analyses. Plasma samples will be sent to a veterinary laboratory for assessment of "standard" health indices (such as cholesterol level, salts, and enzymes characteristic of tissue damage) and also analyzed at our lab for indicators of dehydration (water content), malnutrition (BUN, ketones), stress (haptoglobin), hormone imbalance (angiotensin, ANP) and stress proteins (samples sent to collaborators at Stanford Research Institute). Standard panels that assay plasma sodium, potassium, chloride, phosphorous, creatinine, cholesterol, direct and total bilirubin, total protein, albumin, globulin, alkaline phosphatase, glucose, lactate dehydrogenase, gammaglobulin transferase (GGT), creatinine phosphokinase (CPK), aspartate aminotransferase (SGOT) and alanine aminotransferase (SGPT) will be performed by automated machine analysis at the Fairbanks Memorial Hospital (FMH) using an Ektachem Analyzer. Additionally, concentrations of free fatty acids (FFA), ketones (β-HBA), uric acid, iron, blood urea nitrogen (BUN) and hemoglobin will be determined using standard kits from Sigma Chemical Co. and performed in our laboratory. Complete blood counts of white and red blood cells, platelet and differential white blood cell counts will be performed by technicians at FMH from blood collected in EDTA vacutainers using a Coulter Model S-Plus-4 Counter, and from blood smears produced in the field.

It should be emphasized that the above methods are routine for the marine mammal group at UAF and that we conduct similar assays hundreds of times/year on seal and sea lion species from around the world. Thus, we have the expertise, the databases and the consistency to best analyze these samples from the PWS animals. Statistical comparisons of hematological values, body condition and shape will be performed using PC-based software. The ultimate goal is to derive useful indices of condition and hematology, that when controlled for other sources of variation such as sex, age and season of capture, will enable interannual comparisons of nutritional and health status.

D. EXISTING AGENCY PROGRAM

An award from the Rasmuson Fisheries Research Center was received by Mr. Fadely for a project entitled, "Monitoring ecosystem changes and prey abundance in the Gulf of Alaska using condition indices of harbor seals". This $8,412 stipend and tuition award supported Mr. Fadely between October 1994 and February 1995. The objectives of this study were to continue developing indices based on size, shape and mass of harbor seals to monitor interannual variation in ecosystems and prey abundance in the Gulf of Alaska, and to provide a basis to examine long-term historical databases of harbor seal morphometrics to elucidate past changes in prey abundance or quality.

E. ENVIRONMENTAL COMPLIANCE/PERMIT/COORDINATION STATUS

All permits required to conduct this research are currently active. This research will be performed under Marine Mammal Commission Permit No. 770 to Kathy Frost and Lloyd Lowry of ADF&G. We currently hold an active Animal Care and Use Permit from the University of Alaska, Fairbanks, Institutional Animal Care and Use Committee for this research. No other permits are required.

F. PERFORMANCE MONITORING

Work performance is monitored at several levels for UAF research/academic laboratories:

A) Daily work: Students, staff and faculty are required to provide daily records of hours worked per funded project. Dr. Castellini is in the laboratory on a daily basis and oversees the student/staff workload and general functioning of the facility.

B) Project reports: Students and staff work closely with Dr. Castellini on the production of reports and project results. In addition, laboratory results are often discussed in teaching and seminar situations.

C) Budgetary reports. The UAF/SFOS business office provides monthly status reports on budgetary considerations and assigns a fiscal officer to each grant and/or contract. In addition, our own laboratory runs our own fiscal/software to follow daily costs and charges.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

This project utilizes the same research animals, ships and logistics provided to Project No. 95064, 'Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound', and the same research subjects utilized by Project No. 95117-BAA, 'Harbor seals and EVOS: blubber and lipids as indices of food limitation'. These same animals will also be used by Project No. 95320I, 'Isotope tracers-food web dependencies in PWS (fish, marine mammals and birds)'.

Renouf, D., R. Gales and E. Noseworthy. 1993. Seasonal variation in energy intake and condition of harp seals: is there a harp seal morph? Problems for bioenergetic modelling. J. Zool., Lond. 230:513-528.

Roletto, J. 1993. Hematology and serum chemistry values for clinically healthy and sick pinnipeds. J. Zoo. and Wildl. Med. 24:145-157.

Seal, U.S., L.D. Mech and V.V. Ballenberghe. 1975. Blood analyses of wolf pups and their ecological and metabolic interpretation. J. Mamm. 56:64-75.

Trites, A.W. and M.A. Bigg. 1992. Changes in body growth of northern fur seals from 1958 to 1974: density effects or changes in the ecosystem? Fish. Ocean. 1:127-136.

Worthy, G.A.J., P.A. Morris, D.P. Costa, and B.J. LeBoeuf. 1992. Moult energetics of the northern elephant seal (*Mirounga angustirostris*). J. Zool. (Lond.) 227:257-267.

5. Location

Harbor seals will be captured from haul-out locations within PWS including sites which varied from non-oiled to heavily-oiled during the EVOS. Our laboratory also collects data from harbor seals outside of PWS for comparative purposes.

6. Technical Support

Plasma samples will be sent to Fairbanks Memorial Hospital to perform automated standard veterinary panel analyses. Additional samples will be provided to collaborators at the Stanford Research Institute for experimental stress protein analyses. All other analyses will be performed by our laboratory personnel at the University of Alaska, Fairbanks. Boat and direct field support will be through our ongoing collaboration with ADFG and Project No. 95064.

7. Contracts

No sub-contracts will be associated with this project. Some veterinary blood chemistry analyses will be performed by the Fairbanks Memorial Hospital on a price-per-sample basis.

J. BUDGET

See attached Exxon Valdez Trustee Council budget forms.

Breakdown of FY95 Budget - Personnel

WAGES	Time	Amount		
M.A Castellini	3 months	14199		
J.M. Castellini	3 months	7155		
B. Fadely	6 months	7308		
T. Zenteno	6 months	7308		
TOTAL WAGES			35970	
LEAVE				
M.A. Castellini		2853		
J.M. Castellini		1530		
TOTAL LEAVE			4383	
BENEFITS				
M.A. Castellini		4995		
J.M. Castellini		3534		
TOTAL BENEFITS			8529	
TOTAL SALARIES				**48882**

ACTIVITY	FY95 1	2	3	4	FY96 1	2	3	4	FY97 1	2	3	4
Logistical preparations for upcoming field work	----------	--	------		-----	--	------					
Capture and sampling of harbor seals in PWS, including body morphometrics and blood sampling		-----	----			-----	----					
Analysis of harbor seal body morphometrics and chemical analysis of blood samples	----------	----------	----------	----------	----------	----------	----------	----------	----------	----		
Development of computer analysis of morphometric data and statistical analysis of blood chemistry			--	----------	----------	----------	----------	----------				
Final development of statistical analysis and computer modeling of entire data set									----------	-------		
Attend EVOS workshop		--			--	--			--	--		
Preparation of annual reports				------				------				
Preparation and presentation of data at Marine Mammal Conference				-----								-----
Prepare draft of final EVOS report										----	----------	
Prepare drafts of refereed manuscripts										----	----------	
Prepare and submit final versions of refereed manuscripts												----------
Prepare and submit final EVOS report												----------

EXXON VALDEZ TRUSTEE COUNCIL
1995 Federal Fiscal Year Project Budget
October 1, 1994 - September 30, 1995

Project Description: Recovery of Harbor Seals from EVOS: Condition and Health Status- This project collaborates with the inter-disciplinary and integrative marine mammals ecosystems program submission to EVOS. Outlined under the bread program direction, the goals of the combined collaborative projects are to investigate ecosystem wide questions addressing the recovery of marine mammal injured species, specifically, harbor seals. These issues include the direct impact of oil spills, human interactions, food, competition, climatic factors, disease and habitat loss. This project deals with the issues of body condition and health status of harbor seals with the resulting data applying directly to issues of disease, food limitation and the impact of oil.

Budget Category:	1994 Project No. 94199 Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment: 94 Report	95 Interim	95 Report	96 Field
Personnel	$0.0	$0.0	$48.9	$48.9	$51.3	$0.0	$0.0	$0.0	$51.3
Travel	$0.0	$0.0	$12.4	$12.4	$10.1	$0.0	$0.0	$0.0	$10.1
Contractual	$0.0	$0.0	$15.7	$15.7	$16.1	$0.0	$0.0	$0.0	$16.1
Commodities	$0.0	$0.0	$21.6	$21.6	$21.9	$0.0	$0.0	$0.0	$21.9
Equipment	$0.0	$0.0	$29.6	$29.6	$0.0	$0.0	$0.0	$0.0	$0.0
Capital Outlay	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Subtotal	$0.0	$0.0	$128.2	$128.2	$99.4	$0.0	$0.0	$0.0	$99.4
General Administration	$0.0	$0.0	$25.6	$25.6	$19.9	$0.0	$0.0	$0.0	$19.9
Project Total	$0.0	$0.0	$153.8	$153.8	$119.3	$0.0	$0.0	$0.0	$119.3
Full-time Equivalents (FTE)	0.7	0.0	1.6	1.6	4.9				

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
M. Castellini	0.0	$0.0	3.0	$22.1
J.M. Castellini	0.0	$0.0	3.0	$12.2
B. Fadely	0.0	$0.0	6.0	$7.3
T. Zenteno	0.0	$0.0	6.0	$7.3
Personnel Total	0.0	$0.0	18.0	$48.9

Report writing for this project will be a condition of the contract, no additional funds will be requested.

NEPA Cost: $0.0

*Oct 1, 1994 - Dec 31, 1994

**Jan 1, 1995 - Sep 30, 1995

08/01/94

1995

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Project Number: 95001
Project Title: Recovery of Harbor Seals from EVOS: Condition and Health Status
Agency: University of Alasl Fairbanks

FORM 4A SUB-PROJECT CONTRACTUAL [illegible]

H. PUBLIC PROCESS

Results of this study will be presented at appropriate EVOS workshops, as well as at professional meetings such as the Biennial Conference on the Biology of Marine Mammals, to be held in Orlando, Florida in December 1995.

I. PERSONNEL QUALIFICATIONS

Michael Castellini, Ph.D., specializes in metabolic chemistry problems associated with marine mammals. He is a tenured Associate Professor of Marine Science at UAF and has worked in this field for over 20 years. A one page selected CV is included in this package.

J.M. Castellini, M.Sc., is a UAF Research Associate and has worked on marine mammal biochemistry/physiology projects since 1986. She is currently the laboratory director and provides for daily project monitoring.

B.S. Fadely, M.Sc., a Ph.D. student involved in this project, has previously performed studies involving nutritional physiology of northern fur seals and California sea lions. Currently he has been involved in assessing the health status of harbor seals in the Gulf of Alaska using morphometric and hematological techniques.

T. Zenteno, M.Sc., is a Ph.D. student with a background in biochemistry and zoology. She will be performing all assays related to stress proteins, hormonal balance and haptoglobin levels.

EXXON VALDEZ TRUSTEE COUNCIL
1995 Federal Fiscal Year Project Budget
October 1, 1994 - September 30, 1995

JAN-23-1995 12:16 FROM SOA FISH & GAME ANCHORAGE TO 19074747204 P.07

Commodities:	Reprt/Intrm	Remaining
Intrm 400 assays for hemoglobin, ketone bodies, blood urea nitrogen and fatty acids @ $19/assay	$0.0	$7.6
400 assay kits @ $13.50/kit	$0.0	$5.4
400 sample preps @ $6.425/prep	$0.0	$2.6
400 stress assays @ $3.825/assay	$0.0	$1.5
Ultracold storage boxes 50 @ $10.00	$0.0	$0.5
1 Mustang suit @ $380	$0.0	$0.4
4 Water tight containers @ $155.00	$0.0	$0.6
SYSTAT software	$0.0	$0.7
Graphics software	$0.0	$0.5
Plotting software	$0.0	$0.6
Media	$0.0	$0.6
Presentation media	$0.0	$0.6
Commodities Total	$0.0	$21.6

Equipment:		
Rept Microscope	$0.0	$1.4
Intrm Shipper	$0.0	$1.0
Speedvac	$0.0	$8.0
Moisture analyzer	$0.0	$8.2
Freezer	$0.0	$7.0
Database Computer	$0.0	$3.0
Shipping for the above items	$0.0	$1.0
Equipment Total	$0.0	$29.6

07/14/93

1995

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Project Number: 95001
Project Title: Recovery of Harbor Seals from EVOS: Condition and Health Status
Agency: University of Al[illegible] - Fairbanks

FORM 4B
SUB-PROJECT
CONTRACTUAL
DETAIL

EXXON VALDEZ TRUSTEE COUNCIL
1995 Federal Fiscal Year Project Budget
October 1, 1994 - September 30, 1995

JAN-23-1995 12:15 FROM SOA FISH & GAME ANCHORAGE TO 19074747204 P.06

Travel:	Reprt/Intrm	Remaining
Intrm 8 RT Fairbanks/Anchorage @ 350 + 80 days field per diem @ $50/day	$0.0	$6.8
2 RT Fairbanks/Anchorage for workshops @ $350 + 14 days per diem @ $170/day	$0.0	$3.1
2 RT to Marine Mammal meeting in Orlando @ $700 + 12 days per diem @ $94	$0.0	$2.5
Travel Total	$0.0	$12.4

Contractual:		
Vet lab analysis	$0.0	$3.9
Long distance phone charges	$0.0	$0.5
Postage	$0.0	$0.2
Cargo shipping	$0.0	$1.0
Tuition for two graduate students for 2 semesters	$0.0	$10.1
Contractual Total	$0.0	$15.7

07/14/93

1995

Printed: 8/4/94 3:23 PM

Project Number: 95001
Project Title: Recovery of Harbor Seals from EVOS: Condition and Health Status
Agency: University of Alaska - Fairbanks

FORM 4B
SUB-PROJECT
CONTRACTUAL
DETAIL

Body Condition

Linear and curvilinear length, a series of girths at 7 locations, and mass will be collected from each animal. Blubber depths at 2-3 sites at each girth ring will be measured using a portable ultrasound unit (Scanoprobe II, Model 7310, Scanco, Inc.). These measurements are quickly and easily carried out in the field. In the laboratory, the data will be fit into models of how length, girth and mass are related for harbor seals and will be used to evaluate body condition. Ultrasonic measurements of blubber depth will provide data on the spatial variablility of blubber stores, and also estimation of total body fat (Worthy et al. 1992). Condition indices will be compared using a database of morphometric measurements and corresponding body and sculp masses collected during 1972-1978 by Alaska Department of Fish and Game, and previously presented in Pitcher and Calkins (1979) and Pitcher (1986).

Hematology

Samples will be transported to the ship/lab and examined microscopically to determine red and white cell counts. Blood hematocrit (% red blood cells by volume) will be measured in the field using a portable centrifuge. Samples of whole blood will be pipetted into Drabkin's reagent for hemoglobin analysis. Subsamples of blood will be centrifuged to prepare plasma and plasma, serum and whole blood samples will be frozen in liquid nitrogen for later laboratory analyses. Plasma samples will be sent to a veterinary laboratory for assessment of "standard" health indices (such as cholesterol level, salts, and enzymes characteristic of tissue damage) and also analyzed at our lab for indicators of dehydration (water content), malnutrition (BUN, ketones), stress (haptoglobin), hormone imbalance (angiotensin, ANP) and stress proteins (samples sent to collaborators at Stanford Research Institute). Standard panels that assay plasma sodium, potassium, chloride, phosphorous, creatinine, cholesterol, direct and total bilirubin, total protein, albumin, globulin, alkaline phosphatase, glucose, lactate dehydrogenase, gammaglobulin transferase (GGT), creatinine phosphokinase (CPK), aspartate aminotransferase (SGOT) and alanine aminotransferase (SGPT) will be performed by automated machine analysis at the Fairbanks Memorial Hospital (FMH) using an Ektachem Analyzer. Additionally, concentrations of free fatty acids (FFA), ketones (β-HBA), uric acid, iron, blood urea nitrogen (BUN) and hemoglobin will be determined using standard kits from Sigma Chemical Co. and performed in our laboratory. Complete blood counts of white and red blood cells, platelet and differential white blood cell counts will be performed by technicians at FMH from blood collected in EDTA vacutainers using a Coulter Model S-Plus-4 Counter, and from blood smears produced in the field.

It should be emphasized that the above methods are routine for the marine mammal group at UAF and that we conduct similar assays hundreds of times/year on seal and sea lion species from around the world. Thus, we have the expertise, the databases and the consistency to best analyze these samples from the PWS animals. Statistical comparisons of hematological values, body condition and shape will be performed using PC-based software. The ultimate goal is to derive useful indices of condition and hematology, that when controlled for other sources of variation such as sex, age and season of capture, will enable interannual comparisons of nutritional and health status.

Literature Cited

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Worthy, G.A.J., P.A. Morris, D.P. Costa, and B.J. LeBoeuf. 1992. Moult energetics of the northern elephant seal (*Mirounga angustirostris*). J. Zool. (Lond.) 227:257-267.

5. Location

Harbor seals will be captured from haul-out locations within PWS including sites which varied from non-oiled to heavily-oiled during the EVOS. Our laboratory also collects data from harbor seals outside of PWS for comparative purposes.

6. Technical Support

Plasma samples will be sent to Fairbanks Memorial Hospital to perform automated standard veterinary panel analyses. Additional samples will be provided to collaborators at the Stanford Research Institute for experimental stress protein analyses. All other analyses will be performed by our laboratory personnel at the University of Alaska, Fairbanks. Boat and direct field support will be through our ongoing collaboration with ADFG and Project No. 95064.

7. Contracts

No sub-contracts will be associated with this project. Some veterinary blood chemistry analyses will be performed by the Fairbanks Memorial Hospital on a price-per-sample basis.

C. SCHEDULE

FY95 Project Activities

January-May:	Analysis of harbor seal body morphometrics and chemical analysis of blood samples. Logistical preparation for field studies of harbor seals in PWS including purchase of equipment and supplies.
April/May:	Capture and sampling of harbor seals in PWS, including body morphometrics and blood sampling.
June:	Attend EVOS Workshop.
May-September:	Continued analysis of harbor seal body morphometrics and chemical analysis of blood samples, incorporating new samples.
September/October:	Capture and sampling of harbor seals in PWS, including body morphometrics and blood sampling.
September-December:	Continued analysis of harbor seal body morphometrics and chemical analysis of blood samples, incorporating new samples. Begin development of computer modeling of body morphometric data and statistical analysis of chemical data. Prepare preliminary data for presentation at Marine Mammal Conference (Orlando, Fl, Nov. 1995). Prepare and distribute annual report.

Personnel and Responsibilities

	Capture/ Sampling	Morphometric Analysis	Chemical Analysis	Statistical Analysis/ Computer modeling	Preparation of Reports/ Manuscripts
M.A. Castellini	*			*	*
J.M. Castellini			*	*	*
B.S. Fadely	*	*	*	*	*
T. Zenteno	*		*	*	*

Logistical Needs

Immediate purchase of supplies for May field season, including blood metabolite supplies and field gear. Immediate purchase of all major equipment to allow timely analysis of samples, including microscope, shipper, Speedvac, freezer, computer and associated shipping costs. Continued purchase of supplies and services as needed to support subsequent field seasons and analysis.

DETAILED PROJECT DESCRIPTION

Project Title:	Archaeological Site Restortion - Index Site Monitoring
Project Number:	95007-A
Lead Trustee Agency:	Alaska Department of Natural Resources
Cooperating Agency:	U.S. National Park Service U.S. Fish and Wildlife Service U.S. Forest Service
Project Start-Up/Completion:	Start-up- March 1, 1995 Completion- January 31, 1996
Expected Project Duration:	10 years
Cost of Project:	FY95- $150.0, FY96-2004- $80.0/year estimated
Geographic Area:	Spill area-wide
Project Leaders: P.I.	Douglas R. Reger ADNR, Office of History and Archaeology 3601 C Street, Suite 1278 Anchorage, AK 99510-7001 (907)762-2622 FAX (907)762-2628
Project Manager:	Judith E. Bittner ADNR, Office of History and Archaeology 3601 C Street, Suite 1278 Anchorage, AK 99510-7001 (907)762-2622 FAX (907)762-2628

ARCHAEOLOGICAL SITE RESTORATION-INDEX SITE MONITORING
Detailed Project Descritpion
Project No. 95007-A

A. INTRODUCTION:

The increased evidence of vandalism at archaeological sites during initial cleanup activities for the EVOS dropped dramatically after 1989. That drop probably reflected the more effective archaeological constraint system that was put into place by the participating agencies, with the cooperation of Exxon Corp., by the late summer of 1989. That apparent reduction in vandalism was unexpected and at first suggested that continued vandalism related to the *Exxon Valdez* spill event might not be a significant future concern. However, based on what we know about the behaviour patterns of archaeological looters, the activity focus of vandals may have shifted (or will shift) from general prospecting to a more focused pattern during the initial "prospecting" phase, or simply observed by more discrete potential looters engaged in cleanup operations in the post-1989 era. Artifact hunters are most likely to act on the opportunities presented by this knowledge in the next 15 years while their memories remain fresh; thereafter, the threat should gradually drop as the information loses "immediacy" and specificity. Damage from vandals has continued to be documented at several sites during the past several seasons. Although other sites have not suffered damage, vandals are still active in the area and their level of activity needs to be monitored.

Damage to archaeological sites as a result of cleanup activities after the Exxon Valdez Oil Spill has been amply documented in damage assessment studies performed since the spill. Sites vandalized since the spill have been monitored and plans developed to restore the damages at the studied sites. Monitoring of damaged sites as a gauge of vandal activities in the spill area was identified as a primary strategy for site restoration during fiscal year 1995 (FY95). A concensus was reached among agency archaeologists that the most efficient way to monitor vandalized sites will be to select "index" damaged sites which will provided an indication of the level of vandal activity in the spill area.

A recommendation of the Trustee's archaeological peer reviewer during the January 1995 science workshop was to continue to monitor oiled sites on an intermittent basis. His concern was that subsurface oil would move into archaeological deposits and compromise possible data recovery.

B. PROJECT DESCRIPTION:

1. Resources

Monitoring of archaeological sites injured by the spill or spill related activities will target a small number of sites which are determined to represent those that are most vulnerable to looting. Those index sites will serve as a gauge for levels of vandalism in the spill area. The index sites oiled during the early time immediately after the spill in March 1989 will be also be checked during 1995 to detect recent infiltration of subsurface oil from surrounding sediments.

The resources monitored under project 95007-A are index archaeological sites thought to be representative of the archaeological sites in the spill area which have been and are beng vandalized. Some of the index sites were oiled during the spill and are being monitored to check for recent movement of subsurface oil into site deposits. Sites in the Prince William Sound area include SEW-440 and SEW-469. Outer Kenai Peninsula sites are SEL-188 and SEL-178. Sites in the Kodiak Island archipelago include KOD-171, AFG-098, and AFG-046. See attached site locations map.

2. Relation to Other Damage Assessment Work

Restricted studies of the sites identified as index sites in the EVOS area documented the impacts on those sites. SEW-440 in the Prince William Sound area was visited by the State University of New York at Binghamton archaeologist and by the DNR archaeologists in 1991. Beach sediments sampled by the USFS during 1994 tested positive with the HNU-Hanby test kit. The intertidal area of the site suffered oiling during 1989 and still retains subsurface oil. SEW-469 was visited by Forest Service and Exxon archaeologists and later by CAC archaeologists to document damage by vandals. SEW-440 and SEW-469 will be monitored by USFS archaeologists.

The McArthur Pass Site (SEL-188) received considerable attention from archaeologists of the National Park Service in 1993, Chugach Alaska Corporation and Exxon during 1990 and 1991, and by NPS personnel during 1994. Exxon and NPS archaeologists mapped artifact distributions in the intertidal zone and CAC/NPS archaeologists tested deposits in the upland area of the site. The site was only casually monitored during 1993 and 1994 but will be more intensively monitored during 1995 by the NPS.

Exxon and DNR archaeologists have re-visited the Port Dick Cabin Site (SEL-178) on several occasions to map artifact distributions, house pit boundaries, and location of disturbances to the site. The SUNY archaeologists also visited the site during 1991 to test and found no subsurface oil despite earlier evidence of oil on the beaches of the site. The Office of History and Archaeology will obtain information about the current status of the Port Dick Cabin Site (SEL-178), the Perevalnie Passage Site (AFG-046), and briefly check for subsurface oil at AFG-098.

A USFWS archaeologist will return to the Chief Cove Site (KOD-171) in 1995 to document current condition of that site. Vandalism was documented by Exxon archaeologists during post cleanup assessments during 1989. The site was visited during 1991 by agency archaeologists who documented on-going vandalism.

3. Objectives:

Depending on weather and coordination with other fieldwork in the vicinity of sites, agency archaeologists will complete fieldwork by the end of August 1995. Individual agency archaeologists will be responsible for setting precise schedules for site visits. Sediment samples collected for test with the HNU-Hanby field test kit will be processed by October 1, 1995, and preliminary results of fieldwork written in draft by November 1, 1995. Review to the draft report and preparation of the final report will be complete by January 31, 1996.

4. Methods

A strategy was identified during a 1994 restoration workshop of designating five index sites or sites critically vulnerable to looting which will be monitored on an annual basis. A second group of four sites were identified which are to be monitored biannually as a check over a broader area. The second group of sites may vary over time in order to maintain flexible response to new information such as fresh reports of vandlism or new findings on patterns of looting. The second group of sites provides a cross-check to monitoring data collected at the index sites. Focusing annual monitoring on 4 index sites and using a 2-year monitoring schedule on the additional 4 sites, expenditures will be significantly reduced while maintaining continuity of tracking levels of vandalism over the years. Vulnerability to looting will be the primary criteria of selection with managerial jurisdiction a secondary concern. Sites which were oiled will be monitored for oil so the behavior and effect of oiling can be observed over the long term in archaeological deposits.

Testing for presence of oil in site sediments will be done with the HNU-Hanby field test kit which can identify the presence of petroleum hydrocarbons and give an estimate of the relative concentration of the contaminants in the soil. Once the field tests show positive for oil, plans will be made to obtain funding so that the Auke Bay lab can send personnel to collect suitable samples for identifying the source of the oil and more accurately determine the amount present. This procedure was suggested by Auke Bay lab representatives at the 1995 workplan session so that suitable samples could be properly collected and processed.

Documentation of site status at the localities monitored for vandalism will include re-locating previously established reference points and refering all observations to those points. Field maps will be drawn or surveyed as appropriate. Photo and video documentation will be referenced to datum points and will duplicated earlier perspectives as closely as possible. Test localities will be mapped in reference to site reference points.

SEW-440

The Chugach National Forest oil spill archaeologists will visit the SEW-440 to monitor the beach deposits for vandal activity but primarily will collect samples of cultural sediments from the beach to test for continued presence of oil. A sediment sample collected during the 1994 season from a 30 cm deep hole tested positive. The 1995 samples will be collected from widely spread areas of the beach to document the present distribution of oil in the beach deposits. Sediment samples will be tested for presence of petroleum hydrocarbons using the HNU-Hanby field test kit.

SEW-469

This site will be monitored to detect any vandal activity since the site status was last documented in 1990. At that time cultural remains were re-buried in the site without coordination with the land manager, the U.S. Forest Service. As this is one of the few sites where an individual was prosecuted for antiquities violations, the site is important to monitor to detect any further depredations.

SEL-188

The National Park Service archaeologists will monitor this site to detect any vandal activity by comparing detailed artifact distribution maps prepared in prior years with the current situation. The site was also heavily oiled and needs to be visited to collect a beach sediment sample to detect whether oil still remains in cultural deposits on the site. The sample will be collected, mapped in reference to an existing datum point, and the sample returned to ADNR for testing with the HNU-Hanby field test kit.

AFG-098

The Alaska Department of Natural Resources, Office of History and Archaeology, will return to the AFG-098 Site on Shuyak Island to make a brief test into the intertidal cultural deposits in order to determine whether or not any subsurface oil has migrated into the site. A test unit will be excavated into the exposed cultural layers and samples will be collected from within and below the cultural levels for testing with a HNU-Hanby field test kit. The test pit will be excavated in the middle to upper intertidal zone near the middle of the exposure of fire cracked rocks. If petroleum hydrocarbon is detected, the location will be marked for a return in 1996 to properly collect samples for finger printing of the oil. Operators at the Auke Bay Lab where samples are processed have requested that they be transported to any collection site to properly sample the sediments. Funding for that will be included in a future proposal if necessary.

Perevalnie Passage Site, AFG-046

A return visit to this site will have two immediate objectives. First, the site will be examined to detect whether vandal activity has continued or accelerated over past levels. To that end, a map detailing location of artifacts and bone exposed along with areas of disturbance will be taken into the field to compare with current findings. Photographic reference points will be re-established, and photographs comparable to 1993 and 1994 will be taken. A detailed map locating the erosional face will be made to detect rates of erosion and vandalism for future monitoring visits.

Second, a series of test excavations will be made in the intertidal area where the SUNY-Binghampton field team documented peat deposits. That will allow re-testing for subsurface oil to check for migration of of the contaminant. The HNU-Hanby field test kit will be used to screen for the presence of petroleum hydrocarbons and provide some measure of concentrations. If petroleum hydrocarbons are present then the location will be recorded with reference to a permanent datum point. The location will then be re-visited during the next season to obtain proper samples to identify the source (see discussion under AFG-098 regarding sediment sample collection).

Port Dick Cabin Site, SEL-178

The Port Dick Cabin Site will be visited to test for vandalism and presence of petroleum hydrocarbon. A series of reference points were established during a visit in 1993 for the purpose of photo-documenting the site. Comparative photos will be taken and the site examined for vandal damage. Subsurface testing will be accomplished in the upper intertidal beach on the west side of the spit. Samples will also be taken in the area used for a heliport during cleanup activities. Samples from both areas will be tested for petroleum hydrocarbon using the HNU-Hanby field test kit.

Chief Cove Site, KOD-171

The US Fish and Wildlife Service archaeologist will visit the Chief Cove Site to document the present condition of the site as a check for continued vandalism. The agency plans to contact local set net fishermen and other local residents with cabins on private lands nearby to try to educate them about the need for protecting the site. They plan to attempt recruiting the local people to watch the site for them as protection against site vandalism.

5. Location

The sites will be located throughout the spill area. The sites in Prince William Sound are in the area around the north end of Knight Island. The outer Kenai Peninsula sites are in the Nuka Bay and Port Dick areas. In the Kodiak area, the sites to be investigated are on Shuyak Island and in the Spiridon Bay area.

6. Technical Support

Sediment sample processing and radiocarbon dating will be accomplished at commercial laboratories on an as needed basis.

7. Contracts:

No significant contracts are anticipated. Charter flights and boat charters will be arranged on an as needed basis. A curatorial agreement will be completed with an appropriate repository for any artifacts or samples collected. Until the size of field collections is determined, costs cannot be identified.

C. SCHEDULE:

Detailed Work Plans submitted.. March 1, 1995

Peer Review completed and Final approval.. May 1, 1995

Fieldwork.. May-August, 1995

Draft Report.. November 1, 1995

Final Report.. January 31, 1996

D. EXISTING AGENCY PROGRAM:

None of the participating agencies have existing programs which dovetail with this project. The Alaska Department of Natural Resources and Department of Interior agencies have staff archaeologists that perform fieldwork on a project funded basis. None of those agencies have current projects in the EVOS area other than the 95007-A. The US Forest Service has an approved project of collecting data from EVOS damaged sites in the Prince William Sound area, Project No. 95007-B. That project has objectives and location separate from Project No. 95007-A.

E. ENVIRONMENTAL COMPLIANCE, PERMITTING AND COORDINATION STATUS:

The U.S. Fish and Wildlife Service has agreed to file the necessary finding of no significant impact for project 95007-A. No other permits are necessary as the agency archaeologists will be working on land managed by their agencies.

F. PERFORMANCE MONITORING:

Each of the participating agencies will directly receive funding in support of their fieldwork and analysis. The agency fiscal support organizations will provide fiscal control within each agency. Judith E. Bittner, ADNR, is the overall designated project supervisor within ADNR which is the lead agency for the project. Douglas R. Reger will be the principal investigator within ADNR and will coordinate with principal investigators in other agencies to provide a compilation and analysis of individual agency reports. The contact person and project supervisor in the National Park Service is Dr. Ted Birkedal, Chief of the Division of Cultural Resources. The project supervisor for the USFWS will be Charles

Diters, Regional Archaeologist. The project supervisor and principal investigator for the US Forest Service will be Linda Finn Yarborough.

Reports will follow the final report format required by the Trustees but will additonally meet the professional standards for archaeological outlined under the Secretary of the Interior's Guidelines for Archaeology and Historic Preservation.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT:

Project 95007-A is a continuation of similar monitoring efforts funded under Project No. 94007. The project does not mesh well with other projects however information will be shared with local Native communities in accordance with the process of the Community Interaction/Use of Tradional Knowledge project, Project No. 95052.

H. PUBLIC PROCESS:

The goals of Project No. 95007-A were described in the 1995 workplan mailed to interested public individuals and organizations for comment. The goals were also described and discussed during the 1995 Exxon Valdez Restoration Workshop archaeology session held January 18, 1995. The goals were also discussed during the plenary session presentation by Judith E. Bittner, on January 19, 1995. The goals and findings of the project will also be a possible subject of discussion in local community meeting under the Community Interaction/Use of Traditional Knowledge project.

I. PERSONNEL QUALIFICATIONS:

Personnel used by the agencies for this project will meet the professional qualifications standards specified under the Secretary of the Interior's Guidelines for Archaeology and Historic Preservation. See attached qualifications descriptions.

J. BUDGET:

The detailed budget forms for Project No. 95007-A are attached.

ATTACHMENTS

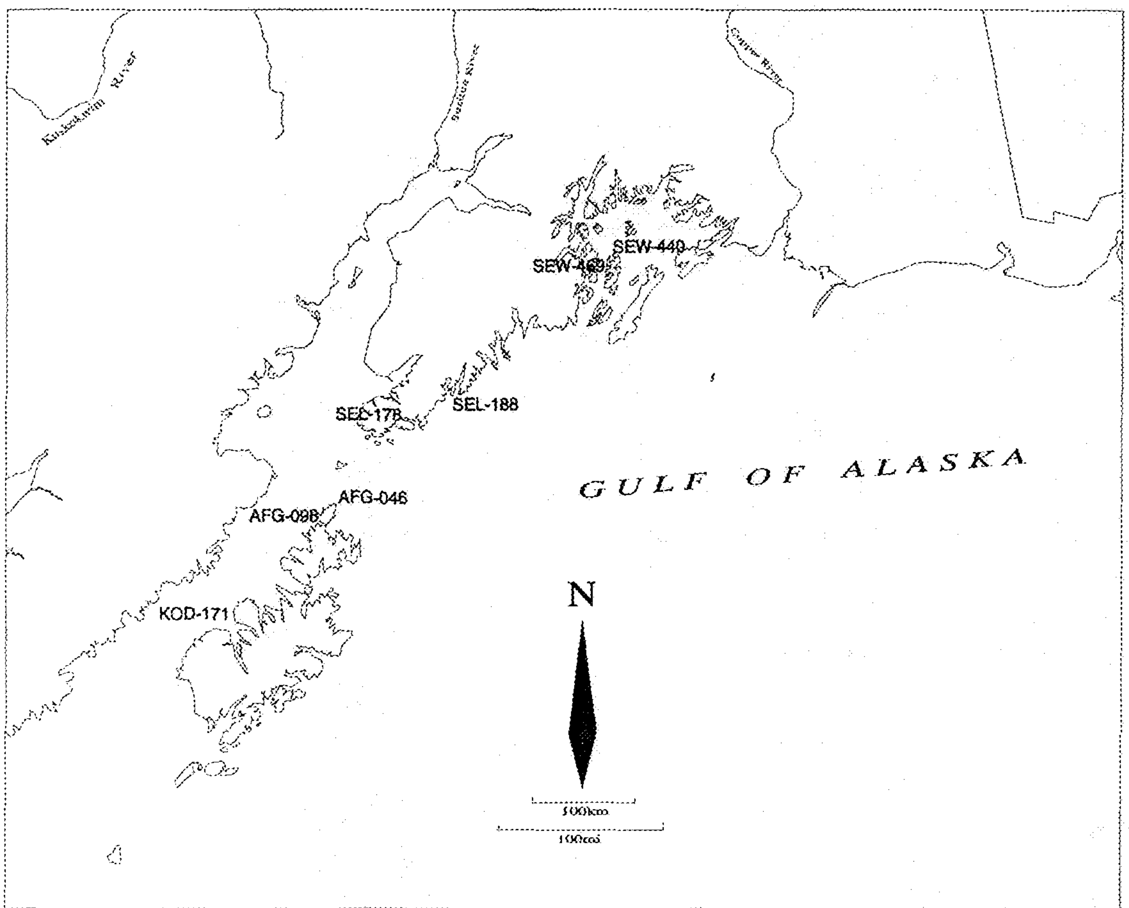

Figure 1 Archaeological Index Monitoring Sites, 1995.

PERSONNEL QUALIFICATIONS

Douglas R. Reger
Archaeologist II
Office of History and Archaeology
Alaska Division of Parks and Outdoor Recreation
3601 C Street, Suite 1278
Anchorage, AK 99510-7001

1981 PhD.- Anthropology, Washington State University

PROFESSIONAL EXPERIENCE:

1964	Field and museum assistant, Univ. of Alaska, Fairbanks
1965	Field assistant, Univ. of Alaska, Fairbanks
1966	Field assistant, Alaska Methodist Univ.
1966-67	Laboratory/research assistant, Alaska Methodist Univ.
1969	Short field surveys, Cordova and Katmai, AK
1970	Field School instructor, Alaska Methodist U., Tangle Lakes
1970-71	Excavated site 49KEN-029, near Kenai, AK
1971	Salvage archaeologist, Alyeska Pipeline Project
1971-74	Teaching assistant, Washington State Univ.
1972	Assistant Highways archaeologist, Washington State Univ.
1973	Project Archaeologist, Homer Society for Natural History
1974-75	Regional archaeologist, USDA Forest Service, Alaska Region
1975-82	Alaska State archaeologist, Alaska Division of Parks
1978-82	Deputy State Historic Preservation Officer, Alaska
1982-86	Archaeologist, Alaska Division of Geological and Geophysical Surveys
1986-	Archaeologist, Alaska Division of Parks and Outdoor Recreation

PUBLICATIONS/REPORTS:

1972	*An archaeological survey in the Utopia area, Alaska,* **Anthropological Papers of the University of Alaska**, 15(2), with R.D. Reger
1974	*Prehistory of the northern Kenai Peninsula,* In **Prehistory of the North American Subarctic: the Athapaskan Question**, edited by J.W. Helmer, S. VanDyke, and F.J. Kense, Univ. of Calgary, p. 16-21
1977	*An Eskimo Site near Kenai, Alaska,* **Anthropological Papers of the University of Alaska**, 18(2): 37-52
1983	*Norton: a changing southeastern boundary,* **Arctic Anthropology** 19(2): 93-99, with Joan B. Townsend
1987	*Archaeology of a late prehistoric subsistence locality, the Clam Gulch Site (49KEN-045),* **Anthropological Papers of the University of Alaska** 21:89-103
1992	Effect of crude oil contamination on some archaeological sites in the Gulf of Alaska, 1991 investigations. Office of History and Archaeology Report No. 30. Alaska Division of Parks and Outdoor Recreation, with J. David McMahan and C. E. Holmes

Terje (Ted) G. Birkedal
Chief, Division of Cutural Resources
Alaska Region, National Park Service
2525 Gambell Street
Anchorage, AK 99503

1968 B.A. - Anthropology, University of Colorado
1970 M.A. - University of Colorado
1976 PhD. - Anthropology, University of Colorado

Field Experience

1965--1992: Survey and excavation experience includes Western Slope of Rockies,
Colorado; High Grass Plains, Colorado; Colorado Plateau Area of American
Southwest; Delta Area of Louisiana; Southwestern Norway; Bella Bella Region of
Canadian Northwest Coast; Guam(Micronesia); and various locations in national
parks of Alaska. Includes both prehistoric and historical archaeological
experience.

Professional Experience

1971-75 Instructor, Department of Anthropology, University of Guam
1976-82 Archaeologist and later Branch Chief, Branch of Indian Archaeological
Assistance, Southwest Region, National Park Service, Santa Fe
1982-85 Chief, Branch of Archaeological Resource Management, Southwest Region, National Park Service, Santa Fe
1986-92 Regional Archaeologist, Alaska Region, National Park Service, Anchorage
1992-Present Chief, Division of Cultural Resources, Alaska Region, National Park Service, Anchorage

(Majority of Federal career has been spent on the conduct, management, and administration of large archaeological projects.)

Professional Affiliations

Society for American Archaeology
Alaska Anthropological Association
National Trust for Historic Places
Sigma xi: Scientific Honorary Society

Charles E. Diters
Regional Archaeologist/ Regional Historic Preservation Officer
Alaska Regional Office
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99503

1971	A.B. - Anthropology, Dartmouth College
1977	A.M. - Anthropology, Brown University

Field Experience

1970	Excavation, Healy Lake Village Site, Unversity of Alaska
1970	Archaeological Survey, Alyeska Pipeline Project, Unversity of Alaska
1971	Archaeological Survey, Aniginigurak and Mosquito Lake Sites, Unversity of Alaska
1977	Archaeological Survey, National Petroleum Reserve, Alaska, National Park Service
1978	Archaeological Survey, National Petroleum Reserve, Alaska, National Park Service
1978	Excavation, Russian Bishop's House, Sitka National Historic Park, Alaska, National Park Service
1980-82	Archaeological survey and project clearances, Chugach National Forest, Alaska
1982-Present	Archaeological survey and project clearances, National Wildlife Refuges throughout Alaska

Other Appointments

1989	Alaska State Museum Collections Advisory Committee, Vice-Chair, 1989-91, Chair, 1991
1991-92	Board of Directors, Alaska Anthropological Association
1991	Iditarod National Historic Trail Advisory Committee

Professional Affiliations

Society for American Archaeology
Alaska Anthroplogical Association
Arctic Institute of North America

Linda Finn Yarborough
Archaeologist
Chugach National Forest
U.S.D.A. Forest Service
3301 C Street, Suite 300
Anchorage, AK 99503-3998

1973	B.A., Anthropology, State University of New York
1974	M.A., Anthropology, University of Toronto
Present	PhD. Program, Anthropology, University of Wisconsin, Madison

Field Experience

Archaeological survey, testing, and excavations throughout many regions of Alaska

Specialty interest areas: Pacific Rim prehistory, prehistory of Prince William Sound and southcentral Alaska, faunal analysis

Current Position

1992-Present Assistant Forest Archaeologist and Cooperative Education Student, Chugach National Forest, Anchorage, Alaska

Publications / Reports

Numerous papers, reports, and articles. List available

DETAILED BUDGET FORMS

See attached Detailed Project Budget Forms 2A and 3A (Excel)
On File, Exxon Valdez Oil Spill Office

I :t Description: Archaeological Site Restoration - Index Site Mor g. This project continues tracking vandalism activities on sites i pil spill a...y concentrating monitor efforts on selected representative sites. ..cy archaeologists will visit key sites over a period of years until lem is no longer a danger and that aspect of restoration will be complete.

RECE... D OCT 31 1994 OHA

Budget Category:	1994 Project No. 94007 Authorized FFY 94	94 Report FFY 95	Index Site Monitoring FFY 95	Total FFY 95	FFY 96
Personnel	$258.5	$80.7	$77.7	$158.4	$96.5
Travel	$25.4	$1.5	$26.7	$28.2	$38.0
Contractual	$242.8	$90.1	$24.9	$115.0	$32.8
Commodities	$22.1	$1.0	$7.3	$8.3	$9.0
Equipment	$8.7	$0.0	$0.0	$0.0	$0.0
Capital Outlay	$0.0	$0.0	$0.0	$0.0	$0.0
Subtotal	$557.5	$173.3	$136.6	$309.9	$176.3
General Administration	$55.8	$18.4	$13.4	$31.8	$16.8
Project Total	$613.3	$191.7	$150.0	$341.7	$193.1
Full-time Equivalents (FTE)	0.0	1.2	1.1	2.2	0.0

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
See Individual 3A Forms for Personnel Details				
Personnel Total	0.0	$0.0	0.0	$0.0

Comment

FY 94 Closeout/Report - $191.7

Project Description: Closeout/Report writing funds will provide for report writing for two major components of 94007: 1. Site Specific Restoration will report on DNR sites and provide a compilation of data from all 4 participating agencies to generate a final project report. In support of this effort data analysis of samples currently being collected will continue and curation and repatriation of samples collected in 93 and 94 will take place as required by Federal and State law. 2. An Historic Preservation Protection Plan for Impacted Communities within the spill area will be completed. Travel associated with this project will take place in October due to weather constraints and needs of local individuals whose input is essential to project completion.

NEPA Cost: $0.0

*Oct 1, 1994 - Dec 31, 1994

**Jan 1, 1995 - Sep 30, 1995

06/01/94

1995 Page 1 of 26

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Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Agency: Alaska Department of Natural Resources

FORM 2A PROJECT DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Project Description: Archaeological Site Restoration - Index Site Monitoring. This project continues tracking vandalism activities on sites in the oil spill area by concentrating monitor efforts on selected representative sites. Agency archaeologists will vist key sites over a period of years until vandalism is no longer a danger and that aspect of restoration will be complete.

Budget Category:	1994 Project No. 94007 Authorized FFY 94	94 Report FFY 95	Index Site Monitoring FFY 95	Total FFY 95	FFY 96
Personnel	$166.1	$80.7	$50.0	$130.7	$60.0
Travel	$10.7	$1.5	$13.0	$14.5	$20.0
Contractual	$109.2	$90.1	$17.3	$107.4	$25.0
Commodities	$8.8	$1.0	$3.5	$4.5	$5.0
Equipment	$2.9	$0.0	$0.0	$0.0	
Capital Outlay	$0.0	$0.0	$0.0	$0.0	
Subtotal	$297.7	$173.3	$83.8	$257.1	$110.0
General Administration	$32.6	$18.4	$8.7	$27.1	$10.8
Project Total	$330.3	$191.7	$92.5	$284.2	$120.8
Full-time Equivalents (FTE)		1.2	0.7	1.8	

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
Rept Archaeologist II	7.0	$42.7		
Archaeologist I	6.0	$30.9		
Chief History & Archaeology	1.0	$7.1	1.0	$7.1
FY95 Project Manager			1.0	$6.5
Archaeologist II			5.0	$31.0
Archaeologist I			1.0	$5.4
Personnel Total	14.0	$80.7	8.0	$50.0

Comment

FY 94 Closeout/Report - $191.7

Project Description: Closeout/Report writing funds will provide for report writing for two major components of 94007: 1. Site Specific Restoration will report on DNR sites and provide a compilation of data from all 4 participating agencies to generate a final project report. In support of this effort data analysis of samples currently being collected will continue and curation and repatriation of samples collected in 93 and 94 will take place as required by Federal and State law. 2. An Historic Preservation Protection Plan for Impacted Communities within the spill area will be completed. Travel associated with this project will take place in October due to weather constraints and needs of local individuals whose input is essential to project completion.

NEPA Cost: $0.0

*Oct 1, 1994 - Dec 31, 1994

**Jan 1, 1995 - Sep 30, 1995

06/01/94

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Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Alaska Department of Natural Resources

FORM 3A SUB-PROJECT DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Travel:		Reprt 94	Monitoring
Rept 94	Field Travel 2 trips - Kodiak @ $500/trip airfare	$1.0	
Rept 94	Field Travel 2 trips - Homer @ $250.00/trip airfare	$0.5	
FY95	Field Travel 6 trips - Kodiak @ $500/trip airfare		$3.0
FY95	Field Travel 6 trips - Homer @ $250/trip airfare		$1.5
FY95	Field per diem @ $115.00/day x 30 days		$3.5
FY95	Curation Travel 2 trips - Fairbanks @ $500.00		$1.0
	Per diem Fairbanks $115.00/day x [illegible] days 6days		$0.7
FY95	Repatriation travel to Kodiak/Port Graham/Nanawalek		$1.0
FY95	Per diem @ $115.00/day x [illegible] days 5		$0.6
FY95	Air freight		$1.7
	Travel Total	$1.5	$13.0
Contractual:			
Rept 94	Report duplication	$2.5	
Rept 94	Curation - no set fee, dependent upon collection size which will be determined at end of field season.	$68.3	
Rept 94	Sediment Sample Processing - 17 samples @ $500/sample.	$8.5	
Rept 94	14C/Radiocarbon Dating - 20 samples @ $265.00/sample.	$5.3	
Rept 94	Film Processing	$1.5	
Rept 94	Photo printing	$1.5	
Rept 94	Repatriation - no set fee, dependant on number of remains and their location.	$2.5	
FY95	Report duplication		$1.5
FY95	Curation - no set fee, dependent upon collection size which will be determined at end of field season.		$5.0
FY95	Sediment Sample Processing - 3 samples @ $500/sample.		$1.5
FY95	14C/Radiocarbon Dating - 5 samples @ $250.00/each.		$1.3
FY95	Air Charter 12.7 hours @ $275.00/hour		$3.5
FY95	Boat Charter 2 days @ $1,000/day		$2.0
FY95	Film Processing ($1.0) and photoprinting ($1.5)		$2.5
	Contractual Total	$90.1	$17.3

06/01/94

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Alaska Department of Natural Resources

FORM 3B SUB-PROJECT DETAIL

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Commodities:		Reprt 94	Monitoring
Rept 94	Office Supplies (paper, printer cartridges, tape, staples, etc.)	$1.0	
FY95	Office Supplies (paper, printer cartridges, tape, staples, etc.)		$1.5
FY95	Field Supplies (bags, tags, pencils, trowels, etc.)		$2.0
	Commodities Total	$1.0	$3.5

Equipment:			
Rept			
Intrm	None		
	Equipment Total	$0.0	$0.0

06/01/94

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Alaska Department of Natural Resources

FORM 3B
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1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1994 - September 30, 1995

Project Description: Archaeological Site Restoration - Index Site Monitoring. This project continues tracking vandalism activities on sites in the oil spill area by concentrating monitor efforts on selected representative sites. Agency archaeologists will vist key sites over a period of years until vandalism is no longer a danger and that aspect of restoration will be complete.

Budget Category:	1994 Project No. . . . . Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment
Personnel	$20.7	$0.0	$9.5	$9.5	$14.0	
Travel	$10.2	$0.0	$5.3	$5.3	$8.0	
Contractual	$79.0	$0.0	$2.3	$2.3	$2.3	
Commodities	$2.5	$0.0	$1.9	$1.9	$2.0	
Equipment	$0.0	$0.0	$0.0	$0.0		
Capital Outlay	$0.0	$0.0	$0.0	$0.0		
Subtotal	$112.4	$0.0	$19.0	$19.0	$26.3	
General Administration	$8.6	$0.0	$1.6	$1.6	$2.3	
Project Total	$121.0	$0.0	$20.6	$20.6	$28.6	
Full-time Equivalents (FTE)		0.0	0.1	0.1		

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
Rept Intrm Archaeologist GS-13			0.7	$4.4
Archaeologist GS-11			1.0	$5.1
Personnel Total	0.0	$0.0	1.7	$9.5

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NEPA Cost: $0.0

*Oct 1, 1994 - Dec 31, 1994

**Jan 1, 1995 - Sep 30, 1995

06/01/94

1995

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Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Department of the Interior - National Park Service

FORM 3A SUB-PROJECT DETAIL

Travel:	Reprt/Intrm	Remaining
Rept		
Intrm Field Travel - Katmai Coast, 4 trips @ $1,000.00/trip		$4.0
Per diem 8 days @ $160.00/day		$1.3
Travel Total	$0.0	$5.3

Contractual:	Reprt/Intrm	Remaining
Rept		
Intrm Film Processing		$1.3
Photo printing		$1.0
Contractual Total	$0.0	$2.3

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Department ... Interior - National Park Service

FORM 3B SUB-PROJECT ...AIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Commodities:		Reprt/Intrm	Remaining
Rept			
Intrm	Office Supplies (printer cartridges, paper, pencils, etc.)		$1.0
	Field Supplies (bags, tags, tape, pencils, trowels)		$0.9
	Commodities Total	$0.0	$1.9

Equipment:			
Rept			
Intrm	None		
	Equipment Total	$0.0	$0.0

06/01/94

1995 Page 7 of 26

Printed: 10/28/94 3:55 PM

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Department of the Interior - National Park Service

FORM 3B SUB-PROJECT DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1994 - September 30, 1995

Project Description: Archaeological Site Restoration - Index Site Monitoring. This project continues tracking vandalism activities on sites in the oil spill area by concentrating monitor efforts on selected representative sites. Agency archaeologists will vist key sites over a period of years until vandalism is no longer a danger and that aspect of restoration will be complete.

Budget Category:	1994 Project No. . . . . Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment
Personnel	$15.5	$0.0	$8.3	$8.3	$8.5	
Travel	$2.5	$0.0	$2.5	$2.5	$2.5	
Contractual	$0.0	$0.0	$0.0	$0.0	$0.0	
Commodities	$0.0	$0.0	$0.0	$0.0	$0.0	
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0	
Capital Outlay	$0.0	$0.0	$0.0	$0.0	$0.0	
Subtotal	$18.0	$0.0	$10.8	$10.8	$11.0	
General Administration	$2.3	$0.0	$1.2	$1.2	$1.3	
Project Total	$20.3	$0.0	$12.0	$12.0	$12.3	
Full-time Equivalents (FTE)		0.0	0.1	0.1		

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
Rept Intrm Archaeologist GS-12			1.5	$8.3
Personnel Total	0.0	$0.0	1.5	$8.3

NEPA Cost: $0.0

*Oct 1, 1994 - Dec 31, 1994

**Jan 1, 1995 - Sep 30, 1995

06/01/94

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Department of the Interior - US&FWS

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Travel:		Reprt/Intrm	Remaining
Rept			
Intrm	Four Field Trips - Kodiak @ $325.00		$1.3
	8 days per diem @ $150.00/day		$1.2
	Travel Total	$0.0	$2.5

Contractual:			
Rept			
Intrm	None		
	Contractual Total	$0.0	$0.0

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Department of the Interior - USF&WS

FORM 3B SUB-PROJECT DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Commodities:	Reprt/Intrm	Remaining
Rept Intrm None		
Commodities Total	$0.0	$0.0

Equipment:	Reprt/Intrm	Remaining
Rept Intrm None		
Equipment Total	$0.0	$0.0

06/01/94

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Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: Department of the Interior - USF&WS

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1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Project Description: Archaeological Site Restoration - Index Site Monitoring. This project continues tracking vandalism activities on sites in the oil spill area by concentrating monitor efforts on selected representative sites. Agency archaeologists will visit key sites over a period of years until vandalism is no longer a danger and that aspect of restoration will be complete.

Budget Category:	1994 Project No. Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment
Personnel	$56.2	$0.0	$9.9	$9.9	$14.0	
Travel	$2.0	$0.0	$5.9	$5.9	$7.5	
Contractual	$54.6	$0.0	$5.3	$5.3	$5.5	
Commodities	$10.8	$0.0	$1.9	$1.9	$2.0	
Equipment	$5.8	$0.0	$0.0	$0.0	$0.0	
Capital Outlay	$0.0	$0.0	$0.0	$0.0	$0.0	
Subtotal	$129.4	$0.0	$23.0	$23.0	$29.0	
General Administration	$12.3	$0.0	$1.9	$1.9	$2.5	
Project Total	$141.7	$0.0	$24.9	$24.9	$31.5	
Full-time Equivalents (FTE)		0.0	0.1	0.1		

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
Rept Intrm GS-11 Archaeologist			1.5	$9.9
Personnel Total	0.0	$0.0	1.5	$9.9

NEPA Cost: $0.0
*Oct 1, 1994 - Dec 31, 1994
**Jan 1, 1995 - Sep 30, 1995

06/01/94

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Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: USDA Forest Service

FORM 3A SUB-PROJECT DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Travel:	Reprt/Intrm	Remaining
Rept		
Intrm Field Travel 6 trips Chenega/Tatitlek @ $350.00		$2.1
18 days per diem (3/trip) @ $150.00/day		$2.7
		$0.4
Field Travel 2 trips Cordova @ $200.00		$0.7
4.5 days per diem Cordova @ $160.00/day		
Travel Total	$0.0	$5.9

Contractual:		
Rept		
Intrm Air Charter 15 hours @ $275.00/hour		$4.1
Film Processing		$0.6
Photo Printing		$0.6
Contractual Total	$0.0	$5.3

06/01/94

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: USDA Forest Service

FORM 3B SUB-PROJECT D[illegible]IL

Commodities:	Reprt/Intrm	Remaining
Rept Intrm Office Supplies (printer cartridges, paper, pencils, etc.)		$1.0
Field Supplies (bags, tags, tape, pencils, trowels, etc.)		$0.9
Commodities Total	$0.0	$1.9

Equipment:	Reprt/Intrm	Remaining
Rept Intrm None		
Equipment Total	$0.0	$0.0

06/01/94

Project Number: 95007A
Project Title: Arch. Site Restoration - Index Site Monitoring
Sub-Project:
Agency: USDA Forest Service

FORM 3B SUB-PROJECT DETAIL

95007B

Rec'd 6/22/95

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

1. Project Title: Archaeological Site restoration

2. Project Number: 95007B

3. Lead Trustee Agency:U.S.D.A. Forest Service

4. Cooperating Agencies: U.S.D.A. Forest Service

5. Project Start-up/Completion Dates:
   Continuation of project begun in 1994, completion expected by January 30, 1996

6. Expected Project duration: 1.5 years

7. Cost of Project:
   FY95 (Jan. 1, 1995-Sept. 30, 1995, combined with monitoring): $102,000

8. Geographic Area: western Prince William Sound

9. Name/Signature of Project Leader(s): Linda Finn Yarborough, Dale Vinson

10. Name/Signature of lead agency Project Manager:
    Linda Finn Yarborough

Detailed Work Plan for Project Number 95007-B

A. Introduction

The objective of this proposal is to ameliorate the damage to the Louis Bay Lamp Site, SEW488, by implementing the restoration measures proposed by McAllister (1992). This restoration work has two parts: to test at the site and recover data allow which will in some measure compensate for data lost when the site was damaged during cleanup operations, and to stabilize the site against future erosion. Work to assess the extent of damage was done in 1991, and a limited amount of data collection restoration work was accomplished in 1994. It is expected that the additional field work still necessary to achieve the restoration goals defined for this project can be completed during the 1995 field season, and that report write-up will be completed during the following year.

B. Project Description

Site Damage

Discovered during the Exxon Valdez Oil Spill Cleanup Program, the Louis Bay Lamp Site, SEW488, was injured both by oiling and subsequent high pressure water treatment, and by unmonitored cleanup activities (Jesperson and Griffin 1992; McAllister 1992). Later assessment of the site also identified erosion as a concern which potentially would result in a significant loss of scientifically and culturally valuable information and items (Dekin 1993). McAllister (1992) proposed restoration measures which include a full field site damage assessment, and recovery, analysis and curation of artifacts.

Previous Research Results

Limited testing during damage assessment in 1991 indicated that the site has potential to reveal an extensive sequence of occupational layers interspersed by beach deposits (Dekin 1993). The expectation was that the site was about 2940 cubic meters in size. Proposal 94007 and 95007 proposed that the mitigative testing for this site consist of excavation of about 10 cubic meters along the eroding site edge, six 50 centimeter square tests to more accurately define site boundaries, and eight 1 meter squares in the main body of the site, for an estimated total of 20 cubic meters, less than .01% of the site.

During the 1994 field season, three 1 meter squares were excavated to approximately 1 meter depth, for a total of about 3 cubic meters. These tests did not reach the bottom of the cultural deposits, and it appears that the remains of occupation may well continue in parts of the site for as much as an additional meter. The data also indicate that at least a portion of the site contains the remains of a prehistoric structure of some sort, a rare occurrence in the Sound.

The second part of the restoration project, stabilization of eroding portions of the site as recognized in 1991, was not undertaken during 1994. Observations indicated that stabilization may not be necessary. This conclusion will be reassessed in 1995. Stabilization in the form of revegetation may be occurring naturally.

Current Restoration Goals

The data recovery goals for the 1995 field season are to determine the still unknown

No human remains are currently known from this site. However, if human skeletal remains are discovered during the course of the archaeological work, they will be examined on site to determine ethnic and cultural affiliation. If such remains are determined to be Alaskan Native, then work will proceed in consultation with the appropriate Native organization(s), as stipulated in NAGPRA.

Analysis and report writing will be accomplished by the GS-11, assisted by the GS-9 and the GS-5s. About 300 person days, which will continue into FY96, are estimated to be necessary for a full analysis. The resulting report will address the age, cultural affiliations, seasonality, and nature of the occupations.

This plan for restoration work at SEW488 should be considered tentative, and may require revision as field work progresses. This comes from the understanding that "an explicit research design is necessary at every stage of the sork, but the investigator must be willing to modify the design at any time in light of data being accumulated" (Watson et al. 1984:168)

C. Expected Results

The data recovery portion of this restoration project is expected to provide information which will apply to a number of research questions. These include the length of occupancy of the site, the seasonal nature of the various occupations, the types of activities that occurred at the site, the nature of biological and botanical resources available and used at the site, the technology needed and used to obtain resources, the types of structure(s) used at the site, rates of natural and cultural deposition and depths of the cultural deposits, and the possible relationship of site occupancy and abandonment to earthquakes, subsidence, and volcanic activity. Such information will allow greater understanding of the use of this site in particular, and the relationship of the inhabitants of this site to both close neighbors and more distant culture areas.

The importance of understanding the prehistoric structural remains at the site stems from the relative lack of knowledge of such remains in this part of the north Pacific rim. Structures in Kodiak and Cook Inlet sites are often indicated by surface depressions which are visible thousands of years after abandonment of the building. In contrast, surface features relating to prehistoric structural remains are rare in Prince William Sound. During her early 20th century surveys of the sound, De Laguna (1956:12, 19) found surface features at only two sites. She noted "several depressions, some opening into each other" on a gravel ridge at COR-081 in Constantine Harbor on Hinchenbrook Island, and two rows of shallow pits at COR-041 on Hawkins Island. Surface features are present at SEW-056, in Esther Passage, but are not necessarily related to the subsurface house remains which exist at that site (Yarborough and Yarborough 1991). COR-001 on Hawkins Island does not have discernible surface features, yet has subsurface evidence of two houses. One house was over 9 meters long, with at least four house posts (de Laguna 1956:43-44). The other, suggested to have been a small winter hut, was about 3 meters wide and 5.5 meters long. It contained a stone fireplace, a discernible mud or clay floor, and a wall marked by a line of four post holes (de Laguna 1956:46-48). The rock-lined post holes discovered at SEW-488 are similar to those found at SEW-056 and COR-001, and are unassociated with any surface features.

The additional faunal remains which are expected to be recovered areimportant in view of the current poor understanding of the prehistoric subsistence base and seasonal subsistence activities of the inhabitants of Prince William Sound. De Laguna (1956) and Birket-Smith (1953) made assumptions about prehistoric subsistence based on an incomplete analysis of the archaeological remains at COR-001, 20th century subsistence practices, and oral history. However, the results of studies of the fauna recovered from SEW-056 show significant differences in subsistence practices (Yarborough and Yarborough 1991). The potential of restoration work at SEW-488 to provide information on available resources, the technology involved with their use, and the ecosystem from which they were obtained is suggested by the recovery in 1994 of butter clam fragments, and harbor seal, fish, and bird bones. Faunal remains are also potential indicators of ecosystem and human cultural changes which may have occurred as a result of Neoglacial climatic change.

D. CONCLUSION

Restoration activities are scheduled to occur at SEW-488 for approximately 20 days, and will include data recovery through excavation of tests, and stabilization of erosion areas if necessary. The data collection portion of the project will provide information towards understanding the depth of the deposits, and the basic nature and condition of the site. It appears that some of the potentially recoverable information will address specific questions about the site, and its relation to other sites in the EVOS area. Analysis and report writing are expected to continue into 1996. The resulting report will be prepared according to the Secretary of Interior's Standards and Guidelines and the EVOS Trustee Council Procedures for the Preparation and Distribution of Final Reports. It will address analysis results and the future management of the site. The report which will be made available to the public will not include location descriptions of the site.

E. LITERATURE CITED:

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1980 Treatment of Archaeological Properties: A Handbook. Advisory Council on Historic Preservation, Washington, D.C.

Binford, Lewis R.
1972 *An Archeological Perspective.* Seminar Press, New York.

Birket-Smith, Kaj
1953 *The Chugach Eskimo.* Nationalmuseets Skrifter Ethnografisk Roekke, VI. Nationalmuseets Publikationsfond, København.

Dekin, Albert A., Jr.; Mark S. Cassell, James I. Ebert, Eileen Camilli, Janet M. Kerley, Michael R. Yarborough, Peter A. Stahl, and Beth L. Turcy
1993 *Exxon Valdez* Oil Spill Archaeological Damage Assessment Final Report. Submitted to U.S.D.A. Forest Service, Juneau, Alaska.

Jesperson, Michele and Kristen Griffin
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1956 Chugach Prehistory: The Archaeology of Prince William Sound, Alaska. *University of Washington Publications in Anthropology No. 13*, University of Washington, Seattle.

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Mobley, Charles M., James C. Haggarty, Charles J. Utermohle, Morley Eldridge, Richard E. Reanier, Aron Crowell, Bruce A. Ream, David R. Yesner, Jon M. Erlandson, and Paul E. Buck
1990 *The 1989 EXXON VALDEZ Cultural Resource Program.* Exxon Shipping Company and Exxon Company, USA (a Division of Exxon Corporation). Anchorage, Alaska.

Plog, Stephen, Fred Plog, and Walter Wait
1982 Decision Making in Modern Survey. *In Advances in Archaeological Method and Theory; Selections for Students from Volumes 1 through 4,* edited by Michael B. Schiffer, Pp. 608-645. Academic Press, New York.

Shott, Michael J.
1987 Feature Discovery and the Sampling Requirements of Archaeological Evaluations. *Journal of Field Archaeology* 14(3):359-371.

Watson, Patty Jo, Steven A, Leblanc, and Charles L. Redman
1984 *Archeological Explanation; The Scientific Method in Archeology.* Columbia University Press, New York.

Yarborough, Michael R. and Linda Finn Yarborough
1991 Uqciuvit: A Multicomponent Site in Northwestern Prince William Sound, Alaska. Final Site Report, submitted to U.S.D.A. Forest SErvice, Chugach National Forest, Anchorage.

Rest. work at SEW-488/Monitor Sites SEW-440 and SEW-469 (Revised)

Personnel	cost/pp	# of pp	# of people	$ Costs
	*(Available funds, 94007-B and 95007-A)			**102,000.00**
GS-11 Archaeologist	2,158.40	13.00	1	-28,059.20
Travel (outside fieldwork)				-1,235.00
Program Manager				-4,800.00
GS-11 Graphic artist	2,160.00	1.00	1	-2,160.00
Subtotal				**65,745.80**

Project Costs for temps, field and lab work				
Pre-field preparation				
GS-9 (80 hrs/pp)	1,336.00	4.00	1	5,344.00
GS-5 (80 hrs/pp)	882.40	1.00	5	4,412.00
Subtotal:				**9,756.00**
Field work and support:				
(GS-11: 24 days on-site supervision, included above)				
GS-9(80 hrs + 10 hrs OT)	1,655.68	2.00	1	3,311.36
GS-5(80 hrs + 10 hrs OT)	1,093.44	2.00	5	10,934.40
GS-5, map work	882.4	0.50	1	441.20
Dispatch				
Subtotal:				**14,686.96**
Other field expenses:				
Meals (6 people x 22 days x $10/day)				1,320.00
(2 people x 4 days x $10/day: LE and GS-5 eng. tech)				80.00
Supplies				750.00
Boat charter	1200/day	4 days		4,800.00
boat expenses (coordinate with LE)				500.00
Subtotal:				**7,450.00**
Lab analysis and write-up:	80 hrs/pp			
Materials analysis (C14, DNA, tephra, pollen, etc.)				9,500.00
GS-9	1,336.00	6.00	1	8,016.00
GS-5	882.40	3.00	5	13,236.00
GS-5, map work	882.4	1.00	1	882.40
GS-11 Graphic artist	2,160.00	1.00	1	2,160.00
Subtotal:				**33,794.40**
Miscellaneous				58.44
Project Costs Subtotal:				65,745.80

*(includes $79,032 from 94007-B and $23,000 from 95007-A as of 1/1/95)

95009D

RESEARCH PROPOSAL

TO: Mr. James Ayers, Executive Director
EVOS Trustees Council, Restoration Office
645 G Street, Anchorage Alaska 99501
(907) 276-8012, -7176 facsimile

FROM: Institute of Marine Science (IMS)
School of Fisheries and Ocean Sciences (SFOS)
University of Alaska Fairbanks (UAF)
Fairbanks, Alaska 99775-1080

and

Prince William Sound Science Center (Science Center)
P.O. Box 705, Cordova, Alaska 99574
(907) 424-5800, -5820 facsimile

TITLE: Survey of octopuses in the intertidal (original title: Survey and experimental enhancement of octopuses in the intertidal)

PRINCIPAL INVESTIGATORS:

Dr. David Scheel
Prince William Sound Science Center

Dr. Raymond Highsmith, Director
West Coast National Undersea Research Center
School of Fisheries & Ocean Sciences
210A O'Neill
University of Alaska, Fairbanks
Fairbanks, AK 99775-1080

NEW OR CONTINUING: New

PROPOSED STARTING DATE: January 1, 1995

PROPOSED DURATION: One to two years

AMOUNT REQUESTED: FY95 - $125,000

Dr. Raymond Highsmith, Director — Date
West Coast National Undersea Research Center
(907) 474-7836 or 474-5870

David Scheel — Date: 9 Dec 1994
PWS Science Center
(907) 424-5800

A.V. Tyler — Date
Associate Dean, SFOS
(907) 474-6732

Ted DeLaca — Date
Director, Office of Arctic Research

Joan Osterkamp — Date
Executive Officer, SFOS
(907) 474-7824

G.L. Thomas — Date: 9 Dec 1994
President, PWS Science Center
(907) 424-5800

EXXON VALDEZ TRUSTEE COUNCIL
FY 95 DETAILED PROJECT DESCRIPTION

A. COVER PAGE

1. Project title: Survey of octopuses in the intertidal (original title: Survey and experimental enhancement of octopuses in the intertidal)

2. Project ID number: 95009-D

3. Lead Trustee agency: US Forest Service; Pacific Northwest Research Station

4. Cooperating agencies: UAF

5. Project Start-up/Completion Dates: FY95: From allocation of funds to 30 Sept. 1995

6. Expected duration: One-two years

7. Cost of project: $125 K, 1st year

8. Geographic area: Prince William Sound

9. Project leader(s):

[signature]
Dr. David Scheel
PWS Science Center
P.O. Box 705
Cordova, AK 99574
Tel: (907) 424-5800
fax: (907) 424-5820

Dr. Raymond Highsmith, Director
West Coast National Undersea Research Center
School of Fisheries & Ocean Sciences
210A O'Neill
University of Alaska, Fairbanks
Fairbanks, AK 99775-7220
Tel: (907) 474-7836

10. Lead agency project manager:

Dave Gibbons
US Forest Service, Regional Office

95009-D Survey of octopuses in the intertidal

A. INTRODUCTION

Nearly 90% of the residents of Tatitlek, Chenega Bay, and Cordova used marine invertebrate subsistence resources prior to the *Exxon Valdez* oil spill (EVOS. Seitz, unpublished MS; data on individual species were not presented). Some portion of these marine invertebrates are octopus, traditionally harvested from their dens in the lower intertidal by subsistence users. Subsistence users in Prince William Sound have noted apparent declines in octopus and other species (e.g. gumboot chiton) since 1989. Although no connection to damage by oil has been established, the decline of these molluscs following EVOS further reduces subsistence resources available for residents in the EVOS affected area. For example, a recent Alaska Department of Fish & Game survey of subsistence harvests indicates that use of octopus has declined relative to pre-spill levels (Seitz, pers. comm). The funding authorized for this project will be used to consult with subsistence users, identify and survey harvest areas for octopus and (incidentally) gumboot chiton, and describe oiling history of survey sites.

The extent, severity, and cause of octopus declines are not known. Nor is it known if changes in the abundance of these molluscs will adversely affect the recovery of other intertidal species. Without information of this type, the course of recovery of octopus in the intertidal cannot be predicted, nor can this resource be managed effectively.

Species of octopus found in Alaska include: *Octopus dofleini*, *O. leioderma*, *O. rebescens*, and *Benthoctopus* spp. Of these, *O. dofleini*, the Giant Pacific octopus, is the most common in-shore (Hartwick, et.al 1978) and the only species that regularly exceeds 5 lbs in weight (Paust 1988). *O. dofleini* occupies waters from the intertidal to about 50 fathoms, and hence are relatively accessible to fisherman and subsistence harvesters. Although this survey will note the presence of all octopus species observed, we expect that *O. dofleini* will be the most frequently encountered octopus and we will conduct the study to focus on this species.

1 Natural history and ecology

Octopus (Cephalopoda) and gumboot chiton (Polyplacophora) are both molluscs. However, this phylogenetic similarity belies great differences in body form and ecology. The reasons for considering them jointly in a single survey are that, first, both are used as subsistence food in rural communities in the EVOS impacted area and are reported in apparent decline; second, both are found in the lower intertidal from where they are traditionally harvested; and third, inclusion of chiton in a visual survey design for intertidal octopus will likely not entail significant additional cost or effort. However, design of a SCUBA survey must be optimized for one species or the other. Given this necessity, we will focus on octopus.

1.1 The Giant Pacific octopus

Details of *Octopus dofleini* life history are drawn largely from Hartwick (1983) and Paust (1988), unless otherwise indicated. Spawning may occur throughout the year, although there is some evidence that a spawning peak occurs in winter in the northeastern Pacific and Paust (1988) states that the peak period for egg laying in Alaska is April-May. Evidence from

Japan also suggests an additional peak in May through July. Spawning takes place in relatively shallow waters (13-30 m). Females lay eggs on the inner side of a rocky den and may lay from 20,000 - 100,000 eggs over a period of several days. Eggs are tended, cleaned and aerated by females until they hatch. Incubation may take from 150 days to seven or more months, requiring 2300-2600 degree days.

Upon hatching, newly emerged larvae immediately swim toward the surface and begin a planktonic phase, estimated to last from 28 - 90 days. Planktonic *O. dofleini* have been reported along the Aleutian Islands (Kubodera 1991). Sampling extended from mid-April to mid-September, but Kubodera reports that *O. dofleini* were only recorded from June through August. Assuming these juveniles were 4-6 weeks old, they would have hatched from mid-April (for June juveniles) to mid-June (for August juveniles). Based on an average temperature for waters off the Aleutians, Kubodera (1991) estimates that spawning for these juveniles must have occurred in winter one and a half years earlier.

Little is known about early benthic life of octopus, but benthic *O. dofleini* between 3-5 g (50 mm total length) have been reported. *O. dofleini* grow quickly, and may reach 0.5 - 1 kg in weight by one year, and 10 kg after 3 years. Gonads mature at a weight of around 15 kg, with males maturing earlier (smaller) than females. Mature males have the third right arm modified with a long hectocotylus that may be up to one fifth the length of the arm. Mating apparently peaks in the fall, and divers from the northeast Pacific report seeing pairs and note an increase in aggression toward divers in the fall. Mating may occur at depths from 20 - 100 m, and takes several hours. Males may mate with more than one female and females receive fairly large spermatophores (up to 1 m long) during mating. Females appear to prefer larger males as mates. Eggs are laid some time after mating (one report of 42 days in captivity in Hartwick 1983).

O. dofleini females die shortly after brooding the eggs. Males may live a few months after mating. Maximum life span in the absence of reproduction is believed to be five years. Little is known about juvenile mortality in the planktonic stage, although post-hatching survival to 10 mm total length has been estimated at 1%. Predation is believed to be a major source of mortality for small to medium benthic octopus, while predation on very large individuals may be much rarer. Non-fatal predation is also reported from direct observations and the high frequency of mutilations or missing arms. Hartwick, et.al (1988) estimate the population frequency of mutilations or missing limbs as high as 25 - 60%, and note that octopus in deeper water show a much higher incidence of such injuries.

Dens are an important resource to octopus during all benthic life stages. They are used both as brooding chambers and as refuges from predators, including other octopus, various fish, sea otters, seal, and sea lions. Most dens are naturally occurring spaces under rocks or in crevices. Smaller octopus will often excavate a suitable cavity in sand or gravel (Hartwick, et al. 1978), and are more likely to use artificial lairs than are adults. Octopus will also occupy man-made objects as dens, and this behavior supports a viable fishery for *O. vulgaris* off Japan. Octopus are large and very mobile predators and return to their dens after foraging excursions. A den may be utilized by the same individual octopus for up to several weeks. Octopus do not appear to be territorial nor to have an established dominance hierarchy. Smaller individuals generally retreat when confronted with larger ones. Provision of supplemental dens successfully enhanced octopus density in some cases (*O. dofleini*, Mottet 1975 cited in Hartwick 1983; *O. joubini*, Mather 1982; *O. briareus*, Aronson 1986 in a salt-water lake), but not in others (Aronson 1986 in coastal waters).

Octopus utilize a wide variety of prey species, and estimates of diet breadth seem to increase with the length of the study (Mather & O'Dor 1991). They consume mostly crustaceans and molluscs, and apparently favor crab and shrimp. Bivalves, snails, fish and other octopus are also eaten. Octopus forage largely at night, and frequently return to a den to feed. Shell and other fragments are discarded in middens at the mouth of the den. For *O. vulgaris* in Bermuda, prey middens represent a biased sample of octopus diet, because prey species differ in the length of time their discarded remains were retained in a midden (Mather 1991).

Little is known about population variation in *O. dofleini*, although it seems generally accepted anecdotally that octopus populations are highly variable. Nevertheless, published data supporting this assertion are scarce. The perception that populations fluctuate may also reflect an onshore-offshore seasonal migration (Hartwick, et.al 1978), an annual cycle in apparent abundance as mature individuals die following reproduction (Hartwick, et al. 1978; for *O. briareus*, Aronson 1986), or the fact that octopus survey methods can produce variable results depending on local conditions (e.g. success of the pot fishery in Alaska, Paust 1988). Some octopus populations are reported as relatively stable (Hartwick 1983). This apparently occurs when populations are limited by den abundance, since the number of dens in an area is fixed. Populations limited by predation and recruitment may be more variable.

A seasonal onshore-offshore migration of *O. dofleini* seems well established, although its ecology and timing remain poorly described. Migrations may occur as individuals move from shallow to deep water at about one year of age, and onshore movements of mature individuals may be related to mating and spawning needs. Paust (1988) states that octopus may move offshore in the fall and return onshore in spring. Hartwick, et.al (1978) provide data on inshore and offshore surveys that suggest offshore movements in November and December and onshore movements in April through June. An inshore mating season and an offshore migration both in the Fall suggest that spawning in September to October may occur before offshore migration in November and December.

1.2 Gumboot chiton

This discussion of chiton biology is drawn largely from Buchsbaum, et al. (1987) and Yonge & Thompson (1976). Chiton are believed to represent a phylogenetically conservative mollusc. The class contains two orders. Lepidopleurida dwell offshore, while the gumboot chiton is of the order Chitonida, which are largely intertidal. The chiton's upper surface is protected by a set of eight overlapping shell plates. The underside is occupied primarily by a large fleshy foot. Protective behavior includes clamping tight to the substrate, or if removed from the substrate, curling up.

For some tropical species, spawning is synchronized to the phase of the moon. At spawning, eggs and sperm are shed into the water. An early free-swimming lifestage (the trochophore) lasts only a few hours or days, and is followed by metamorphosis to the adult form and settlement on the bottom.

Gumboot chiton are sluggish grazers on algaes along rocky marine habitats. They live in intertidal areas, are resistant to desiccation and feed largely at night and during high tides. When moved, they will orient away from light and downward until they reach shade or water. After each feeding foray, they return to shelter in rock hollows. Gumboot chiton are the largest chiton species and may reach a length of 35 cm.

2. Human use of octopus

Octopus is harvested in commercial fisheries in Japan, Korea, Spain, Portugal, Italy and Australia. *O. vulgaris* is a common target species in many of these fisheries. *O. dofleini* forms a significant part of the harvest by Japan and Korea (Paust 1988). Canada and Pacific northwest states in the U.S. have small or experimental octopus fisheries. World wide, octopus is used primarily for food, although the major market for octopus in the U.S. is as halibut bait.

Octopus and chiton are used as subsistence resources by residents of Prince William Sound communities. Surveys and interviews in Tatitlek and Chenega Bay conducted during the 1980s prior to EVOS indicate that between 50 and 90% of households use octopus as a subsistence resource, while 25 - 50% used gumboot or bidarki chiton. Use of octopus was greater in Tatitlek, where over 1600 lbs of octopus (approximately two octopus per person in the village) were reported harvested in the 1988-89 survey. However, use of chiton appeared larger in Chenega Bay (53% of households vs. approximately 25% in Tatitlek used chiton, Stratton & Chisum 1986, Stratton 1990). A similar survey in Cordova indicated that 1-5% of households use octopus or chiton. Most octopus in Cordova were harvested in conjunction with other subsistence or commercial fisheries, i.e. crab or shrimp pots (Stratton 1989).

Subsistence octopus are harvested in two fashions. First, octopus are taken incidentally on longline or in pots when fishing for halibut, cod, shrimp or other bottomfish. Second, octopus are harvested from the intertidal by searching under rocks at low tide, using a stick to poke into potential dens. When located, octopus are persuaded to leave their dens by using a hose to funnel a solution of bleach into the den.

Harvest is not particularly restricted in season. Chenega Bay harvested chiton primarily from February through April and octopus occasionally from February through August while Tatitlek harvested both these resources in all months of the year (Stratton & Chisom 1986, Stratton 1990).

3. Octopus survey methods

Three methods were considered for use in this survey. Lair pots were initially considered as a means of surveying using trap-grid methodologies. However, in Alaska, SCUBA sampling modeled after methods generally used for behavior observation and hand capture of octopus in the subtidal may be more effective. Finally, at minus tides, beach surveys were considered as an indication of the availability of octopus to intertidal harvesters, a technique used for subsistence harvest. Octopus are cryptic and mobile marine predators, and as such are difficult to survey accurately. Each of these three techniques has advantages and shortcomings.

Trapping grids are a common method of surveying small cryptic animals. Traps are usually baited to attract the animal, and the survey's reliability depends on the trap results providing an unbiased sample of the population (Seber 1982). As described above, the octopus' need for shelter supports a fishery using unbaited lair pots. A survey based on lair-pots is particularly attractive in this study because there is some evidence that artificial den placement may also provide a means to locally enhance octopus density under certain circumstances (see above). However, experiments with pot fisheries for octopus in Alaska have revealed that per-pot capture rates can be exceedingly low (Paust 1988), and that pot success is extremely variable depending upon the age of the octopus (Hartwick 1983), the distribution of food, and the availability of natural dens (Paust 1988). For these reasons, a pot-based survey of nearshore octopus may not be the best technique available.

SCUBA survey methods include fixed-width transect survey and area-search survey. Transect surveys provide greater statistical validity, precise estimates of the area surveyed and a careful, regulated sampling of the environment. While they are successful in enumerating abundant, stationary, and visible organisms (e.g. herring spawn, sea cucumbers) transect surveys are less successful when animals are scarce, mobile and cryptic. The linear miles of transect surveys necessary to locate and count reasonable numbers of octopus in Prince William Sound would likely be unmanageably large.

Area-search surveys focus intensively on the best microhabitats to find the target organism. As only prime microhabitats are searched, a greater area can be surveyed and the chances of locating organisms that occur at low densities are increased. Such surveys are non-random with respect to habitat type. Their design prevents precise calculations of the area surveyed and counts are not provided for sub-optimal habitats. However, area-search surveys are ideal for determining the peak local abundance of an animal.

Area-search SCUBA surveys may sample octopus at about the rate of lair-pot lines with less than 100 pots. SCUBA surveys on Titlow beach (Puget Sound) involving a "thorough" search of the study area by multiple divers (research dive classes) yielded on average less than eight octopus found per survey (unpublished data in Kyte 1994). Of 96 octopus tagged and released in the same study, only 11.5% were recaptured. In another study (Kyte 1979), divers on the Edmunds artificial reef (Puget Sound) located 50 individuals over 75 dives (<1 per survey). In both cases, a given individual may have been repeatedly captured. These results may be compared to lair-pot capture rates. At pot occupancy rates of 12-18% reported for Alaska (Paust 1988), from 50-66 lair-pots would be required to catch the same number of octopus per site as were found by divers in Kyte 1994. No comparison of these techniques at the same time, location and depth has been made however.

Surveying at minus-tides above the water line may be modeled after either transect or area-search methods. Foot surveys follow the methods of traditional subsistence harvest and hence reveal that portion of the population available for subsistence use by this method. While these areas might also be sampled at high tides during the dive surveys, this would not indicate to what extent the octopus remain in these areas as the tides retreat.

Several additional variables warrant concern when considering survey results. In particular, food and den availability, and predator abundance (especially of sea otters, which also compete with octopus for food) may have a large influence on local octopus density. The impact of residual EVOS oil on octopus habitat use in not known. These factors may in turn contribute to high seasonal or spatial variability in density.

4. Use of data on oiling history of survey sites

Oil spilled from the *Exxon Valdez* in 1989 was transported via surface currents to many areas in and beyond Prince William Sound. Such currents also carry nutrients, oxygen, plankton and larval organisms and distribute them unevenly to inter- and sub-tidal habitats. Substrates of oiled beaches can differ in their retention of oil. For these reasons, differences between oiled and unoiled sites, or between heavily and lightly oiled sites, may be only partly or not at all due to the effects of oil pollution. Thus, while it may be feasible to report on the oiling history of sites in this study, extrapolating this report to demonstrate an effect of oil in a particular area is questionable.

B. PROJECT DESCRIPTION

1. Resources and/or Associated Services:

Octopus and chiton are included as injured, non-recovering species under the general headings of Subtidal Organisms and Intertidal Organisms. Subsistence use of these resources in Prince William Sound has resulted in the knowledge that these species have declined in apparent abundance. The extent, severity, and cause of these declines are unknown. However, reduced octopus availability comprises a part of the decline in subsistence services.

This project proposes a survey of these species to assess their status. Information from this study will be conveyed to subsistence users.

2. Relation to Other Damage Assessment/Restoration Work:

Previous damage assessment work has not focused specifically on octopus, although other intertidal molluscs have received attention (e.g. mussel beds). Work on subsistence resources has focused on food safety issues, perceptions of food quality, and aiding the recovery of damaged resources. This project examines the availability of a subsistence resource.

Coordination with subsistence community outreach projects is underway through contact with Judy Bitner. Once project schedules are determined, we will take advantage of opportunities for cost sharing and joint community visits.

3. Objectives:

Objectives are related to field effort and will be completed by the Prince William Sound Science Center (D. Scheel, co-PI). Ray Highsmith, co-PI (UAF) will provide direction and consultation based on his experience with nearshore invertebrate communities. Time budgeted for Dr. Highsmith is for this consultation and to assist with data interpretation on completion of the survey and related analyses. Travel funds are budget for the co-PIs to meet.

3.1 Consult with residents of Tatitlek and Chenega Bay to identify sites historically harvested for octopus and chiton, and identify survey sites using criteria of 1) historical subsistence harvest, 2) presence of bathymetric or other features suggesting good octopus habitat, 3) availability of substrate and habitat data from past surveys, 4) known otter distribution;

3.2 At each survey site, determine for nearshore areas judged to be good microhabitat, 1) the local density of octopus, 2) the age and sex distribution of octopus; 3) the number of brooding female octopus, 4) the species composition of feeding litter, and 5) the density of octopus and chiton above the water line at minus tides;

3.3 Identify features of substrate, flora, and fauna typical of areas where octopus are captured. As far as possible using existing data, estimate the extent and location of good nearshore octopus habitat in Prince William Sound.

4. Methods:

Each of the possible methods for surveying octopus has limitations. For this reasons, a survey combining several techniques seems likely to yield the most complete information. We will conduct our survey in three stages. First, initial beach surveys will be conducted at historical harvest sites during minus tides. The initial surveys will serve to familiarize researchers with survey sites, and provide an early season indication of octopus density.

Second, SCUBA surveys will be conducted at three sites. An attempt will be made to find all octopus in shallow, nearshore water within the area by intensively searching areas likely to contain octopus (suitable microhabitats). We will note substrate, vegetation type and indicator organisms present in areas searched intensively. We are now exploring the possibility of chartering a vessel for this work that is also experienced at octopus pot fishing. Should such a vessel be available, we will use the crew's fishing experience to help identify good survey sites, and will conduct lair-pot surveys simultaneously with SCUBA surveys. In between dives, we will examine intertidal habitats by walking beaches during minus tides.

Third, analysis of the SCUBA data will provide estimates of octopus densities in the microhabitats searched. We will use existing sources of underwater habitat data (e.g. ADF&G herring spawn deposition dives, Coastal habitat project) to indicate the regional abundance of habitat features associated with the presence of octopus.

4.1 Identify survey sights - Paust (1988) stresses the importance of experience in successfully finding octopus. Three methods will be used here to identify appropriate survey sites. First, visits will be made to Tatitlek and Chenega. We will ask subsistence harvesters where they have caught octopus on minus tides in the past. If subsistence harvesters are willing, we will also conduct beach surveys with harvesters at minus tides. Second, we will seek the assistance of pot fisherman and divers with experience locating and harvesting octopus to identify site characteristics likely to indicate octopus. Third, preference will be given to those sites for which there is background data on habitat types or sea otter density.

4.2 Survey octopus - Three methods will be used to locate octopus (beach walks, SCUBA surveys, lair-pots). For each octopus found, we will record location, species, size, sex, den characteristics, and whether eggs are present Octopus brooding eggs will not be captured or handled. If feeding litter is present, we will sample this to identify prey. The substrate and characteristics of the den location will be recorded. While surveys are designed to find octopus, we will also collect data on the abundance of chiton, particularly when surveying intertidal habitats. For each chiton located, we will record location, species, size and substrate type.

At each site, we will look for octopus and chiton during beach walks in intertidal habitats. Areas will be searched by looking in likely octopus dens (e.g. crannies along the ocean side of big boulders) and searching for octopus sign (e.g. feeding litter). Nearshore shallow subtidal areas at each site will be surveyed using SCUBA dives. Pairs of divers will search using method similar to those described for intertidal surveys. We will record the extent and defining characteristics of each patch of habitat searched intensively. If we are able to charter an octopus pot-fishing vessel as support vessel for the SCUBA surveys, long-line pots will be deployed at survey sites and immediately offshore. When the bottom is not too deep, divers will survey the pot lines to record the habitat type in which each pot landed. Lair-pots will not be deployed if, in the opinion of the fishermen, dive survey sites are not suitable for pot fishing (e.g. too rocky).

4.3 Octopus habitat - For each octopus located on dive and intertidal surveys, a description of the habitat will be recorded including substrate type, slope, nearby vegetation or prominent invertebrate patches (e.g. mussel beds), and depth. The dive surveys will result only in an estimate of octopus density in areas judged *a priori* to be good habitat, as only these areas are to be searched intensively. *A priori* definitions of good habitat will be developed from expert consultation and descriptions available in the literature. These *a priori* indicators and characteristics of areas where octopus were located will be used to develop a description of the habitat sampled during dives. If available, existing data will then be used to estimate the regional abundance of this habitat.

To be suitable, data on habitat distribution must provide information on substrate and other bottom characteristics, be of similar scale to dive surveys, contain descriptors relevant to octopus distribution, be collected in an unbiased manner, and already be computerized. We are currently looking for existing data that meets these criteria. Candidates include data from ADF&G herring spawn deposition dives, the Coastal habitat project and from shoreline sensitivity indices. Analysis will also include reference to sea otter densities (J. Bodkin, NBS, has provided preliminary aerial survey data).

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5. Location:
This work will be conducted in Prince William Sound. Survey sites may be located in areas near the villages of Tatitlek and Chenega Bay, as well as in Orca Bay.

6. Technical Support:
In order to meet the stated goals, this project will need access to community knowledge of local harvest sites and site history. We will also seek the assistance of local fisherman and the expertise of experience octopus researchers.

Technical support for survey dives will be arranged with the help of R. Trani, Chenega Water Sports, and other sources. All dives will use the buddy-system and follow other PADI recommended safety practices. Only no-decompression dives will be conducted.

7. Contracts:
Funds are allocated for charter of a vessel to support survey dives, beach access and possibly pot surveys. This vessel will likely be a privately-owned fishing or research vessel from a community in the EVOS-impacted area. A smaller vessel may also be needed for a short period of time to conduct preliminary beach surveys. The contracts will be awarded to the most suitable bidders responding to advertisement.

A contract for expert consultation on octopus survey techniques is also needed to provide the best possible search efficiency during dive surveys. At least one such expert, M. Kyte, Pentec Environmental, has consulted on the design of this project and is interested in contracting for the remaining work.

Equipment rental and services may also be needed to support short term use of small equipment in the field. In particular, we anticipate renting dive equipment and a field computer, as well as contracting for diver training and equipment repair. Rental of dive equipment will likely be through R. Trani, Cordova Water Sports, who is providing negotiated rates in support of this project and is the only provider of such equipment in Cordova. Contracts will be awarded as needed to local businesses or individuals who can provide the necessary equipment or service at a reasonable rate.

C. SCHEDULE

The best tides for intertidal sampling (low tides below -3 ft.) occur in May, June and July. As much sampling as possible will be conducted in those periods.

Start up to 14 Mar	Arrange logistics (boats, equipment, contracts, etc.); expert consultation on octopus habitat characteristics; preliminary examination of available habitat databases; obtain NEPA categorical exclusion;
15 Mar - 20 Apr	Consult with subsistence harvesters to identify candidate survey sites; SCUBA review for divers (as needed);
14-20 May	Initial intertidal surveys;
5-16 Jun	Expert consultation on searching for octopus in conjunction with SCUBA surveys and second intertidal surveys;
Jul-Sept	Analysis of field data; analysis of pre-existing habitat data; report writing;
April 1996	Final report on 1995 work.

Alternative schedule in case of delays, weather, etc.

15 Mar - 20 May	Consult with subsistence harvesters to identify candidate survey sites; SCUBA review for divers (as needed);
29 May-2 Jun or 12-16 Jun	Initial intertidal surveys
26-30 Jun and 10-14 Jul	Expert consultation on searching for octopus in conjunction with SCUBA surveys and second intertidal surveys;
Aug-Sept	Analysis of field data; analysis of pre-existing habitat data; report writing;
April 1996	Final report on 1995 work

D. EXISTING AGENCY PROGRAM

Octopus fisheries are managed by Alaska Department of Fish & Game. No monitoring of octopus populations is regularly conducted by ADF&G although by-catch data from ground fisheries and spot shrimp surveys are available. These data indicate trap-robbing by octopus in deep waters and are likely not representative of octopus use of nearshore habitats.

E. ENVIRONMENTAL COMPLIANCE, PERMITTING AND COORDINATION STATUS

This project qualifies for a categorical exclusion under NEPA, which will be obtained before field work begins.

F. PERFORMANCE MONITORING

Dr. Gary Thomas, President of the PWS Science Center, oversees all scientific research conducted at the Science Center. Dr. David Scheel, PI for this project, will be in charge of all aspects of project field work, analysis and reporting. Project assistants will be assigned from existing Science Center employees with appropriate experience and skills or drawn from an applicant pool. In the event of Science Center personnel changes at the PI level, Dr. Gary Thomas will assume leadership of this project for the Science Center.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

This project, based at the Science Center will make every effort to share logistics, personnel and study sites with other restoration research, particularly projects with a base in Cordova (e.g. SEA research).

Air and boat transportation necessary to get researchers to remote locations in PWS will be shared with other restoration projects having similar needs. Cost sharing for transportation to and from field sites will likely occur with SEA projects and possibly with subsistence community outreach projects and has already been accounted for in the proposed budget.

H. PUBLIC PROCESS

This proposal is a direct result of public input received via the EVOS Trustee Research Priorities workshop (April 1994) and conversations about subsistence use of the nearshore with Jody Seitz, Martha Vlasoff, and Tatitlek residents. The project is designed to solicit and support collaboration with subsistence users and area fisherman to sample sites with a historical harvest of octopus. We welcome further public input, and anticipate opportunities to talk with members of the public at EVOS-sponsored workshops and community visits in Tatitlek and Chenega Bay.

I. PERSONNEL QUALIFICATIONS - Attached

J .BUDGET - Attached.

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Education

B.S. 1984, Renesselaer Polytechnic Institute; Troy, N.Y.
M.S. 1986, University of Minnesota, Minneapolis, M.N.
Ph.D. 1992, University of Minnesota, Minneapolis, M.N.

Professional Experience

1993 to present - Prince William Sound Science Center
(Associate Scientist)
1984 to present - University of Minnesota
(Graduate Student, Post-doctoral Associate, Consultant)
1992-1993 - University of Houston
(Post-doctoral Associate)
1985 to 1992 - Serengeti Wildlife Research Institute
(Visiting Scientist and Research Scientist)

Grants and Academic Honors

1994-95 - Co-author, Editor, Co-PI, Sound Ecosystem Assessment/Prince William Sound Systems Investigation, EVOS Trustees Fund (about $4,500,000/year)
1984, 1985, 1989 - Graduate School Fellowship, University of Minnesota
1985, 1986 - Dayton Natural History Fellowship, Bell Museum of Natural History
1984 cum laude graduate, Renesselaer Polytechnic Institute

Related or similar activities

Involved with the Sound Ecosystem Assessment (SEA) research plan for Prince William Sound since September 1993 and contributed to research design and planning. Project PI for one SEA project in 1994 and one in 1995. Project co-PI for two other EVOS Trustee Council restoration research projects in 1995.

1995 EXXON VALDEZ TRUST[illegible] [illegible]UNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Project Description: Survey of octopuses in intertidal habitats. This project will survey intertidal octopus and gumboot chiton densities at several sites.

Budget for Pacific Northwest Research Station., Department of Agriculture, US Forest Service.

Budget Category:	1994 Project No. . . . . Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment
						1995 Report costs, FY96
Personnel	$0.0	$0.0	$0.0	$0.0	$0.0	$27.7 Personnel
Travel	$0.0	$0.0	$0.0	$0.0	$0.0	$1.1 Travel
Contractual	$0.0	$0.0	$118.1	$118.1	$96.2	$0.6 Contractual
Commodities	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0 Commodities
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0 Equipment
Capital Outlay	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0 Capital Outlay
Subtotal	$0.0	$0.0	$118.1	$118.1	$96.2	$29.4 Subtotal
General Administration	$0.0	$0.0	$6.9	$6.9	$6.7	$5.9 GA
Project Total	$0.0	$0.0	$125.0	$125.0	$103.0	$35.2 Total
Full-time Equivalents (FT	0.0	0.0	0.7	0.7	0.0	

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
See Individual 3A Forms for Personnel Details				
Personnel Total	0.0	$0.0	0.0	$0.0

NEPA Cost: $0.0

*Oct 1, 1994 - Dec 31, 1994

**Jan 1, 1995 - Sep 30, 1995

06/01/94

Project Number: 95009-D
Project Title: Survey of octopuses in intertidal habitats
Agency: PNW Research, Dept. of Agriculture, USFS

FORM 2A PROJECT DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1994 - September 30, 1995

Project Description: Survey of octopuses in intertidal habitats. This project will survey intertidal octopus and gumboot chiton densities at several sites.

Budget for Prince William Sound Science Center.

Budget Category:	1994 Project No. Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment
						95 Report costs, FFY96
Personnel		$0.0	$38.8	$38.8	$38.8	$27.7 Personnel
Travel		$0.0	$8.1	$8.1	$7.3	$1.1 Travel
Contractual		$0.0	$41.5	$41.5	$20.1	$0.6 Contractual
Commodities		$0.0	$2.1	$2.1	$5.3	$0.0 Commodities
Equipment		$0.0	$0.0	$0.0	$0.0	$0.0 Equipment
Capital Outlay		$0.0	$0.0	$0.0	$0.0	$0.0 Capital Outlay
Subtotal	$0.0	$0.0	$90.5	$90.5	$71.5	$29.4 Subtotal
General Administration		$0.0	$18.1	$18.1	$14.3	$5.9 GA
Project Total	$0.0	$0.0	$108.6	$108.6	$85.7	$35.2 Total
Full-time Equivalents (FTE)		0.0	0.6	0.6		

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description		Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost	Comment
D. Scheel, co-PI				3.0	$19.7	
field assistants				0.9	$7.2	
project assistant				3.0	$11.9	
D. Scheel, co-PI	Rept (FY96)					$19.7 Rept FY96 3.0 mos
Project assistant	Rept (FY96)					$7.9 Rept FY96 2.0 mos
						NEPA Cost: $0.0
						*Oct 1, 1994 - Dec 31, 1994
Personnel Total		0.0	$0.0	6.9	$38.8	**Jan 1, 1995 - Sep 30, 1995

06/01/94

Project Number: 95009-D

Project Title: Survey of octopus

Agency: PWS Science Center

FORM 3A SUB-PROJECT DETAIL

Travel:					Rept/Intrm	Remaining
Cdv-PWS, travel to study sites & community visits	8 flights	$360	each			$2.9
per diem	12 days	$115	each			$1.4
Cdv-Anc, EVOS workshops, oiled site history	2 rt	$224	each			$0.4
per diem	8 days	$170	each			$1.4
Cdv-Fbks, collaboration between UAF & PWSSC	1 rt	$456	each			$0.5
per diem	5 days	$150	each			$0.8
RT to Natl mtg @ 1K + 5 d per diem @$150	0.5 trip	$1,750	each			$0.9
Rept FY96						
Cdv-Anc, EVOS workshops, oiled site history	1 rt	$224	each =	$0.2		
per diem	5 days	$170	each =	$0.9		
	Rept FY96 total travel			$1.1		
				Travel Total	$0.0	$8.1

Contractual:						
telephone, fax, e-mail						$0.8
postage, shipping, etc						$0.7
copying, etc						$0.7
financial audit	1 annual	$1,500	each			$1.5
data logging & software lease	6 month	$250	each			$1.5
SCUBA training & safety	1 course	$250	each			$0.3
consultant - survey, training (time & expenses)	8 days					$14.4
vessel charter, dive surveys	10 days	$1,300	each			$13.0
dive gear rental	20 person-day	$55	each			$1.1
driver propulsion vehicle	2 units					$2.0
vessel charter, early beach survey	8 days	$700	each			$5.6
Rept FY96						
report printing, publication costs				$0.6		
	Rept FY96 total contractual =			$0.6		
				Contractual Total	$0.0	$41.5

Project Number: 95009-D
Project Title: Survey of octopus
Agency: PWS Science Center

FORM 3B
SUB-
PROJECT
DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1994 - September 30, 1995

Commodities:			Reprt/Intrm	Remaining
foul weather & safety gear	2 people	$400 each		$0.8
field supplies, survey tools, field notebooks, reference materials, etc				$0.8
office & computer supplies				$0.5
		Commodities Total	$0.0	$2.1

Equipment:		
Equipment Total	$0.0	$0.0

06/01/94

1995

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Prepared by DLS, PWSSC

Project Number: 95009-D
Project Title: Survey of octopus
Agency: PWS Science Center

FORM 3B SUB-PROJECT DETAIL

1995 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1994 - September 30, 1995

Travel:			Reprt/Intrm	Remaining
Fbks-Cdv, collaboration between UAF & PWSSC	1 rt	$456		$0.5
per diem	4 day	$140		$0.6
Fbks-Anc, to attend planning workshops	1 rt	$300		$0.3
per diem	0 day	$170		$0.0
		Travel Total	$0.0	$1.3

Contractual:		
Contractual Total	$0.0	$0.0

06/01/94

1995

Page 6 of 7

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Prepared by DLS, PWSSC

Project Number: 95009-D
Project Title: Survey of octopus
Agency: University of Alaska Fairbanks

FORM 3B SUB-PROJECT DETAIL

Project Description: Survey of octopuses in intertidal habitats. This project will survey intertidal octopus and gumboot chiton densities at several sites.

Budget for University Alaska Fairbanks.

Budget Category:	1994 Project No. . . . . Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment
Personnel		$0.0	$6.6	$6.6	$6.6	
Travel		$0.0	$1.3	$1.3	$2.2	
Contractual		$0.0	$0.0	$0.0	$0.0	
Commodities		$0.0	$0.0	$0.0	$0.0	
Equipment		$0.0	$0.0	$0.0	$0.0	
Capital Outlay		$0.0	$0.0	$0.0	$0.0	
Subtotal	$0.0	$0.0	$7.9	$7.9	$8.7	
General Administration		$0.0	$1.6	$1.6	$1.7	
Project Total	$0.0	$0.0	$9.5	$9.5	$10.5	
Full-time Equivalents (FTE)		0.0	0.1	0.1		

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
Ray Highsmith, co-PI			1.0	$6.6
Personnel Total	0.0	$0.0	1.0	$6.6

NEPA Cost: $0.0
*Oct 1, 1994 - Dec 31, 1994
**Jan 1, 1995 - Sep 30, 1995

Project Number: 95009-D
Project Title: Survey of octopus
Agency: University of Alaska Fairbanks

FORM 3A SUB-PROJECT DETAIL

Commodities:	Reprt/Intrm	Remaining
Commodities Total	$0.0	$0.0
Equipment:		
Equipment Total	$0.0	$0.0

Project Number: 95009-D

Project Title: Survey of octopus

Agency: University of Alaska Fairbanks

FORM 3B SUB-PROJECT DETAIL

Exxon Valdez Trustee Council project 95009-D: Survey of octopuses
Response to reviewer comments.

Dive personnel and observer variability: As currently designed, surveys will be conducted by a single dive team. This team will be trained in octopus surveying in Prince William Sound at the first of the three proposed dive sites (Michael Kyte has offered to provide training). Observer variability will be minimized by having the same personnel conduct all surveys at all sites. During the first survey, when divers will be learning to spot octopus and chitons, they will be accompanied by a training diver experienced at finding octopus.

As co-PI, David Scheel will be conducting survey dives as one member of the team. David is a PADI-certified open water diver. Included in the budget is support for David to complete training to the level of advanced open water diver and become familiar with dry suit diving in Prince William Sound. Courses and training dives are scheduled for March - May, prior to training for SCUBA surveys of octopus. A second diver will be hired to accompany the PI on survey dives. For safety reasons, this person must be an experienced diver in the Sound. The second diver has not yet been identified.

Handling of octopus - This project does not propose the lethal sampling of octopus. If opportunity permits, some tissue samples may be collected from subsistence harvest for eventual stable isotope analysis. Although the DPD mentioned determining the "age and sex distribution" (page 9) of the population, this phrase was an unfortunate oversight and should have read "the size and sex distribution". The measurements taken on each octopus are detailed on page 10, section 4.2. In addition to those mentioned, we will also record scars and missing or damaged arms. Training in handling and releasing octopus will be provided by an experienced octopus handler (likely Michael Kyte) during work at the first dive site. Michael has also expressed an interest in further supporting the project by donating additional time to participate in the surveys at the other sites.

Native and subsistence user involvement - This proposal was initiated because of concerns about the availability of octopus to a subsistence harvest. These concerns were brought before both PIs by Martha Vlassof at a meeting to discuss research in nearshore habitats. One PI (Scheel) visited Tatitlek in the process of developing the DPD to discuss with residents the design and sampling locations for the research. Upon availability of funds, visits to Chenega and Tatitlek are planned. At each village, Scheel will provide a public presentation about the project, and request input regarding project techniques, sampling sites and goals. Feedback from this interaction will be used to improve the design of the study and to encourage participation in the study. Advertisements for all hirings for this project (diver, research assistant, boat) will be made in Tatitlek, Chenega, Valdez and Cordova, including at Native Corporations and Village Councils. Experience with native subsistence harvest of octopus is a strongly preferred qualification for all hirings, as this experience will be invaluable to the project. Jody Seitz, formerly of the Subsistence Division ADF&G, is assisting the PIs in including as much involvement with resource users as possible. We have also contacted Rita Maraglia to begin coordination of this work with subsistence community outreach, and also expect to coordinate our visits with the Science Center's outreach education program. We would like to conduct follow-up visits to Tatitlek and Chenega to report on the results of this survey in the winter of 1995-96, if support is available. Additional suggestions are welcome.

Sampling design The most difficult comment to address is that the study as proposed lacks rigor to demonstrate or disprove an effect of EVOS oil and of sea otter predation on octopus. Concerns were raised following the initial proposal that due to our incomplete knowledge of octopus in the area, an enhancement study was unwarranted; as was a reliance on a single-method survey design. In response, the study was revised to provide a more exploratory design utilizing three different sampling techniques. Two additional tasks for this project have now been suggested: first, that we determine whether octopus are damaged by oil; and second, that we determine if predation by marine mammals (sea otters, harbor seals) is depressing octopus populations. This array of tasks is too great for a relatively modest start-up project, but should be manageable over several years if results from this year indicate that further work is feasible and warranted. We anticipate that the work proposed for 1995 will suggest answers to both of these questions and provide important additional information for continued work designed to answer these questions more definitely.

Proper design and completion of research to address these questions depends on establishing that octopus are in PWS in sufficient numbers to allow research, on locating suitable study sites, and on establishing an adequate sampling protocol. Existing information on octopus does not allow us to establish any of these at this time. The work proposed for 1995 can realistically achieve these goals. First, the project will determine whether octopus in Prince William Sound are available in sufficient numbers to allow further research, and should identify study areas where octopus are accessible. Second, the project can compare survey methods to provide any future studies with information on which technique is best suited to survey needs and available resources. Third, results should indicate whether a damage assessment or predation studies are desirable and feasible. For example, we should be able to determine whether residual oil occurs in or near octopus dens, and whether grossly oiled areas are avoided by octopus.

A series of testable predictions can be made given the hypothesis that continued effects of oil have depressed octopus populations. This hypothesis predicts that (1) oil should be present in likely octopus habitat on the west side of the Sound; (2) that octopus avoid oiled substrates or, if they use oiled substrates, that octopus in oiled areas show effects (e.g., smaller size, lesions or disease, lower density); (3) that octopus prey is less available and/or less suitable in oiled areas; and (4) that oiled substrates are extensive in likely octopus habitat.

Similarly, predictions follow from the hypothesis that predation by marine mammals is depressing octopus populations. From this, we predict (1) that octopus density and sea otter density are negatively correlated; and (2) that the frequency of injured octopus (scars, missing or damaged arms) is positively correlated with sea otter density.

Finally, a third hypothesis should be considered: that octopus have been overharvested at subsistence harvest sites. From this, we predict that octopus density and harvest intensity are negatively correlated. Historic harvest intensity at each site may be difficult to determine, but possible indicators of intensity could include time since last regular harvest, distance to village, and frequency and size of harvest (if this information is available). Additional hypotheses are possible (the usual list of disease, food availability, climate, etc.), but at this stage seem less likely and less amenable to study than these three.

Preliminary tests of these predictions with data collected in 1995 can be used to assess need and direction for further work. As these predictions involve the density of predators and amounts of oil remaining in octopus habitat, we will need to assess these factors. We propose to utilize sea otter data already being collected by NBS (pers. comm., J. Bodkin) to estimate relative otter density between sites. This data set indicates that our proposed eastern sampling site (Orca Bay) has a sea otter density approximately twice that of sites near Tatitlek or Chenega Bay, thereby providing a large contrast between sampling areas. When sampling the environment at each patch and each octopus location (DPD, pg 10, section 4.2), we will dig into the sediment and record the presence of any visible evidence of surface or subsurface oil. This information along with available records of oiling history at each site should allow an initial assessment of whether oil persists in the environment, whether continued exposure to oil can be documented, and what extent of exposure is likely. Quantitative, chemical assessment of sediment hydrocarbons in each sample is not proposed for 1995 due to cost. If considered essential during the first year of study, this might be included if further funds were allowed to cover the costs of sample handling time, processing and analysis, and reporting.

Our sampling window (low tides below -3 ft. in May-July) and the number of sites we can be confident of surveying in that time (3-4) are relatively restricted. This places constraints on the statistical power of our data analysis. However, we hope to offset this somewhat by sub-sampling habitat patches at each site. Patches at a single site will provide repeated measures of octopus density in areas with similar characteristics, as well as (perhaps) similar oiling and weathering histories. Sampling of many such patches within each dive site will allow a statistical comparison of octopus density between sites (high vs. low otter density and oiled vs. unoiled) that would not otherwise be possible. However, we cannot at this time predict either the number of separate patches that will occur at each site nor the speed with which we can sample each patch.

The results of the 1995 study should be used to gauge the likely success of further work, and to design efficiently studies for the future. Understanding what limits octopus populations will require a mechanistic, population-level model of their biology that accounts for production, recruitment and mortality. This project will begin to assess what might influence production and mortality. (Octopus settle on the bottom following a planktonic stage. Hence, understanding recruitment would require dramatically different study techniques.)

In the future, once it is determined that oil persists in the habitat, and octopus either avoid it or continue to be exposed to it, the effects of oil could be quantified in a study using a modified BACI design. Octopus outside of oiled areas may not have been exposed to oil (providing a possible 'control') and may relocate into oiled areas (providing 'before' and 'after' exposure conditions). A BACI study would probably require tagging of octopus and several visits per season to a sampling site. Hydrocarbon analysis of tissue, prey, and sediments would likely be proposed.

If predation appears important, the major predators on benthic (as opposed to planktonic) life stages would have to be identified, with the initial hypothesis that sea otters and seals are important predators. Isotope and fatty acid analysis would be proposed to help quantify the amount of octopus eaten by important predators. Predator and octopus distributions would need to be understood in order to relate predator and prey seasonally and geographically.

95012

95 012
(RFP Portion)

P.I.
SCHEEL

COMPREHENSIVE KILLER WHALE INVESTIGATION IN PRINCE WILLIAM SOUND, ALASKA

A PROPOSAL FROM THE NORTH GULF OCEANIC SOCIETY (NGOS)
Response to solicitation No: 52 ABNF-5-00090

Technical Proposal

Detailed Work Plan

Part 1.

Objectives 1 and 2

Methods proposed to obtain photographic data necessary to meet objectives #1 and #2 will be similar to those used by the North Gulf Oceanic Society to monitor killer whales in Prince William Sound for the past ten consecutive years. The overall goal is the photoidentification of each individual in each pod/group, particularly AB pod. This level of resolution is necessary to accurately assess demographics and population dynamics important in meeting the objectives of the proposed project.

Thus, it is important that researchers maximize the time actually spent with killer whales (particularly AB pod) to assure thorough identification of individuals. Although a general transect line will be followed that includes upper and lower Montague Strait and lower Knight Island Passage, searches for whales will not be made on random transects, but transects based on current and historical sighting information. In addition whales will be located by listening for killer whale calls with a directional hydrophone, or by responding to VHF radio calls from other vessels reporting sightings of whales. Regular requests for recent killer whale sightings will be made on hailing Channel 16 VHF.

A vessel log and chart of the vessel track will kept for each day the research vessels operate. The elapsed time and distance traveled will be recorded and vessel track plotted. Record will be made of the time and location of all whale sightings and the weather and sea state noted at regular intervals (see attached data sheets).

Specifics of each encounter with killer whales will be recorded. Data recorded will include date, time, duration, and location of the encounter. Rolls of film exposed and the estimated number of whales photographed will also be recorded. A chart of the whales' trackline during the encounter will be completed and the distance traveled by the vessel with the whales calculated. General behavior of the whales (i.e. feeding, resting, traveling, socializing, milling) will be recorded. The current data sheet used for collection of this data is included (see attached), however, it will be modified before the field season to facilitate the more accurate collection of data for Part 2 Section 1 of this proposal.

Photographs for individual identification will be taken of the port side of each whale showing details of the dorsal fin and white saddle patch. Photographs will be taken at no less than 1/1000 sec using Ilford HP5, a high speed black and white film, exposed at 1600 ASA. A Nikon 8008 autofocus camera with internal motor drive and a 300 mm f4.5 autofocus lens was used. When whales are encountered, researchers will systematically move from one subgroup (or individual) to the next keeping track of the whales photographed. If possible, individual whales will be photographed several times during each encounter to insure an adequate identification photograph. Whales will be followed until all whales are photographed or until weather and/or darkness makes photography impractical.

All photographic negatives will be examined under a Wild M5 stereomicroscope at 9.6 power. Identifiable individuals in each frame will be recorded. When identifications are not certain, they will not be included in the analysis. Unusual wounds or other injuries will be noted. Photographic negatives will be analyzed using a photographic database that spans ten years. Identities of each whale that appears in every frame of usable film will be recorded and stored in VAX computer system. Final analysis and assessment will follow Matkin et al. (1994). (Attached)

A substantial photographic database was collected from 1992, 1993 and 1994 by NGOS with private money. These photographs have not been completely analyzed. As part of this project, these photographic negatives will also be examined frame by frame and the whale identities computerized. This will be data will be important in the overall assessment of population dynamics within pods and within the population. It is important that changes within AB pod in 1995 be placed within this larger context. This multiyear analysis will also provide a more detailed account of the status of the AT1 transient group.

The primary vessel used to secure identification photographs will be a 27' deisel inboard/outboard powered vessel that can sleep two individuals (<u>Whale 2</u>). With sleeping accomodations and large fuel capacity, the Whale 2 will not need to return to camp or to Chenega Village (fuel storage) each night which greatly increases available time searching for or photographing whales. The vessel will operate 7 days a week (as weather permits) for a total of at least 70 hours per week. Although this vessel will primarily collect photoidentification data, it will secondarily collect feeding habit observations/samples and biopsy samples (for Part 2 of the project). The operator of this vessel, Eva Saulitis, has eight years experience in the Sound conducting photoidentification of killer whales and humpback whales and collecting food habit data. This vessel will operate a total of 68 days, from late June through early September. From historical data these dates are judged to be to be the most likely time to encounter AB pod (target pod) as well as many of the other resident pods that use the Sound. Photographic data will also be collected secondarily from the 43' R.V. Lucky Star and its associated skiff (32 days in the field) when it does not interfere with the primary goal of this vessel (providing feeding habit observations/samples and biopsy samples for Part 2 of this project.) The Lucky Star will also deliver fuel to designated locations and provide other logistical support for the operation of the Whale 2.

The North Gulf Oceanic Society currently owns or has lease priorities on both vessels and skiffs to be used in this project. All cameras and photographic equipment will be supplied by the NGOS. Directional hydrophones, binoculars, all logs and data sheets will be provided by the NGOS.

The final report for Part 1 of this project will include a detailed accounting of changes in AB pod and the calculation of recruitment rates and mortality rates for AB pod and the other major resident pods, providing that all pods can be completely photographed. Changes within AB pod will be examined with consideration for the age and sex structure of the pod and maternal groups within the pod. Changes in the AT1 transient group will also be assessesed. Using statistical methods, the likelihood that the numerous missing AT1 whales are dead will be examined. A summary of effort and of all encounters with killer whales will be included. (Copies of all data sheets will be provided as specified in the RFP under deliverables)

Specifics of each encounter with killer whales will be recorded. Data recorded will include date, time, duration, and location of the encounter. Rolls of film exposed and the estimated number of whales photographed will also be recorded. A chart of the whales' trackline during the encounter will be completed and the distance traveled by the vessel with the whales calculated. General behavior of the whales (i.e. feeding, resting, traveling, socializing, milling) will be recorded. The current data sheet used for collection of this data is included (see attached), however, it will be modified before the field season to facilitate the more accurate collection of data for Part 2 Section 1 of this proposal.

Photographs for individual identification will be taken of the port side of each whale showing details of the dorsal fin and white saddle patch. Photographs will be taken at no less than 1/1000 sec using Ilford HP5, a high speed black and white film, exposed at 1600 ASA. A Nikon 8008 autofocus camera with internal motor drive and a 300 mm f4.5 autofocus lens was used. When whales are encountered, researchers will systematically move from one subgroup (or individual) to the next keeping track of the whales photographed. If possible, individual whales will be photographed several times during each encounter to insure an adequate identification photograph. Whales will be followed until all whales are photographed or until weather and/or darkness makes photography impractical.

All photographic negatives will be examined under a Wild M5 stereomicroscope at 9.6 power. Identifiable individuals in each frame will be recorded. When identifications are not certain, they will not be included in the analysis. Unusual wounds or other injuries will be noted. Photographic negatives will be analyzed using a photographic database that spans ten years. Identities of each whale that appears in every frame of usable film will be recorded and stored in VAX computer system. Final analysis and assessment will follow Matkin et al. (1994). (Attached)

A substantial photographic database was collected from 1992, 1993 and 1994 by NGOS with private money. These photographs have not been completely analyzed. As part of this project, these photographic negatives will also be examined frame by frame and the whale identities computerized. This will be data will be important in the overall assessment of population dynamics within pods and within the population. It is important that changes within AB pod in 1995 be placed within this larger context. This multiyear analysis will also provide a more detailed account of the status of the AT1 transient group.

The primary vessel used to secure identification photographs will be a 27' deisel inboard/outboard powered vessel that can sleep two individuals (Whale 2). With sleeping detailing sampling was submitted to the National Marine Fisheries Service, Office of Protected Resources.

The field observation and sampling of prey items as required in Objective 2 will require the the small manueverable skiff (described above) and the the use of fine mesh, extendable nets for scooping remains from the water. Detection and recovery of fish scales or small bits marine mammals requires an experienced observer. Members of our research team pioneered the use of this technique and are well versed in its operation. Signs of killer whale predation are often subtle and transitory. Generally fragments of blubber, hair, blood, oil, or scales of fish are the only evidence of a predation. When obtained, samples will be preserved by freezing (tissues) or in envelopes (fish scales, hair) for later identification. It should be noted that especially with transients, extensive time must often be spent with the whales before a kill is observed.

Methods used to find killer whales for Part 2 will be similar to those outlined in Part 1 (for the R.V. Whale 2). However, it anticipated that for Part 2 longer time periods will spent with particular groups of whales due to the extensive time required to collect biopsy samples as well as collect prey items.

Molecular analysis will be used to evaluate whether Prince William Sound resident and transient killer whales are genetically isolated from each other, and also whether there is evidence of gene flow between these whales and resident or transient killer whales sampled in British Columbia. The mitochondrial DNA (mtDNA) characteristics of the two forms will be compared using a) restriction fragment length polymorphism (RFLP) analysis and b) direct sequencing of the D-loop region. Because mtDNA is only transmitted maternally, this type of analyis provides reliable information about whether females move between populations. Preliminary studies using these methods have revealed genetic differences between resident and transient killer whales from British Columbia. If the mtDNA analysis does rule out female movements between Prince William Sound residents and transients, it would be appropriate in future to investigate the possibility of male movements, or of inter-form matings during temporary associations. One appropriate technique for this determination is exon-primed intron crossing (EPIC) analysis (this is suggested for future research, not included in response under this RFP.) Since the mtDNA analysis will be conducted at the same laboratory (University of British Columbia) and by the same individual (Lance Barrett Lennard) currently completing analysis on British Columbia killer whales, it will possible to compare the findings in Prince William Sound with British Columbia, and also to look for evidence of gene flow between the two regions.

All equipment needed to complete the contracted field research is owned by the North Gulf Oceanic Society, including nets, hydrophones, biopsy equipment, and on board

Part 2

Objective 1 The background and methods for completion of this objective is detailed in addendum 1 from the Prince William Sound Science Center.

Objectives 2 and 3

The R.V. Lucky Star and associated skiff will be used as the primary platform in obtaining and processing samples for completion of Objectives 2 and 3 of the RFP. Additionally, the Whale 2, the primary platform for the completion of Part 1, will operated with the equipment to allow opportunistic collection of biopsy samples. Biopsies will be collected by the Whale 2 when it does not interfere with the the primary completion of Part 1 field sampling. The R.V. Lucky Star can house 4 scientists and has a work area and equipment sufficient for complete workup of samples taken by biopsy as well as samples of prey items. Freezing facilities for storage of samples are available. (Since the Whale 2 has only temporary freezing facilities, frozen samples of blubber taken from this vessel will be stored at the Port San Juan Aquaculture fish hatchery.

Most biopsy sampling will actually occur from a 17' fiberglass skiff that will be launched from the R.V. Lucky Star. The skiff is equipped with high sides and a raised deck, an operations console (hydraulic steering, remote speed and and shift controls) and a 60hp oil injected outboard motor.

The biopsy samples for completion of Objectives 2 and 3 of Part 2 will be collected without handling or tranquilizing the whales. A small dart will be fired from a specially outfitted rifle powered by air pressure from a .22 caliber blank cartridge. The setup is similar to that used to deliver tranquilizing drugs to terestrial mammals in wildlife research. A lightweight plastic dart (approx. 10 cm long by 1.2cm dia.) is fitted with a bevelled tubular sterile stainless steel tip that will take a small core of skin and blubber (approximately 1.8cm long and 0.5cm diameter). The sterilized dart will be fired from a range of 16-20m. The dart hits the animal in the upper back (in the area of the saddle patch), excises a small tissue sample and bounces off. The dart floats with sample contained until retrieved. Identification photographs using data back equipped cameras will be taken of all whales biopsied to assure accurate identification of the individual. The whales will be approached by researchers in the manner currently authorized under permit No. 840 (held by the North Gulf Oceanic Society) for photoidentification and biopsy sampling of killer whales. NGOS successfully biopsy sampled 21 individually identified killer whales in Prince William Sound in 1994 under this permit. The required report

Key Personnel and Responsiblities

Craig Matkin (M.S. University of Alaska), is the project leader. Mr. Matkin will be responsible for supervising the completion of all fieldwork and insuring successful operation of boats and equipment. He will be the operator of the R.V. Lucky Star and supervise directly all work completed from that platform or the attendent skiff. He will assemble all material for the final report and be responsible for completion and submition of the unified final report. He will represent and present the work to the EVOS Trustee Council.

Mr. Matkin has studied killer whales in Prince William Sound since 1977. He initiated systematic killer whale photoidentification in Prince William Sound, and is the founder of NGOS. Recently he completed the "The Biology and Management of Killer Whales in Alaska" for the U.S. Marine Mammal Commission. His most recent pertinent publication is of the EVOS killer damage assessment results ("The Status of Killer Whales in Prince William Sound 1984-1992", Craig O. Matkin, G. M. Ellis, M.E. Dahlheim, and J. Zeh in T.R. Loughlin. ed. Marine Mammals and the Exxon Valdez.)

David Scheel (Phd. University of Minnesota) is an Associate Scientist, at the Prince William Sound Science Center. Dr. Scheel will be responsible for the completion of Part 2, Objective 1 of this project. He will supervise the input of all data into the GIS system at the Prince William Sound Science Center. He will conduct all analysis on the historical data and will provide interpretation of that analysis for the final report.

Dr. Sheel's research projects have included predator-prey dynamics of Serengeti lions and their prey, habitat selection models of Texas mammals, frequency and density dependence in models of community evolution, social behavior and resource/ habitat use of primates in Gombe.

Eva L. Saulitis (M.S. University of Alaska) , a director of NGOS, has conducted fieldwork on killer whales in Prince William Sound each season since 1987. Eva will be the primary data collector for Part 1 of this project (photoidentification) and will operate the research vessel Whale 2. She will make ready and maintain all necessary equipment, complete photoidentification work and all logs and data sheets as required and coordinate her activities with that of the other research vessel Lucky Star. Eva will also provide research assistance aboard the Lucky Star when its cruises do not occur at the time of operation of the Whale 2. Eva will also help assure accurate entry of historical data into the GIS system.

Eva recently completed her MS thesis "The Behavior and Vocalizations of the AT Group of Killer Whales in Prince William Sound, Alaska." She coauthored the "Biology and Management of Killer Whales in Alaska" for the U.S. Marine laboratory supplies and equipment. An additional biopsy rifle and darts will be obtained to allow simultaneous sampling on board the Whale 2. Additional supplies and minor equipment will be purchased as necessary. Apple Macintosh and IBM compatible computers owned by NGOS as well as computers at the PWSSC as detailed in the addendum 1 will be used in analysis.

The following field schedule will be kept by the R.V. Lucky Star in completing objectives 2 and 3, the primary function for this vessel. In addition the Whale 2 will collect biopsy samples and feeding data opportunistically while completeing Part 1 of this project. The Lucky Star will complete its first trip at the date indicated below or as soon as possible after the RFP is awarded.

Trip 1	May 12- May 20	8 days
Trip 2	June 5-June 13	9 days*
Trip 3	September 3-17	15 days

*approx 1 day will involve logistics work for Part 1

The early season fieldwork (particularly the May trip) will be aimed at sampling transient killer whales. Resident whales are sighted more frequently later in the season. The September trip will concentrate on resident killer whales. At this time of year residents are consistently encountered typically involved in socializing or feeding on silver salmon, making them approachable and potentially less reactive to biopsy sampling. In 8 days of operation in September 1994 we obtained 21 biopsies of resident individuals. We expect additional samples will be collected by the Whale 2 during August.

Two biolgists from the NMML or contractor will participate in the May and June cruises aboard the Lucky Star and at least one biologist from NMML or contractor will participate in the September cruise aboard the Lucky Star.

Field work will be completed by September 30, 1995. Analysis of photographs and examination of pod compositions will occur in October and November (Part 1). Data entry and preliminary analysis of Part 2 Objective 1 (historical data) will be complete by late November. Genetic analysis and interpretation and analysis and summary of predation observed in the field will also occur in October and November. A draft final report will be sumitted by December 30, 1995.

The North Gulf Oceanic Society and Prince William Sound Science Center are both non-profit research and education corporations. The two groups work under a Memmorandum of Understanding that has been ammended to include reference to the proposed project. The PWSSC will be responsible to the NGOS for timely completion of Part 2, Objective 1 in the RFP and all billing and payment for their services will be handled by NGOS.

Summary of North Gulf Oceanic Society Previous Federal Contracts

1984 NMFS 84-ABA-02018 Identification of Humpback Whales in PWS. Linda Jones $4200.

1985 NMFS 40-HANF-6-00068 Killer Whale Longline Interactions. Steve Zimmerman. $4048

1985 NMFS 43-ABNF 53127 Humpback Whale Identification and Catalogue. Linda Jones. $8250.

1986 NMFS 40 ABNF-62262 Killer Whale Longline Interactions in PWS. Marilyn Dahlheim. $9,985.

1989 NMFS 50 ABNF 900118 Killer Whale and Humpback Whale Photo ID studies. Marilyn Dahlheim. $85,970

1990 NMFS 50 ABNF 000100 Killer Whale and Humpback Whale Photo ID studies. Marilyn Dahlheim $109,960

1990 NMFS 43 ABNF 000930 Killer Whale Photographic Catalogue Marilyn Dahlheim. $17,675

1991 NMFS 50 ABNF 100110 Killer Whale Photoidentification Studies. Marilyn Dahlheim. $90,185

All projects were fully and satisfactorily completed.

Mammal Commission. Eva has operated research vessels in Prince William Sound every season since 1988.

Lance Barrett Lennard (MS, University of British Columbia). Lance (an American citizen) is a Phd candidate at the University of British Columbia. Lance will conduct or supervise all genetic lab work for Part 2, Objective 2 of this project at the Unversity of British Columbia. He will also provide interpretation of those results. His extensive experience taking biopsy samples from killer whales will be employed in his participation in biopsy work conducted aboard the R.V. Lucky Star and Whale 2 in completion of Part 2, Objective 2 and 3.

Mr. Barrett-Lennard has researched killer whales for 8 years, specializing in their acoustics and genetics. He has operated research vessels in Prince William Sound and British Columbia. He is currently completing a project on killer whale predation on Steller sea lions in Alaska and is conducting genetic analysis on over 70 killer whale biopsy samples taken in British Columbia over the past 3 years.

Graeme Ellis has participated in killer whale photoidentification studies in Canada and Alaska for over 20 years. Ellis will do all final identifications of individual killer whales from historical data (1992-1994) as well as the current year's data. He will examine all negatives on a repetitive frame by frame basis and supervise the input of the final identification data into the VAX computer system. With Matkin he will update all life history information on individual whales and provide positive identifications from photographs of each whale biopsied. He will participate in approximately 2 weeks of field work. Currently Mr. Ellis directs whale identification work at the Pacific Biological Station in Nanaimo, British Columbia and has done final identifications on Prince William Sound killer whale photographic negatives since 1983. He has more experience than any other individual identifying Prince William Sound killer whales from photographic negatives.

ADDENDUM 1

A GIS database of historical killer whale data from Prince William Sound

Need and Scope Historical data on killer whales is available from North Gulf Oceanic Society (NGOS) for the period 1983-1994 and from NMFS and NGOS from 1989-1993. This eleven-year span includes six years of pre-EVOS data, and provides the best available record of how killer whale habits may have changed following the oil spill. The goal of this project is to begin the task of entering this data in to a geographic information database. Later, it will be valuable to analyze this database to address questions of interest to restoration management.

The killer whale was injured by EVOS and is currently listed as recovering, but staple prey species of these whales are listed as injured and not recovering. These include harbor seals and pink salmon At least for harbor seals, predation by killer whales is considered an important alternative to the food limitation hypothesis as an explanation for continued lack of population growth. The unrecovered status of these species may alter whale feeding patterns and behaviors. Further, the recovery of these species may be impacted by predation by whales.

In the face of restoration management following the 1989 oil spill, this data is the best record available to answer questions about the impact of oil on whale diet or habitat use, to examine the impact of whales on other injured species (especially harbor seals), to maximize the utility of currently planned data collection efforts through improved sampling protocol, and to corroborate results from studies of whale biology relying on alternative methods (i.e. stable isotope and fatty acid analysis).

However, while demographic information from these data has been computerized and utilized for both damage assessment and ecological studies, much of the distribution and behavioral data remains in file drawers in a relatively inaccessible state. Entry of this data into a computerized, geographically referenced database is the first step to making the knowledge contained in the data available to answer questions raised by restoration management.

The data has not been completely inventoried. However, we estimate that NGOS records from 1983 to 1994 contain about 560 encounters recorded encompassing 1700-3500 hours of whale observation during 9000-18000 hours of field effort (including NMFS/NGOS data from 1989 - 1993, but not 1993 NMFS data). Roughly 25 additional whale encounters are anticipated to exist in the NMFS data from 1993.

Data was recorded during summer months each year. Only one or a few sightings were recorded on any field day, but encounters with whales averaged from 3-6 hours, providing considerable behavioral information (travel rates, duration of feeding bouts, etc.). In addition to the thousands of frames of film already computerized for demographic analyses, NGOS has numbers, IDs, and pods of whales present at each sighting, as well as the location of encounters. Basic behavioral information (resting, feeding, traveling, etc.) is available for each sighting. Scale samples and bits of marine mammal flesh were collected when possible during feeding bouts, providing positive evidence of predation and of prey type. These feeding and habitat data have not yet been analyzed extensively.

records by habitat, or associate whale behavior with the spatial distribution of possible prey. Particular requirements are that searches and analyses can be performed on a chosen spatial area, time period, or attribute category (e.g. feeding behavior, or resident vs. transient pod type), and that search effort can be reconstructed to the extent that it was recorded.

Two categories of spatial information are contained in the historical data: vessel paths, which indicate both search effort and routes while watching whales; and whale paths, which indicate the routes travelled by the whales while under observation. Each category of spatial record is associated with different attribute data. The proposed data base structure (Figure 1) will store these two categories of spatial information in two GIS layers. Associated attributes will be stored in a series of related tables. This basic structure is already developed, but additional work will be required to ensure the best design for searching and analysis. We will consult with Charles Falkenberg (Computer Science Department, University of Maryland) and the SEA DATA project on optimizing the structure of the database. Dr. Falkenberg's consultation is in-kind support to the Comprehensive Killer Whale project and is funded through the University of Maryland and the Advanced Visualization Laboratory, UMD.

As the final stage of database design, we will create a trial database containing a handful of representative records from a couple of years. During this stage of design, a graphical, menu based data entry interface customized to the killer whale data set will be created using the Arc/Info arc macro language. The interface will be designed to facilitate rapid data entry, and to minimize incomplete or improperly formatted entries through selected entry checking.

Sample analyses and searches on the trial database will be conducted in order to develop search and analysis routines and to ensure that the database structure meets project requirements. These database trials will be conducted prior to entry of the bulk of the data. Searches will be conducted using Arc/Info SELECT commands as well as visual selection of spatial data with a mouse. Trial analyses will include counts of records meeting selection criteria and tabulation of length or event durations.

Following database design, data entry will commence. Data will be entered beginning with the most recent year (1994) and proceeding backwards to the earliest data. Geographical data from sketches in the data will be digitized on screen against a background map of the area in ArcEdit. Textual and numeric data will be entered from the keyboard in ArcEdit and Tables. Metadata (e.g. platform, personnel, record IDs, data source) will be entered at the same time.

2. Estimate the sampling effort, to provide a measure of sightings per unit effort.

This task will be accomplished through a literature review to examine the usefulness of different methods of calculating search effort, followed by an analysis of the computerized data. Prior to the literature review, it is premature to detail the methods of reconstructing the search effort. However, we will use the most appropriate method for the proposed analyses and use of the results. We currently intend to model this analysis after the grid-based geographic analysis of killer whale ecology of Heimlich-Boran (1988 Can. J. Zool. 66:565), as this study was conducted in a similar manner on the same species. A geographic grid can be laid over the killer whale study area using Arc/Info GENERATE or GRID routines. Once this grid is created, the amount of time and distance traveled by each research vessel in each grid cell can be tabulated. Killer whale encounters or time spent with the whales can be tabulated in a similar manner. For each cell, it will then be possible to calculate a measure of sightings per unit effort. This method currently appears suitable, but we expect to refine these calculations based on the review of literature.

3. Conduct a time-sequence analysis to look for changes in behavior over time span of behavior

This analysis will be designed to address question regarding long-term changes in whale behavior, and the relationship between such changes and the 1989 oil spill. For example, it has been suggested that transient whales have become more difficult to locate following the oil spill. We will examine measures of whale behavior and distribution by comparing sightings per unit effort and behavior frequencies in the pre- and post-spill periods. This will be accomplished first by calculating sightings per unit effort for each year of the database. Comparison between years in each time period (pre- and post-spill) will be used to indicate whether any group of whales have become more difficult to locate within the study area and whether the change corresponds in time to the oil spill. Similar calculations will indicate whether feeding or other behaviors have changed in frequency or moved in location over the years. For example, the grid-based analysis used for calculating search effort can be repeated on occurrences of each behavior category in each cell. As appropriate and allowed by sample sizes, these can be split by pod type, pod ID, or month and year of sampling. Parametric and non-parametric statistics will be used to evaluate the evidence for the hypothesized changes in behavior.

4. Estimate the extent of feeding segregation between resident and transient-type of killer whales.

Previous analyses of these data (e.g. Matkin & Saulitis 1994, US Marine Mammal Commission) as well as results from other studies indicate that resident and transient-type killer whales have minimal dietary overlap. A analysis of observations of transients feeding (Saulitis 1993, Univ. of Alaska Fairbanks thesis) found very little indication of fish in the transient diet. A comparable tabulation of observation time and feeding habits of resident whales has not been published from this data. We will tabulate the number, duration, and location of feeding behaviors for all records in the database and examine the results for evidence of dietary overlap between the two types. This behavioral analysis will provide an ideal comparison to chemical dietary analysis using stable isotopes and fatty acids.

5. Compare killer whale data to indices of prey availability to explore hypotheses regarding changes in killer whale behavior.

As suggested by the results of the previous four tasks, we will formulate and evaluate hypotheses regarding possible causes for the patterns documented. This may involve use of data on the distribution of prey that is available from other research projects. Possible candidate data sets on prey availability include the SEA program data base, expected to include detailed data on the seasonal distribution of pink salmon, herring, and pollock; ADF&G data on the distribution of harbor seals from population surveys or as reflected in the distribution of subsistence harvests; annual salmon or herring harvests by the fishing fleet; or other data as available.

While the most appropriate analyses methods will depend on the data set and the hypothesis to be tested, we expect that many analysis would have in common a desire to relate whale distributions to prey distributions. This will be accomplished through the spatial overlay capabilities of Arc/Info. Whale distributions will be obtained from the data base through a grid-based analysis of encounters per unit effort (see above). Prey distributions will be obtained by the most appropriate means from the candidate data set. The prey and predator distributions can then be overlaid in Arc/Info to examine hypotheses regarding the spatial associations of whales and their prey or of whales and other important features of their habitat (e.g. rubbing beaches, etc.).

It is likely that an important part of this work will involve evaluation of the hypothesis that killer whale predation is having an impact on the recovery rate of harbor seals in Prince William Sound. The detail of this analysis may be limited by both the available data on killer whales and the available data on harbor seals. However, the spatial distribution of killer whales and harbor seals in Prince William Sound will be important prerequisites for an estimate of seal mortality due to killer whale predation.

<u>Work Plan</u>

1. Computerize the historical data relative to feeding, habitat use, behavior, and distribution of killer whales into a GIS format.

Obtaining data: Within the project's first month, NGOS data will be obtain under an amended MOU as described above and a request will be made of NMFS to provide copies of other killer whale data they wish to have included in the database. Craig Matkin and David Scheel will oversee the transfer of original data sheets to ensure that data is available at the Science Center in the project's first month. David Scheel will initiate the request to NMFS.

Designing database: Within the project's first three months, David Scheel will finalize data base design, and will create a prototype database and a graphical, menu based data entry interface. By the project's third month, he will conduct sample analyses and searches on the trial database and will use these to begin data entry.

Entering data: The timeline for this project is estimated using a 2:1 ratio of analysis:field sampling time. The NGOS data contains an estimated 560 sightings encompassing 1700-3500 hours (NMFS from 1992-93 is not included, and may contain an additional 150-200 hours). This will take from 2000-4000 hours to process and analyze. At 176 hours per person-month, historical data analysis may take a minimum of 11 person-months. The resources allocated to this task will support the first 5.5 person-months of this task. This is a minimum estimate of likely costs. Following this effort, it will be possible to make a more precise estimate of both the extent of the available data and the cost of the remaining analyses.

Therefore, in the first month of this project, applications for a data-entry technician will be reviewed. Beginning in the second to third month of this project, a data technician will enter the data sheets into the computer. Entry will begin with the most recent data and proceed back in time until all data are entered. It is not expected that data entry will be completed without renewal of the project for a second year. However, as much progress as possible will be made under the existing support. At this time, we anticipate that, with continuing support, data entry could be completed in the first quarter of an additional project year.

Analyses 1) sampling 2) changes 3) feeding segregation 4) prey availability: As data entry will not be completed under this fiscal year's support, only a preliminary analysis of sampling effort and an inventory of entered data will be completed for the final report in November 1995. Suggestions to improve the design of future field sampling and monitoring efforts will be formulated based on the initial phase of data entry and included in the report. These preliminary analyses will be completed and their results reported by the end of November 1995. Analyses of changes in behavior, feeding segregation and comparisons with prey availability will not be possible until the completion of data entry.

Organization, Staff and Management

David Scheel will oversee the database portion of this project and complete much of the database design and data-entry interface. He will also organize the infrastructure and software support from OSRI at the Science Center, and coordinate the in-kind contributions from SEA-DATA and UMD. He will report project results to Craig Matkin, NGOS. At least one site visit to the Science Center by NGOS personnel familiar with data collection will be provided by NGOS. This visit will allow a careful review of the prototype database design by the field personnel responsible for collecting the data. One data entry technician will be hired by the Science Center to type data into the computer.

Personnel

PI: Dr. David Scheel C.V. See attached.
Data entry technician - to be named.

Organization background and qualification

See annual report for Prince William Sound Science Center.

Equipment and Facilities

The computer equipment described above (Technical Approach & Tasks) are the only equipment needed in performance of the database portion of this project.

Item	Source	Level	Stored Width	Display Width	Type	Dec.	Description	Units
	NB: One log per vessel per day, each log has a vessel path attached to it.							
Log-ID	Log	meta	4	4	Char	-	Year-page number of log (numbered consecutively)	
Date	Log	primary	8	8	Date	-	Day, month, year of vessel log (repeated on Sighting)	Date
Platform	Log	meta	12	12	Char	-	Name of vessel (repeated on Sighting)	-
Personnel	Log	meta	16	16	Char	-	Initials of personnel on vessel	-
LB-Loc	Log	primary	50	15	Char	-	Place name where vessel began the day	-
LE-Loc	Log	primary	50	15	Char	-	Place name where vessel ended the day	-
LB-time	Log	primary	6	6	Num	2	Begining time of log	dec hours
LE-time	Log	primary	6	6	Num	2	End time of log	dec hours
LS-time	Log	primary	6	6	Num	2	Duration spent searching	dec hours
LW-time	Log	derived	6	6	Num	2	Duration spent with whales	dec hours
LS-length	Log	derived	5	5	Num	1	Length of trackline surveyed, as recorded on the Log	dec miles
LS-rec	Log	meta	5	5	Int	-	Refers to encounter number in database	
Log-comm	Log	primary	200	15	Char	-	Running commentary on events	-
	NB: Multiple weather/seastate, whale sightings may be recorded per log.							
Log-ID	Log	meta	4	4	Char	-	Year-page number of log (numbered consecutively	
Wea-time	Log	primary	5	5	Num	2	Time of wheather/sea state observation	dec hours
Wea-cov	Log	primary	7	7	Char	-	Cloud cover as: Sunny, ptcl, mstcl, cldy	-
Wea-wind	Log	primary	7	7	Char	-	Wind as: SW15, NE40 etc (direction and velocity in knots)	-
Wea-sea	Log	primary	4	4	Char	-	4 char code for sea state and visiblity (Beaufort).	Unk
LS-Rec	Log	meta	5	5	Int	-	Refers to encounter number in database	-
LWhl-time	Log	primary	6	6	Num	2	Time of whale observation	dec hours
LWhl-spp	Log	primary	4	4	Char	-	2-3 char code for species observed	-
LWhl-loc	Log	primary	50	15	Char	-	Place name where sighting occured	-
LWhl-no	Log	primary	3	3	Int	-	Number of whales recorded in the sighting in the Log	animals
LWhl-behv	Log	primary	7	7	Char	-	See list	-
	NB: May be multiple encounter sheets per log; each encounter sheet has a vessel path attached to it.							
Enc-ID	enc	meta	5	5	Char	-	Year-page number-encounter	
Log-ID	log	meta	4	4	Char	-	Year-page number of corresponding log sheet	
Enc-date	enc	primary	8	8	Date	-	Day, month, year of animal encounter (repeated on Log)	Date
Enc-platform	enc	meta	12	12	Char	-	Name of the vessel (repeated on Log)	-
Observers	enc	meta	16	16	Char	-	Initials of observers making encounter record	-
EB-time	enc	primary	6	6	Num	2	Begining time of encounter	dec hours
EE-time	enc	primary	6	6	Num	2	End time of encounter	dec hours
EB-Loc	enc	primary	50	15	Char	-	Place name where encounter began	-
EE-Loc	enc	primary	50	15	Char	-	Place name where encounter ended	-
Pods	enc	derived	16	8	Char	-	2-3 char codes for pods represented at encounter	-
Mi-trav	enc	derived	5	5	Num	1	Nautical miles traveled with pod, as recorded on form	dec miles
Tot-whl	enc	primary	3	3	Int	-	Total number of whales counted in the encounter	whales
adM	enc	primary	3	3	Int	-	Total number of adult males counted in the encounter	whales
adF-I	enc	primary	3	3	Int	-	Total number of adult females or immatures counted	whales
juv-calf	enc	primary	3	3	Int	-	Total number of juv/immatures counted in the encounter	whales
Rec-ind	enc	primary	200	16	Char	-	3-4 char names of all individuals sighted.	-
Tot-pho	enc	primary	3	3	Int	-	Total number of whales photographed	whales
Tot-har	enc	primary	3	3	Int	-	Total number of whales harassed by researchers	whales
Oil	enc	primary	8	8	Char	-	None if no oil present, otherwise type of oil present	-
	NB: May be multiple rolls of film, recording tapes, or observations per sighting sheet.							-
Enc-ID	enc	meta	5	5	Char	-	Year-page number-encounter	
Log-ID	log	meta	4	4	Char	-	Year-page number of corresponding log sheet	
Film-date	enc	primary	8	8	Date	-	Day, month, year of film roll	Date
Film-enc	enc					-	[Not used] Encounter ID for film roll	-
Film-roll	enc	primary	3	3	Int	-	Roll number ID of film roll	-
Film-ini	enc	primary	8	3	Char	-	Roll initial ID of film roll	-
Rec-tape	enc	primary	3	3	Int	-	Tape number ID of recording	-
Rec-side	enc	primary	1	1	Char	-	Side on which tape was recorded (A or B)	-
Rec-beg	enc	primary	4	4	Int	-	Counter number where recording began	-
Rec-end	enc	primary	4	4	Int	-	Counter number where recording ended	-
Enc-ID	enc	meta	5	5	Char	-	Year-page number-encounter	
AB-time	enc	primary	6	6	Num	2	Beginning time of activity	Time
AE-time	enc	primary	6	6	Num	2	Ending time of activity	
Activ-behv	enc	primary	7	7	Char	-	See list	-
Activ-vess	enc	primary	50	15	Char	-	Vessel traffic	-
Activ-inter	enc	primary	50	15	Char	-	Interaction with whales by other boats	-
Activ-grp	enc	primary	50	15	Char	-	Sub-groupings of whales listing individual IDs	-
Activ-note	enc	primary	50	15	Char	-	Additional information on the activities	-

GIS layer 2: Encounters

Film attributes

Film-rec	Enc-ID	Film-date	Film-roll	Film-ini
1	1	8-Jul-94	1	PWS-ES
2	1	8-Jul-94	2	PWS-SS
3	2	9-Jul-94	1	PWS-NS

Associated vector object:

(Whale path)

Encounter attributes

Enc-ID	EB-time	Log-ID	Pods	Tot-whl	Tot-pho
1	12.83	1	AB	15	13
2	8.1	2	AT1,AC	29	10
3	13.0	2	AE	2	2

Tape attributes

Rec-rec	Enc-ID	Rec-tape	Rec-beg	Rec-end
1	2	9-Jul-94	0	225
2	3	9-Jul-94	225	end
3	3	9-Jul-94	0	end

Activity attributes

Obs-rec	Enc-ID	Act-time	Act-behv	Act-grp
1	1	12.83	trav	AE10,14,15/AE5,17,6/9/
2	1	14.5	rest	AE3,2,16
3	2	8.1	breach	AB4,5,11,10,2,33,39

Sighting attributes

LS-rec	Enc-ID	Log-ID	Lwhl-spp	Lwhl-no	Lwhl-behv
1		1	HBWH	1	Breach
2		1	HBWH	1	
3	1	1			
4		2	DAPO	2	Trav

Associated vector object:

(Vessel path)

Log attributes

Log-ID	Date	Vessel	Personel	LS-time
1	8-Jul-94	Whale 2	ES, JL	4.5
2	9-Jul-94	Whale 2	ES,JL	3.0
3	9-Jul-94	Whale 3	CM,HO	5.5

Weather attributes

Wea-rec	Log-ID	Wea-time	Wea-sea	Wea-wind
1	1	9.5	B1V1	
2	1	15.0	B3V2	SW15
3	2	8.0		Calm

GIS layer 1: Vessel logs

Figure 1: Tabular data structure for vessel logs and whale encouter sheets showing linkage to geo-referenced vector objects (some attributes not shown; data is fictional)

ctures/evosstuf/killerwh/ltkwdbas.pre

TOTAL P.03

100 DAILY

DAILY RESEARCH LOG

DATE____________ PLATFORM______________________

BEGIN LOCATION________________ END LOCATION______________________

____________________________ __________________________________

____________________________ __________________________________

BEGIN TIME__________________ END TIME__________________________

SEARCH TIME______________ TIME WITH WHALES________________(Hrs)

TOTAL MILES SURVEYED (trackline) ______________________________

PERSONEL____

____

WEATHER & SEA STATE /TIME ______________________________________

____

____

WHALE
SIGHTINGS/TIME____

____

ACTIVITIES/COMMENTS ____

____

____

____

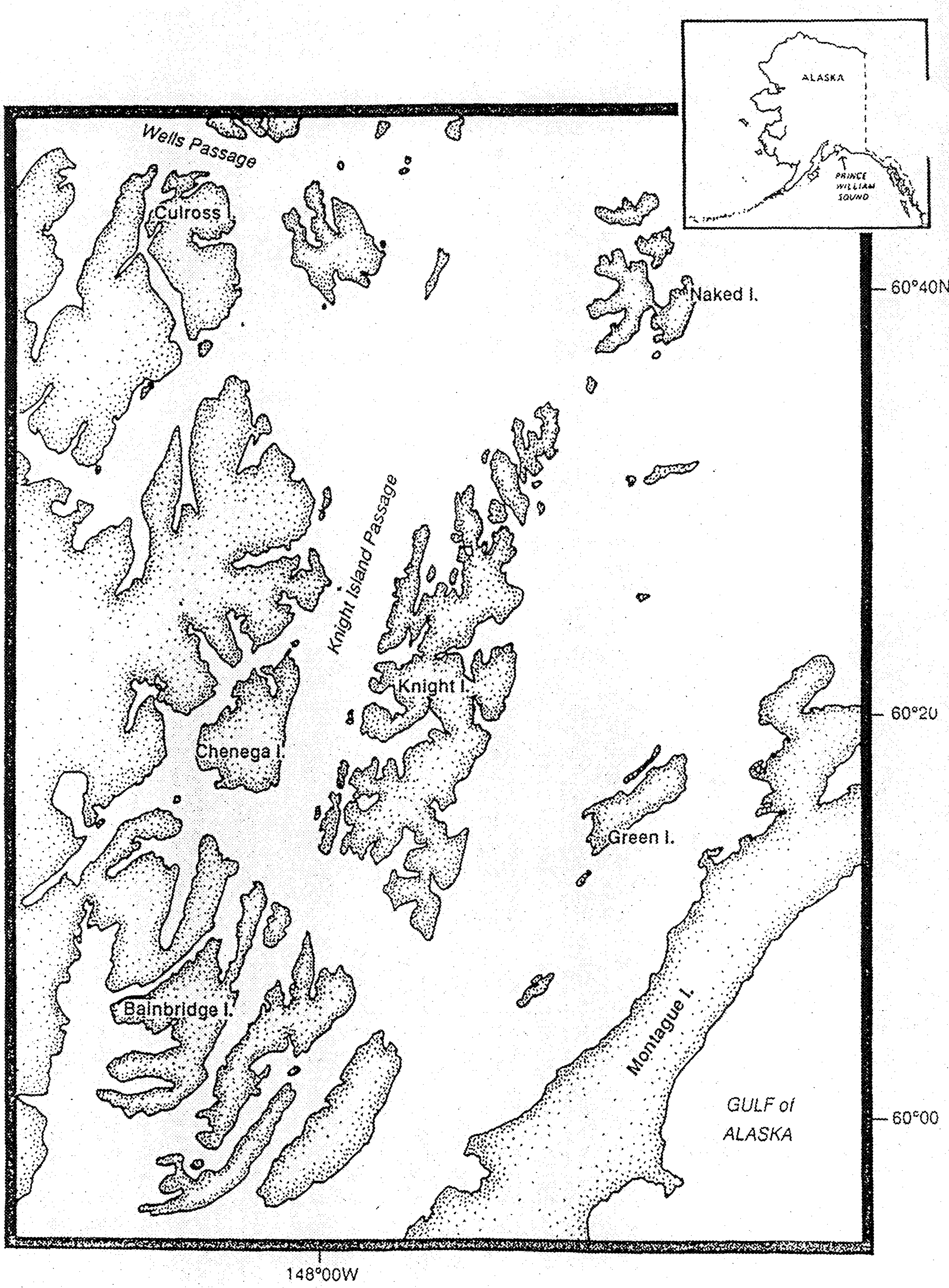
____

____

____

____

VESSEL TRACK ON REVERSE--------



Wells Passage
Culross I.
Naked I.
Knight Island Passage
Knight I.
Chenega I.
Green I.
Bainbridge I.
Montague I.
GULF of
ALASKA
60°40N
60°20
60°00
148°00W
ALASKA
PRINCE
WILLIAM
SOUND

Date/Enc.#__________________ N.G.O.S. KILLER WHALE SURVEY

Platform__________________

Observers__________________ Time (Beg/End)__________________

Location (Beg/End) ____

____

Pods__________________ naut. miles traveled w/whales__________

Total whales________ ad ♂ _____ ad ♀/imm♂_____ juv/calve_____

Recognized Individuals ____

____

_____________________________________# whales photographed______

Film (Date/Enc#/Roll#/Initials) ________________________________

Recordings Yes/No Tape#/Side Beg/End ______________________

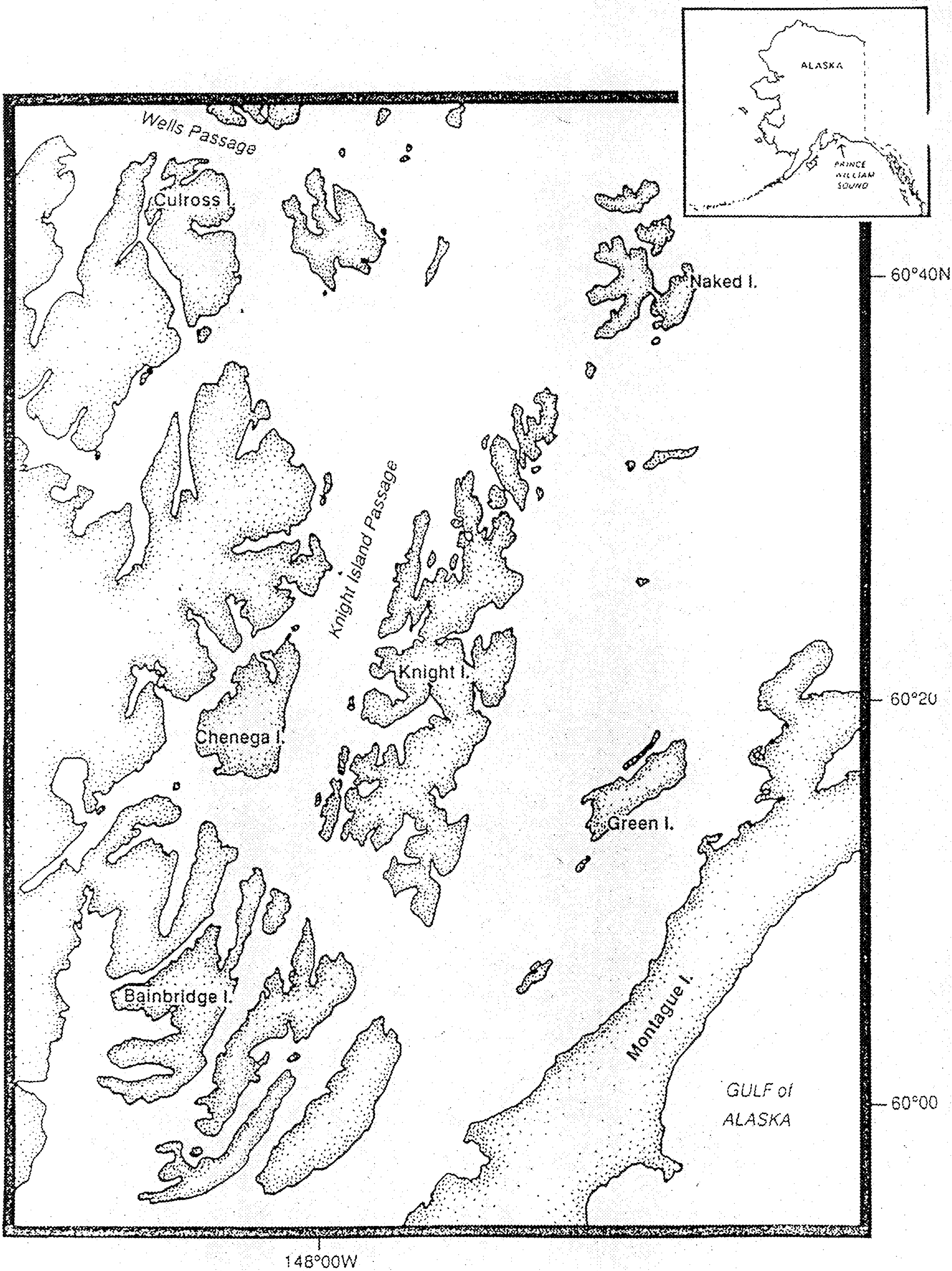
____

Observations:

Oil present Yes/No Type______________
Harassment of whales by resarchers Yes/No #harassed__________

Note: Behavior (Feeding,Resting,Traveling,Social/Sexual,Milling)
Note: Vessel traffic and interaction w/ whales

Time	Observation


ALASKA
PRINCE WILLIAM SOUND
Wells Passage
Culross I.
Naked I.
60°40N
Knight Island Passage
Knight I.
60°20
Chenega I.
Green I.
Bainbridge I.
Montague I.
GULF of ALASKA
60°00
148°00W

PROJECTS AND FUNDING SOURCES: 1980-1993
NORTH GULF OCEANIC SOCIETY

The goal of the North Gulf Oceanic Society is to conduct long term monitoring of the killer and humpback whale populations in Prince William Sound, Alaska, in order to further conservation of and public education about these species. In addition to contractual support, we have received numerous tax deductible donations from private individuals.

1980-1981. Completed contract with U.S. Fish and Wildlife Service Special Studies, Anchorage, Alaska (Contract #70181-0125-80) titled "A Marine Mammal Survey of southwestern Prince William Sound.

1981-1982. Completed contract with the Alaska Department of Fish and Game, Game Division Regional Office, Juneau, Alaska (Contract #82-0848) titled "A Preliminary Evaluation of Wildlife Populations on Gustavus Beaches and Dude Creek Uplands".

1982-1983. Completed contract with State of Alaska, Alaska Council on Science and Technology, Juneau, Alaska, titled "A Survey of Humpback Whales in southwestern Prince William Sound, Alaska".

1984. Completed contract with Hubbs Sea World Research Institute, 1700 South Shore Road, San Diego, California (Proposal #HSWRI 83-02) titled "Population Census of Killer Whales in Prince William Sound, Alaska".

1985. Completed contract with the National Marine Mammal Laboratory, NMFS, Seattle, Washington, to produce a catalogue of humpback whale flukes for Prince William Sound, Alaska and a report on the results of the humpback whale survey in Prince William Sound in 1984.

1985. Completed contract with National Marine Fisheries Service, Juneau, Alaska, to document, by survey of fishermen, the killer whale interactions with the black cod longline fishery in Prince William Sound, Alaska. Documented bullet wounds in members of the AB pod of killer whales.

1986. Completed contract with the National Marine Mammal Laboratory, Seattle, Washington, to photoidentify killer whales in Prince William Sound, and to study their interactions with the black cod longline fishery. Published a catalogue of the killer whales in southern Alaska, including southeastern Alaska and Prince William Sound.

1986-1988. Investigated the interactions of killer whales with the black cod longline fishery and censused killer whales in Prince William Sound for the Alaska Sea Grant Marine Advisory Program. Investigated potential methods of deterring killer whales from removing fish from longlines.

1989-1991. Assessed the population status of killer whales in Prince William Sound following the Exxon Valdez oil spill for the National Marine Mammal Laboratory, Seattle, Washington. Documented the death of fourteen members of the AB pod of killer whales in the three years following the spill.

1989-1990. Assessed the population status of humpback whales in Prince William Sound following the Exxon Valdez oil spill for the National Marine Mammal Laboratory, Seattle, Washington.

1989-1991. Investigated the behavior and vocalizations of the AT group of killer whales in Prince William Sound, Alaska as part of the graduate work of Eva Saulitis at the Institute of Marine Science, University of Alaska, Fairbanks. Funded by Alaska Sea Grant College Program, American Museum of Natural History, and International Women's Fishing Association.

1992-1993. Continued monitoring of populations of killer and humpback whales in Prince William Sound. Funded by member donations and savings. Worked in conjunction with Dr. John Ford, University of British Columbia, Vancouver, B.C. to determine acoustic dialects of resident killer whale pods in Prince William Sound.

PUBLICATIONS AND REPORTS RESULTING FROM RESEARCH CONDUCTED BY THE NORTH GULF OCEANIC SOCIETY

Matkin, C.O. and D.R. Matkin. 1981. Marine mammal survey of southwestern Prince William Sound: 1979-1980. Prepared for U.S. Fish and Wildlife Service, Anchorage, Alaska, Contract #70181-0125-80, 15pp.

Leatherwood, S.L., K.C. Balcomb III, C.O. Matkin, and G. Ellis. 1984. Killer whales (Orcinus orca) of southern Alaska: Results of field research, 1984. HSWRI Technical Rept. No. 84-175, 59pp.

Matkin, C.O., O. von Ziegesar, G. Ellis, and B. Goodwin. 1985. Repeated use of Prince William Sound, Alaska by identifiable killer whales with evidence of pod stability. Abstract submitted to the Sixth Biennial Conference on the Biology of Marine Mammals, Vancouver, B.C.

Matkin, C.O. 1985. Studying killer whales on Alaska's south coast. Alaska Magazine 51(5): 20-23.

Matkin, C.O. and S.L. Leatherwood. 1986. General biology of the killer whale (Orcinus orca): A synopsis of knowledge. Pages 35-68 in Kirkevold, B.C. and J.S. Lockard, eds. Behavioral biology of killer whales. Alan R. Liss, Inc., New York, 457pp.

von Ziegesar, O., G. Ellis, C. Matkin, and B. Goodwin. 1986. Repeated sightings of identifiable killer whales (Orcinus orca) in Prince William Sound, Alaska 1977-1983. Cetus 6(2): 9-13.

Matkin, C.O. 1986. Killer whale interactions with sable fish longline fishery in Prince William Sound, Alaska, 1985, with comments on the Bering Sea. Final rept. NMFS, Juneau, Alaska, Contract #010686, 10pp.

Matkin, C.O., G. Ellis, O. von Ziegesar, and R. Steiner. 1986. Killer whales and longline fisheries in Prince William Sound, Alaska, 1986. Final Rept. to NMML, NMFS, Seattle, Wa., Contract #40ABNF6-2262, 15pp.

Matkin, C.O., R. Steiner, And G. Ellis. 1987. Photoidentification and deterrent experiments applied to killer whales in Prince William Sound, Alaska, 1986. University of Alaska, Sea Grant Marine Advisory Program, Cordova, Alaska, 18pp.

Ellis, G., Editor. 1987. Killer whales of southern Alaska: A catalogue of individuals photoidentified, 1976-1986. Hubbs Sea World Marine Research Center Tech. Rept. #87-200, 76pp.

Matkin, C.O. 1988. Status of Prince William Sound killer whales and the sablefish fishery in late 1987. Rept. to University of

Alaska Sea Grant Marine Advisory Program, 10pp.

Matkin, C.O., G. Ellis, and E. Saulitis. 1989. Killer whales in Prince William Sound in 1989 after the Exxon Valdez oil spill. Rept. to NMML, NMFS, Seattle, Wa., Contract #50ABNF900118, 23pp.

Matkin, C.O. and G. Ellis. 1990. Population biology and longline fishery interactions of Prince William Sound killer whales. Abstract presented to the Third International Orca Symposium, Victoria, B.C.

Saulitis, E. 1990. Acoustic behavior of transient killer whales in Prince William Sound, Alaska. Abstract presented to the Third International Orca Symposium, Victoria, B.C.

Leatherwood, S., C.O. Matkin, J.D. Hall, and G.M. Ellis. 1990. Killer whales (Orcinus orca) photo-identified in Prince William Sound, Alaska, 1978 through 1987. Canadian Field-Naturalist 104(3): 362-371.

Matkin, C.O. and G. Ellis. 1990. The status of killer whales in Prince William Sound in 1990. Rept. to NMML, NMFS, Seattle, Wa. for contract #52ABNF000100, 20pp.

Matkin, C.O. and G. Ellis. 1991. An assessment of killer whales in Prince William Sound, 1991. Rept. to NMML, NMFS, Seattle, Wa. for contract #50ABNF100110, 27pp.

Saulitis, E.L. 1993. The vocalizations and behavior of the AT group of killer whales in Prince William Sound, Alaska. MSc. Thesis, University of Alaska, Fairbanks.

Matkin, C.O. and E. Saulitis. In press. Killer whales (Orcinus orca). In Lentfer, J.W., ed. Selected marine mammals of Alaska: Species accounts with management recommendations. Marine Mammal Commission, Washington, D.C.

Matkin, C.O. In prep. A natural history of the killer whales of Prince William Sound. Prince William Sound Books, Valdez, AK.

Matkin, C.O., G. Ellis, and M.E. Dahlheim. In prep. Status of killer whales in Prince William Sound following the Exxon Valdez oil spill. In Loughlin, T., ed. Effects of the Exxon Valdez oil spill on the marine mammals of Prince William Sound.

95021

95021

DEC 03 1994

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

COVER PAGE

1. Project Title: Seasonal Movements and Pelagic Habitat Use by Common Murres from the Barren Islands

2. Project Number: 95021

3. Lead Trustee Agency: DOI (National Biological Survey)

4. Cooperating Agencies:

5. Project Start-up/Completion Dates: 1 December/30 September 1995

6. Expected Project Duration: 3 years

7. Cost of Project: $53.8K (FY95)
   $221.1K (FY96)
   $221.1K (FY97)

8. Geographic Area: Barren Islands

9. Name/Signature of Project Leader(s): Scott A. Hatch P.I.

   Scott A. Hatch

10. Name/Signature of lead agency Project Manager: Leslie Holland-Bartels

   Leslie Holland-Bartels

95021

RECEIVED
DEC 03 1994
EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

COVER PAGE

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   Scott A. Hatch

10. Name/Signature of lead agency Project Manager: Leslie Holland-Bartels

   L Holland-Bartels

Through the combined use of satellite transmitters and time-depth recorders, this project will provide a three-dimensional view of murre foraging patterns around the Barren Islands in summer. Additionally, transmitters deployed in fall and tracked through the winter months will reveal the primary wintering areas used by this population. It may also be possible to locate key foraging areas of juvenile murres by deploying transmitters on breeding males late in the season. Flightless murre chicks are led to sea by their male parents, who continue to provide parental care for several weeks as the young learn gradually to feed themselves.

B. PROJECT DESCRIPTION

1. Resources

Common murres are the injured resource intended to benefit from this project. An assessment of murre foraging patterns is essential for understanding the causes of long-term declines in this species at the Barren Islands and other colonies within the oil spill area. This understanding will aid the evaluation of injuries inflicted by the oil spill and may guide the development of restoration strategies for murres.]

2. Relation to Other Restoration Work

The Chief Scientist has emphasized the need to obtain information on the foraging ranges and behavior of seabirds impacted by the oil spill to use for the interpretation of data on the distribution and abundance of their prey. This strategy is integral to research proposed for seabirds and forage fish in Prince William Sound (Project 95163). Work proposed here anticipates the expansion of the seabirds/forage fish project into portions of the oil spill area outside of Prince William Sound (e.g. FY 1996 or later). Wherever possible, it is desirable to establish the spatial distribution of seabird foraging effort before attempting to delineate prey resources or understand the oceanographic factors affecting those resources. Early implementation of this project should allow that natural progression of research strategies to occur in relation to common murres.

3. Objectives

- Determine the foraging range and primary feeding areas of common murres from the Barren Islands, including assessment of individual and temporal variation.

- Locate important nursery and/or wintering areas of common murres from the Barren Islands and determine the timing of use of those critical habitats.

- Obtain average time-at-depth profiles for a sample of foraging murres from the Barren Islands.

4. Methods

In year 1 of this project (1995), the plan is to conduct a limited investigation of murre foraging by deploying 6 satellite transmitters at the Barren Islands, refining bird capture techniques and surgical procedures in the process. Pending funding approvals in the out-years (1996 and 1997), we will expand the use of satellite telemetry (> 20 transmitters) and add the study component involving time-depth recording.

Murres will be captured with poles and nooses during incubation or chick-rearing in the Lighthouse Rock portion of the colony on East Amatuli Island. Transmitters will be surgically implanted by a qualified and experienced veterinarian. The ARGOS Data Collection and Location System will be used to track the movements of instrumented birds. Transmitters will be programmed to emit signals on one of two duty cycles: (1) continuous transmission, providing frequent information on locations (accurate to < 1 km) over a 3-week period (expected battery life), or (2) low-interval transmissions (e.g., 6 h every 4 days) for less frequent position data over a portion of the nonbreeding period (2-6 months). Position data will be mapped using CAMRIS (Computer Aided Mapping and Resource Information System) or other suitable GIS software. An example of the graphical products expected to result from this study is attached.

Time-depth recorders are relatively inexpensive devices employing hypodermic syringes and photographic film to record the depth-dependent position of an light-emitting diode (Wilson et al. 1989). The instruments are attached externally to the dorsal feathers and must be retrieved after an appropriate interval to obtain the data on diving depths. Information on the depth and duration of dives is cumulatively recorded on the film, and the exposed film is analyzed using a densitometer. Each unit is calibrated prior to deployment. LED depth recorders have been used successfully with thick-billed murres in the Canadian Arctic (Croll et al. 1992) and on smaller alcid species in the North Pacific (Burger 1991).

5. Location

Field operations will be conducted on East Amatuli Island of the Barren Islands, located at the mouth of Cook Inlet in the northern Gulf of Alaska.

6. Technical Support

This project requires the services of an experienced veterinarian and access to the ARGOS data-logging and distribution system, both of which are available in the Alaska Science Center of the National Biological Survey.

7. Contracts

The manufacture, calibration, and optical density measurements of LED depth recorders will be contracted to a qualified specialist. Aspects of this project involving satellite telemetry will be implemented by the Alaska Science Center, National Biological Survey. In addition to the in-house technical support mentioned above, Center personnel have unique experience with implantable satellite transmitters for recording the movements of birds at sea (Petersen et al., MS). The Principal Investigator and co-workers conducted a pilot study of transmitter implants and satellite tracking of common murres on Middleton Island (north-central Gulf of Alaska) during July 1994. Results of that work are attached.

C. SCHEDULE

Fiscal Year 1995

Nov-June	Recruit personnel, procure satellite transmitters and other equipment.
July-Aug	Field operations at East Amatuli Island, begin data acquisition via ARGOS.
Sept	Continue ARGOS data acquistion and analysis.

Fiscal Year 1996

Oct-Dec	Continue ARGOS data acquisition, data analysis and report preparation.
March	Draft annual report.
June	Final annual report.

Key project personnel include the Principal Investigator, responsible for planning, overall scientific direction in the field and office, and preparation of the annual report; a veterinarian, licensed in Alaska and trained in the surgical procedures required to do the transmitter implants; and a data management specialist experienced in the procedures for ARGOS data acquistion and GIS processing of animal location data.

D. EXISTING AGENCY PROGRAM

The National Biological Survey will contribute approximately $11,000 during the period October 1, 1994 to September 30, 1995 to cover salary costs of the Principal Investigator, which are not included in the budget submitted for funding by the EVOS Trustee Council.

E. ENVIRONMENTAL COMPLIANCE, PERMITTING, AND COORDINATION STATUS

Study plans for this project are subject to approval by the Animal Care and Use Committee (ACUC) of the Alaska Science Center, National Biological Survey, which is responsible for ensuring compliance with the provisions of the Animal Welfare Act. Surgical implants for satellite transmitters follow a standard protocol approved by the ACUC. This project meets NOAA requirements for Categorical Exclusion under the NEPA process.

F. PERFORMANCE MONITORING

Scientific and technical aspects of this study will be subject to internal review within the Alaska Science Center, National Biological Survey. Work plans, study design, and final reports will be subject to the peer review process established by the Trustee Council and the Chief Scientist. Significant findings presented in final reports will be submitted for publication in peer reviewed journals and presented at scientific meetings as they become available.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

Work on East Amatuli Island will be coordinated with the monitoring study of common murres proposed for that site (Project 95039) to facilitate field operations for the telemetry study and to avoid any conflicts between projects. Results of this study should be applied in planning future investigations of food limitation hypotheses as they pertain to common murres (Project 95163).

H. PUBLIC PROCESS

The idea of using satellite transmitters to identify the foraging areas of common murres was introduced at a meeting of public and government representatives interested in forage fish research (Anchorage, 9 May 1994). Further opportunities for public input will be available at two winter workshops planned for 1994-95 by the Exxon Valdez Oil Spill Restoration Office.

I. PERSONNEL QUALIFICATIONS

1. Scott A. Hatch, Principal Investigator

Scott Hatch is employed as a Research Wildlife Biologist in the Alaska Science Center, National Biological Survey. He has conducted research on the population dynamics and feeding ecology of seabirds in Alaska since 1975. Dr. Hatch has authored more than 30 published papers on those topics and has managed interagency programs for seabird research and monitoring since 1987. Curriculum vitae are filed and available on request from the Restoration Office, Exxon Valdez Oil Spill Trustee Council.

Education:

Ph.D., University of California, Berkeley, 1985, Zoology

M.S., University of Alaska, Fairbanks, 1979, Wildlife Management

B.S., University of Washington, 1975, Wildlife Science

Selected Publications:

Hatch, S.A. 1983. The fledging of common and thick-billed murres on Middleton Island, Alaska. J. Field Ornithol. 54: 266-274.

Hatch, S.A. 1984. Nestling diet and feeding rates of rhinoceros auklets in Alaska. Pages 106-115 in D.N. Nettleship, G.A. Sanger, and P.F. Springer, eds. Marine birds: their feeding ecology and commercial fisheries relationships. Can. Wildl. Serv. Spec. Pub., Ottawa.

Hatch, S.A. 1987. Did the 1982-1983 El Nino-Southern Oscillation affect seabirds in Alaska? Wilson Bull. 99: 468-474.

Hatch, S.A. 1987. Adult survival and productivity of northern fulmars in Alaska. Condor 89: 685-696.

Hatch, S.A. and M.A. Hatch. 1989. Attendance of murres at breeding sites: implications for monitoring. J. Wildl. Manage. 53: 483-493.

Hatch, S.A. and M.A. Hatch. 1990. Breeding seasons of oceanic birds in a subarctic colony. Can. J. Zool. 68: 1664-1679.

Hatch, S.A. and M.A. Hatch. 1990. Components of breeding productivity in a marine bird community: key factors and concordance. Can. J. Zool. 68: 1680-1690.

Hatch, S.A. 1990. Time allocation by northern fulmars during the breeding season. Ornis Scand. 21: 89-98.

Hatch, S.A. and G.A. Sanger. 1992. Puffins as samplers of juvenile pollock and other forage fish in the Gulf of Alaska. Mar. Ecol. Prog. Ser. 80: 1-14.

Hatch, S.A., B.D. Roberts, and B.S. Fadely. 1993. Adult survival of black-legged kittiwakes *Rissa tridactyla* in a Pacific colony. Ibis 135: 247-254.

Hatch, S.A., G.W. Kaiser, A. Ya. Kondratyev, and G.V. Byrd. 1994. A seabird monitoring program for the North Pacific. Trans. 59th No. Am. Wildl. & Natur. Resour. Conf.: 121-131.

2. Daniel M. Mulcahy, DVM

Dr. Mulcahy is presently the wildlife veterinarian for the Alaska Science Center, National Biological Survey. For two years he was an independent contractor supplying veterinary services to practices and government agencies in Alaska. For 13 years he was an employee of the U.S. Fish and Wildlife Service, including 10 years as a research scientist investigating diseases of free-ranging and hatchery salmonid fishes, and three years as head of research at the National Wildlife Health Research Center in Madison, Wisconsin. Dr. Mulcahy has experience with fish, marine mammals and birds. In addition to his work at ASC, he practices small animal medicine and is a volunteer veterinarian at the Bird Treatment and Learning Center in Anchorage.

Dr. Mulcahy is the only veterinarian in Alaska experienced with the current technique of satellite transmitter implantations. He has performed nearly 40 of the surgeries to date.

Education:

D.V.M. 1992. University of Wisconsin, Madison.

Ph.D. 1977. Oregon State University, Corvallis. Microbiology.

B.S. 1970. California State University, Long Beach. Zoology.

Professional Memberships:

American Veterinary Medical Association
Southcentral Alaska Veterinary Medical Association (President-elect)
Wildlife Disease Association
Association of Zoo Veterinarians
American Association of Avian Veterinarians
International Sled Dog Veterinary Medical Association
American Animal Hospital Association
American Fisheries Society
Fish Health Section, AFS

Publications:

Dr. Mulcahy has published about 50 scientific publications in refereed journals or as monographs and special publications. A list of publications is available on request.

3. David C. Douglas, ARGOS System Specialist

David C. Douglas, Research Wildlife Biologist, Alaska Science Center, National Biological Survey, Anchorage, Alaska

Mr. Douglas received an MS Degree in Wildlife Biology at Washington State University in 1986. Since that time, he has worked in Anchorage for the USFWS/NBS where he currently serves as Leader of the High Technology Project. Since 1986, Mr. Douglas has processed and disseminated ARGOS satellite telemetry data (over 800 animal deployments) to a diverse community of scientists studying the movements and behaviors of mammals and birds. He has consulted with manufacturers to improve transmitter performance as well as with Service ARGOS to improve the applicability of the ARGOS system for wildlife research. His expertise also includes digital processing of satellite imagery to document and monitor environmental conditions applicable to subsequent GIS analyses with wildlife distribution data.

Relevant publications:

Petersen, M. R., D. C. Douglas, and D. M. Mulcahy. 1995. Use of implanted satellite transmitters to locate spectacled eiders at-sea. Condor. (in press).

Douglas, D. C., M. S. Udevitz, and J. Takekawa. 1992. Successful performance of satellite transmitters attached to migrating lessor snow geese. USFWS RIB #92-30.

Harris, R. B., S. G. Fancy, D. C. Douglas, G. W. Garner, S. C. Amstrup, T. R. McCabe, and L. F. Pank. 1990. Tracking wildlife by satellite: current systems and performance. U.S. Fish and Wildl. Serv., Tech. Report No. 30. 53 pp.

Douglas, D. C., J. C. Greslin, and L. F. Pank. 1989. Satellite telemetry and geographic information systems: powerful tools for wildlife research and management. Pages 83-93 in J. G. Buhyoff, ed., Proc. Resour. Technology 88. First. Symp. on Advanced Technology in Nat. Resour. Manage. Am. Soc. Photogram. and Remote Sensing, Falls Church, VA. 277 pp.

Garner, G. W., S. C. Amstrup, D. C. Douglas, and C. L. Gardner. 1989. Performance and utility of satellite telemetry during field studies of free-ranging polar bears in Alaska. Pages 67-76 in C. J. Amlander, Jr., ed. Biotelem. Proc. of the 10th Int. Symp. on Biotelemetry. Univ. of Arkansas Press, Fayetteville.

Garner, G. W., S. T. Knick. and D. C. Douglas. 1989. Seasonal movements of adult polar bears in the Bering and Chukchi seas. Int. Conf. Bear Res. and Manage. 8:219-226.

Fancy, S. G., L. F. Pank, D. C. Douglas, C. H. Curby, G. W. Garner, S. C.

Amstrup, and W. L. Reglin. 1988. Satellite telemetry: a new tool for wildlife research and management. U.S. Fish and Wildl. Serv., Resour. Publ. No. 172. 55 pp.

I. BUDGET

See attached.

J. LITERATURE CITED

Burger, A.E. 1991. Maximum diving depths and underwater foraging in alcids and penguins. Pages 9-15 in W.A. Montevecchi and A.J. Gaston, eds. Studies of high-latitude seabirds. 1. Behavioural, energetic, and oceanographic aspects of seabird feeding ecology. Can. Wildl. Serv. Occ. Pap. 68, Ottawa.

Burger, J. 1980. The transition to independence and postfledging parental care in seabirds. Pages 367-347 in J. Burger, B.L. Olla, and H.E. Winn, eds. Behavior of marine animals. Vol. 4: marine birds. Plenum Press, New York.

Croll, D.A., A.J. Gaston, A.E. Burger, and D. Konnoff. 1992. Foraging behavior and physiological adaptation for diving in thick-billed murres. Ecology 73: 344-356.

Hatch, S.A. 1987. Adult survival and productivity of northern fulmars in Alaska. Condor 89: 685-696.

Hatch, S.A., B.D. Roberts, and B.S. Fadely. 1993. Adult survival of black-legged kittiwakes (*Rissa tridactyla*) in a Pacific colony. Ibis 135: 247-254.

Petersen, M.R., D.C. Douglas, and D.M. Mulcahy. MS. Use of implanted satellite transmitters to locate spectacled eiders at sea. National Biological Survey, Alaska Science Center, Anchorage, AK.

Wilson, R.P., A.E. Burger, B.L.H. Wilson, M.-P.T. Wilson, and C. Noldeke. 1989. An inexpensive depth gauge for marine animals. Mar. Biol. 103: 275-283.

1995 Exxon Valdez Tru.... Council Project Budget
October 1, 1994 - September 30, 1995

Project Description: Common murres were among the vertebrate species most seriously injured by the Exxon Valdez oil spill. This project will test the hypothesis that failure of the species to recover is a result of food availability limiting breeding success and survival. Forage range, primary food areas, nursery and wintering areas will be studied.

Budget Category:	1994 Project No. . . . . Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment
Personnel		$0.0	$18.4	$18.4	$107.3	Fiscal Year 1996 budget includes cost of data analysis and write-up of work conducted in FY 95.
Travel		$0.0	$3.0	$3.0	$9.6	
Contractual		$0.0	$0.0	$0.0	$10.5	
Commodities		$0.0	$7.4	$7.4	$22.9	
Equipment		$0.0	$22.2	$22.2	$54.0	
Capital Outlay		$0.0	$0.0	$0.0	$0.0	
Subtotal	$0.0	$0.0	$51.0	$51.0	$204.3	
General Administration		$0.0	$2.8	$2.8	$16.8	
Project Total	$0.0	$0.0	$53.8	$53.8	$221.1	
Full-time Equivalents (FTE)		0.0	0.7	0.7		

Dollar amounts are shown in thousands of dollars.

Budget Year Proposed Personnel: Position Description	Reprt/Intrm Months	Reprt/Intrm Cost	Remaining Months	Remaining Cost
Rept				
Intrm				
Biotechnician (1 @ 8 mos)			7.0	$14.0
Computer Technician, GS 9			0.5	$2.0
Veterinarian, GS 13			0.5	$2.4
Personnel Total	0.0	$0.0	8.0	$18.4

NEPA Cost: $0.0
*Oct 1, 1994 - Dec 31, 1994
**Jan 1, 1995 - Sep 30, 1995

06/01/94

1995

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Project Number: 95021
Project Title: Seasonal Movement and Pelagic Habitat Use by Common Murres from the Barren Islands
Agency: Dept. of Interior, National Biological Survey

FORM 2A PROJECT DETAIL

Travel:	Reprt/Intrm	Remaining
Rept		
Intrm		
Field camp per diem (50 person-days @ $3)		$0.2
Round-trip air-fares, Anchorage-Homer (5 @ $150)		$0.8
Helicopter transport of personnel to/from field site (2 round-trips @ $1K)		$2.0
Travel Total	$0.0	$3.0

Contractual:	Reprt/Intrm	Remaining
Rept		
Intrm		
Contractual Total	$0.0	$0.0

Project Number: 95021
Project Title: Seasonal Movement and Pelagic Habitat Use by Common Murres from the Barren Islands
Agency: Dept. of Interior, National Biological Survey

FORM 2B PROJECT DETAIL

Commodities:	Reprt/Intrm	Remaining
Rept		
Intrm		
Field camp food (50 person-days @ $10)		$0.5
Cooking and outboard fuel		$0.1
ARGOS data acquisition and processing:		
Data tapes (8 mo. @ $150)		$1.2
Tymnet log-on (8 mo. @ $50)		$0.4
Continuous sampling PTT's (3 @ $225 plus 'class-0' processing @ $34)		$0.7
Low-interval PTT's (3 @ $107/mo. x 12 mo.)		$3.9
Class-0 processing for above PTTs		$0.6
Commodities Total	$0.0	$7.4

Equipment:		
Rept		
Intrm Satellite transmitters (6 @ $2.7K)		$16.2
Inflatable boat, 2 outboard motors for transportation between field camp and murre colony		$5.5
Miscellaneous cook/camp gear		$0.5
Equipment Total	$0.0	$22.2

07/14/93

1995

Printed: 11/30/94 2:59 PM

Project Number: 95021
Project Title: Seasonal Movement and Pelagic Habitat Use by Common Murres from the Barren Islands
Agency: Dept. of Interior, National Biological Survey

FORM 2B
PROJECT
DETAIL

ATTACHMENT 1

SEASONAL MOVEMENTS AND PELAGIC HABITAT USE BY COMMON MURRES DETERMINED BY SATELLITE TELEMETRY

Scott A. Hatch, Daniel M. Mulcahy, and David C. Douglas

Alaska Science Center, National Biological Survey, 1011 East Tudor Road, Anchorage, AK 99503

Introduction

Common murres were the bird species most seriously injured by the Exxon Valdez oil spill. About 75% of the 35,000 bird carcasses recovered after the spill were murres, and estimates of murre losses were in excess of 100,000 individuals. After the oil spill, fewer breeding murres were found at the Barren Islands compared to historical data, and annual censuses have not detected any recovery in numbers. Also, based on data from Nord Island, production of chicks was almost zero in both 1989 and 1990, and still low in 1991 and 1992 compared to colonies outside the spill zone.

One hypothesis to explain the failure of recovery in common murres is that food availability is limiting the ability of birds to breed successfully or to survive in sufficient numbers during the nonbreeding season. An evaluation of that hypothesis requires that we identify the principal feeding areas of murres in both seasons and design appropriate oceanographic studies to assess factors affecting food availability.

Small (<35 g) satellite transmitters have recently become available for use in wildlife telemetry. These implantable devices are proven effective when deployed on birds in the size range of common murres, i.e., about 1 kg. This development offers a more efficient approach for determining the at-sea movements and habitat requirements of murres than is possible using traditional survey methods. We conducted a pilot study during 1994 to assess the feasibility of using implantable satellite transmitters to determine the foraging patterns and seasonal movements of common murres.

Procedures

Two PTT (Platform Transmitting Terminal) transmitters were delivered by Microwave Telemetry Inc., Columbia, Maryland, on 14 July and flown immediately to Middleton Island (59° 25' N, 146° 20' W) for deployment in common murres. Surgical implants were performed on 16 July in birds weighing 1135 g and 1060 g. At 34.5 g and 33.5 g, the transmitters constituted about 3% of the birds' body mass. A 20-cm long multistrand stainless steel antenna exited percutaneously near the tail. Both birds were released to the water in apparently healthy condition within 2 hours after surgery and began transmitting location data immediately. One PTT (#7877, carried by bird number CM01) was programmed to transmit on a cycle of 8 hours on-8 hours off for 50 cycles (about 33 days), then switch to a cycle of 6 hours on every 4.67 days. PTT #5891 (carried by CM02) was programmed initially to be alternately on for 6 hours and off 12 hours for 5 cycles (90 hours total), then switch to a long-term pattern of 6 hours on every 4.67 days (similar to 7877). Transmitters were also equipped with sensors to provide information on body temperature and battery voltage with each transmission. Transmitted data were received by NOAA satellites 11 and 12 and processed by the ARGOS Data Collection and Location System.

Results

Visual observation of the birds immediately after release indicated that one murre (CM02) carried its antenna upright and well exposed to the air while swimming. The other installation (CM01) appeared unsatisfactory because the antenna was submerged much of the time as the bird swam. Subsequent performance of the two transmitters confirmed this assessment. Few usable data were obtained from CM01, and the transmitter was not heard from after 22 July (6 days post-surgery).

PTT #5891 (CM02) provided location data from soon after release through much of August. Between 18 July and 24 July, CM02 foraged to the north of Middleton Island, especially in the vicinity of a shoal area known as Wessels Reef (Fig. 1). One location on 18 July near the east side of Montegue Island may be spurious, but the relatively tight grouping of other locations obtained on that date and during subsequent transmission periods clearly indicate repeated foraging activity by this individual at locations 10-30 km from its nest site. After 24 July, CM02 migrated from its breeding place on Middleton Island to waters around the Barren Islands and north end of Afognak Island. Later transmissions indicated declining battery voltage, and ARGOS was unable to compute locations after 19 August. Temperature data received as late as 20 September indicated the instrumented bird was alive on that date.

Evaluation and Prognosis

This pilot study was intended to answer questions about the ability of common murres to undergo surgery and carry implanted transmitters, as well as questions about the adequacy of ARGOS data to determine the movements and habitat use of murres during summer and winter. We are encouraged by our results on both counts. Murres appear to tolerate well the necessary anesthesia and surgical procedures, and the package size (3% of body weight, minimal drag) is well within accepted guidelines for telemetric studies of birds. The accuracy of our location data is comparable to previous animal tracking studies employing satellite transmitters and ARGOS data processing, i.e., errors are generally <1000 m, but unknown for individual locations. Because of redundancy in the locations obtained (i.e., during a 6-hour transmission interval), it is possible to determine with acceptable precision the foraging areas of breeding murres in relation to their nest sites. Seasonal movements and wintering areas are also clearly established by this method.

We encountered two significant problems. One of our implants had an unsatisfactory orientation of the antenna in the free-ranging bird. We believe this outcome can be avoided in the future by: (1) reconfiguring the transmitter package to provide a more upright angle between the antenna and transmitter (easily done according to the manufacturer), and (2) applying what we learned about the surgical techniques required to obtain a good installation in common murres. The second problem was unexpectedly short transmitter life (about 1 month in PTT #5891 instead of the expected 8 months based on calculations of load and capacity). From the results of this study, other applications in 1993-94, and bench tests, Microwave Telemetry has determined that the lithium batteries they are using are prone to self-discharging at three times the expected rate when kept at the constant high internal temperature of a bird (40° C). The company is working with its battery supplier to correct the problem and expects to provide a transmitter with much improved performance for use in 1995.

In summary, this pilot study has verified that the objectives identified for EVOS study 95021 ("Seasonal Movements and Pelagic Habitat Use by Common Murres from the Barren Islands") are attainable using the methods proposed. The full-scale study will increase the number of transmitters deployed and will use appropriate statistical algorithms to identify important habitat areas in both summer and winter.

One additional and unanticipated result of our pilot study is noteworthy. The instrumented bird that departed Middleton Island in late July moved to the vicinity of the Barren Islands, possibly to spend the winter. Substantial numbers of murres regularly winter in the bays along the Kenai Peninsula and in the Kodiak archipelago, but previously we had no idea from what colonies these birds originate. This is the area in which large numbers of murres contacted oil and died in April 1989. As murres did not return to their breeding sites on Middleton Island until 17 April 1989, it is possible that birds from this colony were included in the mortality associated with the Exxon Valdez spill. (A few oiled murres--dead and dying--were in fact recovered on the beaches of Middleton Island in late April 1989). Thus, our preliminary results suggest that wide application of satellite telemetry could be useful in assessing the geographic extent of likely impacts of the oil spill on murres.

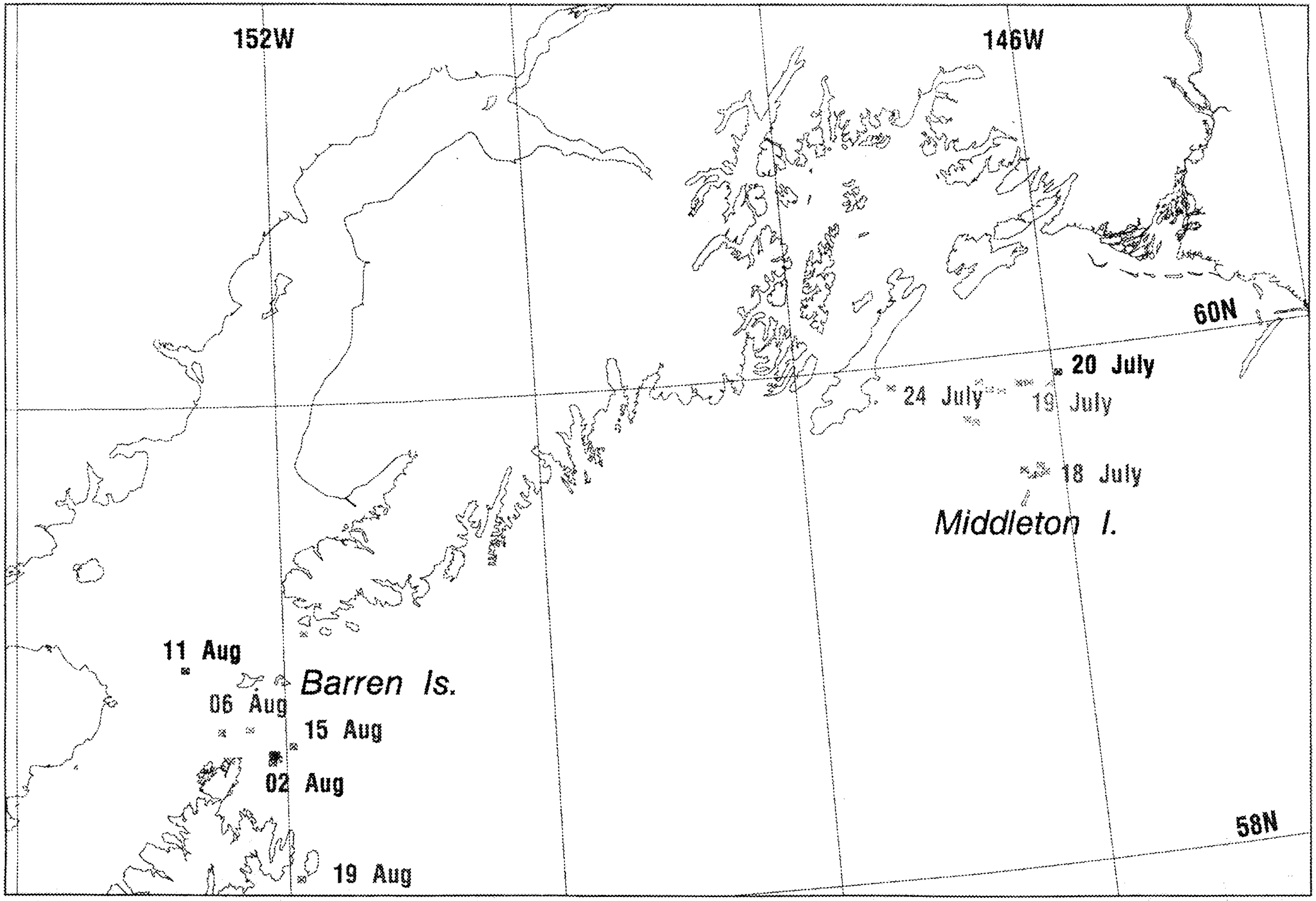

Figure 1. Satellite relocations of one common murre (CM02) captured at Middleton Island and implanted with a transmitter on 16 July 1994. Repeated locations obtained during a 6-hour transmission interval are color-coded.

95025 NBS

95025-Plan

DEC 0_ 1994

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

1. **Project Title:** Nearshore Vertebrate Predator Package: Planning and Development

2. **Project Number:** 95025

3. **Lead Trustee Agency:** National Biological Survey

4. **Cooperating Agencies:** NOAA

5. **Project Start-up/ Completion Dates:** during FY95

6. **Expected Project Duration:** 6 months

7. **Cost of Project:** 130K

8. **Geographic Area:** Prince William Sound

9. **Project Leader:**
Dr. Brenda Ballachey - National Biological Survey, Alaska Science Center
Mr. Jim Bodkin - National Biological Survey, Alaska Science Center
Dr. Terry Bowyer - University of Alaska Fairbanks
Dr. Tom Dean - Coastal Resources Assoc.
Dr. Larry Duffy - University of Alaska Fairbanks
Mr. Dan Esler - National Biological Survey, Alaska Science Center
Dr. Stephen Jewett - University of Alaska Fairbanks
Ms. Karen Laing - U. S. Fish and Wildlife Service
Dr. Chuck O'Clair - National Marine Fisheries Service
Dr. Alan Rebar - Purdue University
Dr. Dan Roby - National Biological Survey/University of Alaska Fairbanks
Dr. Glenn VanBlaricom - National Biological Survey/University of Washington

10. **Project Manager:**
Dr. Leslie E. Holland-Bartels
National Biological Survey, Alaska Science Center

A. INTRODUCTION

The release of oil during the *Exxon Valdez* Oil Spill is documented to have caused injury to numerous populations of both vertebrate and invertebrate species in the nearshore environment. In April, 1994, scientists and managers examined potential processes limiting the recovery of this ecosystem. Five hypotheses involved ecosystem processes and explicitly referred to alteration in community structure by direct impacts of oiling and clean-up on intertidal or benthic species or by removal of key species (EVOS Trustees Council. 1994. Science for the Restoration Process. Proceedings of the Workshop). The other hypotheses involved impacts of initial or continued exposure to oil. The Nearshore Vertebrate Predator Project has been proposed to examine the processes that may still be constraining recovery of that system within Prince William Sound through an integrated study focusing on several different components of the top predator community to obtain various assessment windows of restoration status and mechanisms for recovery. The proposed effort represents a collaboration among eleven scientists from university, federal, and private centers.

Given the comprehensive nature of the proposed Nearshore Vertebrate Predator (NVP) project and following recommendations of the Trustee Council Chief Scientist, funds were requested for further development and planning of the project. During this phase, the package of multiple projects will be refined and a cohesive conceptual framework and action plan will be developed.

B. PROJECT DESCRIPTION

1. **Resources and/or Associated Services:** Sea otters, pigeon guillemots, river otters, harlequin ducks, blue mussels, clams and sea urchins were all injured by the oil spill. In order to determine how recovery can be promoted, the processes that are constraining recovery must first be identified. By doing so, it will be possible to determine whether or not restoration measures are possible and if so, understanding the processes involved will help understand how best to employ them. In the event it is determined that only natural processes for recovery are possible, then research efforts and dollars can be refocused and the injured resources monitored over the long term in their recovery.

2. **Relation to Other Damage Assessment/Restoration Work:** NVP relates to other damage assessment and restoration work in two main ways. First, it builds on previous studies of injured nearshore species. Information obtained in previous damage assessment or restoration studies, many of which were conducted by project leaders now participating in NVP, provides the justification for proposing the components of the present study plan. Secondly, it complements ecosystem packages proposed or underway by other researchers. The other ecosystem packages

currently funded or being proposed include the PWS System Investigation (SEA Plan) and the Forage Fish Package, both of which focus on pelagic rather than nearshore species.

3. **Objectives:**

a. Provide financial support to Principal Investigators for travel to three planning meetings.

b. Develop guidelines for Program Management for the project, including selection of a Project Chief Scientist and a Program Manager.

c. Identify, map and select common study sites.

d. Develop a data management program.

e. Establish sampling and QA/QC protocols.

f. Integrate each component of the project logistically which will result in development of a sampling timeline and coordinated use of equipment, charters and personnel.

4. **Methods:** Team members will meet once per month November through January to develop the final detailed proposal for the overall Nearshore Vertebrate Predator Package. At these meetings and from subsequent product assignments, the various elements of the detailed package will be completed. Products will include: A refined series of hypotheses and study approaches integrated across species components; Identification, mapping and selection of common study sites; Development of a data management program; Establishment of sampling and QA/QC protocols; and Integration of each study component of the project logistically which will result in development of a sampling timeline and coordinated use of equipment, charters and personnel.

5. **Location:** Planning meetings will be conducted in Fairbanks and Anchorage, Alaska. Plan development will be supervised and conducted at the Alaska Science Center, National Biological Survey, Anchorage, AK.

6. **Technical Support:** Not applicable to planning process.

7. **Contracts:** Two professional services contracts will be required, one for the development of a data management plan (Project member, Dr. T. Dean, Coastal Resources Associates) and one for the synthesis of existing invertebrate data from Prince William Sound (Team member, Dr. G. VanBlaricom, University of Washington). Both of the subject areas are to be conducted under sole source

contract because the contractees are within the project and possess all or significant portions of the required data. Contracting, therefore, is an efficient and cost effective mechanism to produce the required products in the limited timeframe established for plan completion.

C. SCHEDULE

The first meeting was held 7-9 November, 1994 in Fairbanks. At this meeting, the project hypotheses were refined and the production of the Project DPD outline was delegated as were outlines for a data management plan and QA/QC. One member was also assigned the task of compiling and synthesizing existing data on invertebrates from Prince William Sound. The sampling timeline was determined and the Project Chief Scientist and Project Manager for the planning period were selected.

A second meeting is scheduled for 14-16 December in Anchorage, where appropriate, assigned tasks are to be completed by then. Work will begin on the Project DPD and decisions made, regarding the data management plan, sampling QA/QC protocols and coordination of sampling efforts.

D. EXISTING AGENCY PROGRAM

Not applicable to the planning process.

E. ENVIRONMENTAL COMPLIANCE, PERMITTING AND COORDINATION STATUS

National Biological Survey is the lead agency for NEPA compliance. A Marine Mammal Permit is required for handling sea otters and collection of blood; a permit which covers this work is already approved and in possession of the P.I.s (renewable permit number PRT 740507). Permits from USFWS and the State are required for the collection of harlequin ducks, and an export permit is required from the USDA, for carcass analysis in Canada. Also, State permits are required for fish, invertebrate, and river otter collections associated with the actual conduct of the proposed study.

F. PERFORMANCE MONITORING

The Project is under the direction of the recently selected Chief Scientist for the Project, Dr. Leslie Holland-Bartels. Dr. Bartels has direct line supervision of the NBS project scientists in the Alaska Science Center and functions as the contract officer for funds transferred. She can ensure through normal agency protocols the completion of assigned tasks of NBS and contract participants. Because of the short timeline nature of the planning process, other personnel changes are unlikely. However, the Alaska Science Center would ensure that projects were completed should personnel change through the redirection of appropriate NBS personnel or contracting to other appropriate scientists.

95025 DOI

95025

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

1. **Project Title:** Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

2. **Project Number:** 95025

3. **Lead Trustee Agency:** National Biological Service

4. **Cooperating Agencies:** ADFG, NOAA, USFWS

5. **Project Start-up/ Completion Dates:** July 1995 to October 1999

6. **Expected Project Duration:** 5 years

7. **Cost of Project:** FY95 $596,208; FY96 $1,644,595; FY97 $1,644,595; FY98 $1,644,595; FY99 $450,000

8. **Geographic Area:** Western Prince William Sound

9. **Cooperators:**
   Dr. Brenda Ballachey - National Biological Service, Alaska Science Center (ASC)
   Mr. Jim Bodkin - National Biological Service, ASC
   Dr. Terry Bowyer - University of AK Fairbanks (UAF)
   Dr. Tom Dean - Coastal Resources Associates, Inc.
   Dr. Larry Duffy - UAF
   Mr. Dan Esler - National Biological Service, ASC
   Mr. Stephen Jewett - UAF
   Ms. Karen Laing - U.S. Fish and Wildlife Service
   Dr. Lyman McDonald -Western Ecosystems Technology
   Dr. Chuck O'Clair - National Marine Fisheries Service
   Dr. Alan Rebar - Purdue University
   Dr. Dan Roby - National Biological Service/UAF
   Dr. Paul Snyder - Purdue University
   Dr. Glenn VanBlaricom - National Biological Service/University of Washington

10. **Chief Scientist:** P.I.

    ____
    Dr. Leslie E. Holland-Bartels
    National Biological Service, ASC

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

1. **Project Title:** Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

2. **Project Number:** 95025

3. **Lead Trustee Agency:** National Biological Service

4. **Cooperating Agencies:** ADFG, NOAA, USFWS

5. **Project Start-up/ Completion Dates:** July 1995 to October 1999

6. **Expected Project Duration:** 4 years (useful results can be obtained in 3 years, but to be effective the project should be supported a minimum of 4 years)

7. **Cost of Project:** FY95 $596,208; FY96 $1,644,595; FY97 $1,644,595; FY98 and FY99 outyears will depend on program review

8. **Geographic Area:** Western Prince William Sound

9. **Cooperators:**
Dr. Brenda Ballachey - National Biological Service, Alaska Science Center (ASC)
Mr. Jim Bodkin - National Biological Service, ASC
Dr. Terry Bowyer - University of AK Fairbanks (UAF)
Dr. Tom Dean - Coastal Resources Associates, Inc.
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Mr. Dan Esler - National Biological Service, ASC
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Dr. Alan Rebar - Purdue University
Dr. Dan Roby - National Biological Service/UAF
Dr. Paul Snyder - Purdue University
Dr. Glenn VanBlaricom - National Biological Service/University of Washington

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10. **Chief Scientist:** [signature]
Dr. Leslie E. Holland-Bartels
National Biological Service, ASC

Table of Contents

List of Figures

List of Tables

1.0 Introduction

1.1 Overview

The nearshore marine ecosystem of Prince William Sound (PWS) plays a critical role in the commercial, subsistence, and recreation economy of southcentral Alaska. Because of shorelines and coastal physiography, the nearshore ecosystem served as a repository for much of the oil spilled by the T/V *Exxon Valdez* (EVOS). As a result, many of the injured resources under study by the *Exxon Valdez* Trustees Council are components of the nearshore system (Table 1). Thus, we propose the Nearshore Vertebrate Predator (NVP) study, which describes a research approach for assessing the biological and ecological significance of trophic issues and contaminants present in the environment. We focus on the status of system recovery and a suite of injured apex predators as indicators of environmental stress--the invertebrate feeding sea otter and harlequin duck, and fish feeding pigeon guillemot and river otter. NVP takes a multispecies, integrated approach to assess several potential key mechanisms constraining recovery of the nearshore system. For our test species, EVOSTC (1994a) suggested that three of the twelve mechanisms hypothesized (Appendix 6.1) to be impacting the nearshore system had high potential as factors constraining recovery:

1) *Recovery of nearshore resources injured by EVOS is limited by recruitment processes;*

2) *Initial and/or residual oil in benthic habitats and in or on benthic prey organisms has had a limiting effect on the recovery of benthic foraging predators; and*

3) *EVOS induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators.*

Based on that consensus, the NVP study will examine status of recovery of the 4 selected nearshore vertebrate predators. We will measure population density, as well as demographic factors (e.g., size and age distributions, birth rates, survival rates) at both oiled and unoiled sites to examine possible reasons for lack of recovery, and to assess progress toward recovery given demographic restraints. Simply stated, we will ask "are vertebrate populations recovering, and if so, are they recovering as quickly as possible given potential rates of population increase?".

In contrast with these "recovery monitoring" studies, we will address two working hypotheses with respect to possible constraints to the recovery process:

1) *Initial and/or residual oil in benthic habitats and in or on benthic prey organisms has had a limiting effect on recovery of benthic foraging predators; and*

2) *Prey availability and competition for prey is constraining recovery of sea otters, river otters, pigeon guillemots, and harlequin ducks.*

In simpler terms, "is it oil?", or "is it food?". These questions will be addressed through evaluation of demographic measures, health assessments, biomarkers of oil exposure, and availability of prey for the four nearshore vertebrate predators.

1.2 General State of Recovery

The EVOS caused immediate, acute impacts to the nearshore ecosystem. Oil moved over 1,100 km of coastline (Morris and Loughlin 1994), with over 20% of the PWS shoreline heavily oiled (ADEC 1992). Additional disturbances of the nearshore system occurred as heavily oiled beaches were washed (Morris and Loughlin 1994). Mortalities occurred across the suite of apex predators in the system (Table 2) and mussels, clams, and other benthic invertebrates were injured (Houghton et al. 1993a, Highsmith et al. 1993). Initial changes in composition and abundance of nearshore invertebrates and apex vertebrate predators resulting from these acute mortalities and habitat disturbances likely caused continued modifications in important structuring processes in the nearshore invertebrate populations (i.e., competition, predation, and recruitment), thus constraining recovery.

Effective implementation of the EVOS Trustees Council's policy (EVOSTC 1994b) that "Restoration should contribute to a healthy, productive and biologically diverse ecosystem...", is complicated by the diversity and trophic interdependence of the numerous injured resources within the nearshore system. Beyond these ecological constraints, we are practically constrained in judging restoration by a lack of accurate and precise pre-spill population demographic data for many injured resources upon which to judge the progress of restoration. However, sufficient evidence exists to suggest that a wide variety of nearshore vertebrate predators and crucial subtidal and intertidal invertebrate prey are not recovered (Table 2, EVOSTC 1994a,b).

1.3 Factors Constraining Recovery

1.3.1 Demography

The rate of recovery of nearshore vertebrate predators may be constrained by oil-related factors (continued toxicity of oil and food availability) as well as non-oil related processes. The latter include death and birth processes as affected by factors such as intrinsic reproductive capacity and mortality due to adverse weather conditions. It may be, for example, that death and birth rates do not differ among injured and non-injured subpopulations of nearshore vertebrate predators, but that the rate of population increase is too slow to have allowed for complete recovery of the injured nearshore vertebrate predator populations. In other words, the nearshore vertebrate predator populations may not be fully recovered, but may be recovering as quickly as possible under naturally-occurring conditions, in the absence of continued effects of oil.

1.3.2 Continued Hydrocarbon Exposure

Today, hydrocarbon impacts may still exist. Between 8-16% of the 10.8 million gallons of crude oil spilled by the *Exxon Valdez* remains buried in marine sediments (Wolfe et al.

1994). Such oil is not subject to degradation by marine organisms and remains in a form that is toxic to many vertebrates (Braddock et al. in press, Tumeo et al. 1994). Moreover, microbial analyses suggest that oil in sediments along oiled shorelines is still several orders of magnitude more common than in unoiled sites (Tumeo et al. 1994). Various bioindicator and health measures suggest that continued injury may be occurring (Table 2).

Studies initiated following EVOS suggest continued biochemical effects potentially related to oil toxicity. Specifically, hematology and serum chemistries performed on blood and serum from sea otters suggested that animals sampled in oiled regions had greater antigenic stimulation (more inflammatory and/or infectious conditions) than did animals from unoiled areas (Rebar et al. 1993; Ballachey, unpubl. data). Indication of an inflammatory response to oil was further supported by observations of elevated concentrations of haptoglobin and interleukin 6 (IL-6) in serum from river otters in oiled areas (Duffy et al. 1994b). Jewett et al. (1994) reported hemosiderosis in demersal fishes from oiled areas. These initial observations support the hypothesis that continued exposure to crude oil may be affecting animal health through chronic or recurrent infections resulting from diminished immune responses. The effects of hydrocarbons on the immune system have been well documented (reviewed in White et al. 1994; Ward et al. 1985).

1.3.3 Food Availability

Biological communities of the nearshore region are functionally distinct from those of pelagic and upland realms by spatial, energetic, and structural considerations. Here, energy is transported from primary producers to apex predators through the sessile, subtidal and intertidal macrofaunal portions of the food chain (e.g., some mollusks and polychaetes) or demersal fishes (e.g., sculpins) to apex demersal predators (e.g., sea ducks and birds, sea and river otters), while in the pelagic zone, energy is transported from phytoplankton to microzooplankton to apex planktivores (e.g., whales) and predators such as salmon (Figure 1a, Parsons 1986). Considerable overlap and potential competition for food exists among the apex predators of the nearshore system (Figure 1b).

There is strong evidence to suggest that population densities of many nearshore vertebrate predators are limited by food. For example, Garshelis (1983) found that after initial immigration of sea otters into eastern PWS in 1979, the population increased rapidly over the next several years. Concurrent with this increase in otters was a rapid decline in many preferred prey items, including Dungeness crabs. Following prey reduction, sea otter populations declined and became relatively stable. Similar patterns have been observed at Amchitka Island (Kenyon 1969) and the Commander Islands (Burdin in press). Kruuk et al. (1991) noted that populations of *Lutra* were limited by the abundance of marine fishes. Other suggestions of food limitation exist for sea ducks (Stott and Olsen 1973).

There is circumstantial evidence that pigeon guillemots nesting at Naked Island in central PWS are food-limited. Historically, Naked Island has been an important breeding area for pigeon guillemots, supporting about 20% of the sound-wide breeding population. Concurrent with a 50% decline in the numbers of breeding guillemots at Naked Island, there has been a decline in growth rates of nestlings (D.L. Hayes, unpubl. data). These declines have been associated with a major diet shift for adult guillemots feeding nestlings. Before the EVOS, over one third of the prey fed to guillemot nestlings was sand lance, and most of the remaining prey items were blennies and sculpins (Kuletz 1983). After the EVOS, nestling diets on Naked Island were dominated by juvenile gadid, a comparatively low-quality prey, and sand lance constituted less than 10% of the diet (D.L. Hayes, unpubl. data). The apparent decline in the availability of a high-quality prey type (sand lance), and its replacement in the diet by prey types with half the energy density (cod, pollock), suggest that pigeon guillemot productivity on Naked Island is constrained at least in part by food availability.

There is evidence that population densities of at least some important vertebrate prey species declined as a result of the EVOS. For example, mussels, which are an important component of the diets of sea otters and sea ducks (Calkins 1978, Estes et al. 1981, Koehl et al. 1982, Sanger and Jones 1982, Vermeer and Bourne 1982, Doroff and Bodkin 1994, Patten 1994) were less abundant at oiled sites relative to unoiled sites following the EVOS (Highsmith et al. 1995). Many of the prey species of the nearshore vertebrate predators, including crabs (Jewett et al. 1994) limpets, chitons, and mussels (Highsmith et al. 1993) have failed to recover fully in some habitats.

The possibility of food limitation of vertebrate predators, coupled with the evidence for injury from the EVOS to prey species, suggests that recovery of some vertebrate populations may be food limited.

1.4 NVP Approach

1.4.1 Species Selection

1.4.1.1 Selection Criteria

We have identified two principal trophic pathways from primary production to apex predators in the nearshore ecosystem. One pathway leads through fishes, the other through benthic invertebrates. We will integrate component studies of apex predators, co-predators (within the invertebrate pathway), and prey with measures of individual and population health and environmental contaminants. This will improve our ability to determine the status of populations relative to recovery, isolate processes constraining recovery, and identify potential activities to facilitate recovery of injured resources. Four vertebrate predator species were selected for study because there was evidence for possible injury from the EVOS and for lack of recovery (see section 1.2 and Tables 1 and 2), they are important members of the nearshore ecosystem in PWS and elsewhere in the spill affected area, they represent species with a varied prey base (Figure 2), and their trophic dependence on nearshore prey items can be effectively measured. These species are sea otter (*Enhydra lutris*) and harlequin duck (*Histrionicus histrionicus*), and fish feeding pigeon guillemot (*Cepphus columba*) and river otter (*Lutra canadensis*). A brief description of the natural history of each species, evidence for injury from the EVOS, their amenability to research and their major foods follows. Also, we provide a rationale for inclusion in the study of primary prey species and brief overviews of previous studies of these prey.

1.4.1.2 Sea Otter

Sea otters live 10-15 years, become reproductive at 2-5 years, and produce single pups about once per year during prime reproductive age (3-9 years). They rely on their pelage rather than fat to maintain body temperature (Costa and Kooyman 1982). This means of thermoregulation requires a high metabolic rate that depends on a high caloric intake (up to 25% of their body mass in prey consumed per day). Constrained by diving limitations to waters < 100 m in depth, sea otters in PWS and elsewhere in the Pacific are distributed along a narrow band of nearshore habitat extending offshore from the intertidal zone. In PWS, about 80% of the sea otters are observed in water depths < 40 m (Bodkin, unpubl. data), with most foraging activity occurring within this depth (Reidman and Estes 1990). Home ranges of sea otters generally include from a few to > 40 km of coastline (Lensink 1962, Kenyon 1969, Garshelis and Garshelis 1984, Reidman and Estes 1990), thereby integrating environmental effects and influencing benthic community structure over large areas. Two consequences of sea otter physiology and habitat requirements are a high susceptibility to contaminants, particularly external oiling (Costa and Kooyman 1982), and a large influence on prey populations. Preferred prey of sea otters include sea urchins, mussels, clams, snails and crabs.

By late 1991, results of three injury assessment studies suggested that effects from the spill were continuing (Ballachey et al. 1994): the age class distributions of sea otters dying were abnormal relative to pre-spill data (Monson and Ballachey 1994), post-weaning survival was low, and surveys revealed no increase in abundance in oiled areas. By late 1993, juvenile survival had increased and mortality patterns appeared to begin returning to normal. However, surveys of abundance failed to detect increases of sea otters. Analyses of data from a new aerial-survey methodology implemented in 1992 indicate that densities of sea otters are up to an order of magnitude lower in areas of PWS where oiling was most severe and persistent and where sea otter mortality was high, and suggest that recovery had not occurred by 1994.

Sea otters are a good choice for investigating processes constraining recovery of the nearshore ecosystem for several reasons: 1) they reside nearshore and their activities (including food habits) can be quantified from shore, 2) their predominant prey are sedentary bivalves whose abundance and size class distribution can be easily measured, 3) effects of the EVOS are well documented, including both immediate and chronic injuries, 4) baseline data on sea otter population demographics, physiological indices and their prey are available specifically for PWS, 5) tools are available for unbiased and precise estimates of sea otter density, and 6) the role of sea otters in structuring invertebrate prey is well understood and provides an opportunity for not only a separate means of evaluating the status of the population, but also identifying potential mechanisms constraining recovery.

Proposed sea otter studies will include assessments of abundance, reproduction, mortality, prey selection, bioindicators and individual health. Measures of population status will be integrated with the abundances and size class distributions of marine invertebrates that compose most of the diet of sea otters.

1.4.1.3 Harlequin Duck

Harlequin ducks, like other sea ducks, are long-lived with relatively low annual reproductive output (Goudie et al. 1994). Breeding philopatry of sea ducks is high (e.g., Savard and Eadie 1989). If wintering site fidelity also is high (Limpert 1980, Goudie, pers. comm.), winter survival would directly influence annual changes in specific wintering populations. Because harlequin ducks spend much of their annual cycle on wintering areas, assessments of limiting factors during that period are valuable for determining population health and sustainability.

Harlequin ducks suffered direct oiling mortality during the initial stages of the oil spill and were at high risk during the spill because of the high numbers occupying PWS during March (Agler et al. 1994). Continued oil effects might have affected harlequin duck recovery. Patten (1994) found hydrocarbon metabolites in harlequin ducks collected from the oiled area, and also suggested that reproductive effort and productivity of harlequin ducks were lower in oiled areas.

Harlequin ducks are inextricably linked to nearshore habitats. They are spatially limited by foraging depth and occurrence of prey. Harlequin ducks feed on a diverse array of nearshore benthic invertebrates (Dzinbal and Jarvis 1982, Goudie and Ankney 1986, Goudie and Ryan 1991, Patten 1994). In general, sea ducks may be sensitive to constraints on food quality and availability because of the severe weather encountered in northern wintering areas; this may be especially true for harlequin ducks due to their small body size (Goudie and Ankney 1986). Life-history traits of harlequin ducks, coupled with the concentration of oil-spill injury on nearshore habitats, suggest that these birds will be particularly sensitive indicators of system health.

Proposed studies focus on assessments of differences in harlequin duck population health between oiled and unoiled study sites. This will include measures of female overwinter survival, harlequin duck abundance relative to prey resources, body composition and bioindicators of molting harlequin ducks, and distribution and habitat associations of wintering harlequin ducks.

1.4.1.4 Pigeon Guillemot

Guillemots are the most neritic members of the marine bird family Alcidae, which includes murres, puffins, and auks. Guillemots first breed at 2 years of age and adults have high annual survivorship (85%, Asbirk 1979). Young guillemots normally return to the natal area to breed. Nest site fidelity of breeding pairs is high and even in instances when pairs relocate nests, the distances involved are usually small (< 30 m). Eggs are laid in a wide variety of natural crevices and holes, but most nest sites in the study area are located in cavities in rock masses (K. Kuletz and K. Oakley, pers. comm). Eggs are usually laid about 50 cm from the entrance of the nest crevice (Asbirk 1979), thus eggs, chicks, and attending adults are frequently accessible for data collection. Guillemots are unusual among alcids in that they normally lay two-egg clutches and raise two chicks per nesting attempt. 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, if necessary, collected for contaminant analyses.

As of 1994, results of damage assessment studies indicated that the pigeon guillemot population on Naked Island is continuing to decline. Naked Island is a major guillemot breeding colony site in PWS and has been the site of breeding biology studies since the late 1970s. The diet of guillemot nestlings on Naked Island has changed considerably from the pre-spill period, and growth rates of nestlings have declined (D.L. Hayes, pers. comm.). Nestling growth rates are currently lower than those on Jackpot Island, a colony in PWS that was not oiled.

Pigeon guillemots are a well-suited species for monitoring nearshore ecosystem health for several reasons: 1) they are a common and widespread seabird species breeding in coastal Alaska, and in PWS specifically (Sowls et al. 1978, Sanger and Cody 1993); 2) they forage within 5 km of the nest site in the subtidal and nearshore zones (Drent 1965, Kuletz 1983); 3) unlike most seabird species, they do not breed in large, dense colonies; 4) they raise their young almost entirely on fish, preying primarily on nearshore demersal fish (e.g., blennies, sculpins) and on nearshore schooling fish (e.g., sandlance; Drent 1965, Kuletz 1983); and 5) the one- or two-chick broods are fed in the nest until the young reach adult body size.

Research is currently underway by project investigators (Roby, Duffy, and Bowyer) to assess pigeon guillemots as an avian bioindicator for coastal ecosystems in Alaska. This research is being conducted in Kachemak Bay, Alaska, and will provide crucial baseline information for the proposed work in PWS.

Proposed pigeon guillemot studies will include assessments of numbers of breeding pairs, reproductive success, nestling growth rates, fledgling condition indices, blood biomarkers of contaminant exposure, and other indices of individual health. Indices of reproductive success will be integrated with nestling provisioning rates, taxonomic composition of the diet, and the abundances of these fish taxa in foraging areas near nesting aggregations. Prey taxa will be assessed for evidence of exposure to petroleum hydrocarbons, including cytochrome P450. In addition, we will estimate the abundance of prey within the foraging range.

1.4.1.5 River Otter

River otters inhabiting marine environments make extensive use of, and concentrate their activities in, intertidal and subtidal zones (Larsen 1984, Woolington 1984, Dubuc et al. 1990, Bowyer et al. 1994). These high trophic-level carnivores are long-lived ($\geq$ 12 years; Docktor et al. 1987), and occur at densities of 0.2-0.8 otters/km of shoreline throughout the Gulf of Alaska (Testa et al. 1994). River otters are extremely sensitive to aquatic pollutants, yet continued to reside within the area of oil-contaminated shorelines in PWS, Alaska following the spill (Testa et al. 1994). These characteristics make river otters an excellent model for assessing effects of marine pollution on mammals, and provide an overall index to the health of the nearshore ecosystem.

River otters living in marine environments consume a diet dominated by marine fishes, which they prey upon in intertidal and subtidal zones; they also consume a wide variety of marine invertebrates (Larsen 1984, Stenson et al. 1984, Bowyer et al. 1994). Such nearshore areas are the most often affected by pollution. For instance, the spill contaminated extensive areas of the intertidal and subtidal environments, which was reflected in a loss of dietary diversity for otters inhabiting oil-contaminated shorelines (Bowyer et al. 1994). Likewise, river otters living in oiled areas exhibited a significantly lower body mass (when controlled for sex and total body length) than did otters inhabiting unoiled areas (Duffy et al. 1993). Otters have extremely large home ranges (20-40 km of shoreline--Bowyer et al. 1995), and hence integrate effects of pollution over wide areas.

Population dynamics of European otters (*Lutra lutra*) in coastal areas have been linked to the abundance of marine fishes (Kruuk et al. 1991); this is also likely the case for river otters inhabiting PWS. Bowyer et al. (1994) previously demonstrated that diversity of otter diets declined significantly following the spill. Similarly, body mass of otters was significantly lower on oiled, compared with unoiled, areas of PWS (Duffy et al. 1993, 1994b).

Proposed river otter studies will include assessments of abundance, morphometrics, and bioindicators of individual health. Indices of population status will be integrated with the abundances of marine fishes that compose most of the diet of river otters.

1.4.1.6 Invertebrates - Clams

Clams are an abundant and diverse component of the benthic invertebrate fauna of PWS, and the predominant prey of sea otters in PWS (Calkins 1978, Estes et al. 1981, Doroff and Bodkin 1994). All major nearshore sediment types in PWS support significant densities of clams. Species most commonly recognized in the diets of nearshore vertebrate predators are in four families: Veneridae: *Saxidomus giganteus* and *Protothaca staminea*; Myidae: *Mya truncata* and *Mya arenaria*; Mactridae: *Tresus capax*, and Tellinidae: *Macoma* spp. Venerids, myids, and mactrids are filter feeders while tellinids are deposit feeders. All clams listed here have a planktonic larval phase, and thus are subject to significant interannual and spatial variation in recruitment intensity in response to changing oceanographic conditions.

Houghton et al. (1993b) noted that densities of the little neck clam, *Protothaca staminea*, were lower at oiled (their "oiled" sites included "oiled/washed" and "oiled/not washed") than at unoiled sites in PWS following the EVOS. Recovery status of PWS clam resources is listed as "unknown" (Table 1). Hydrocarbon content of subtidal clam tissues did not reflect spill effects two years after the EVOS, and the EVOS apparently did not affect the representation of clams in sea otter diets in 1991 (Doroff and Bodkin 1994).

We will compare abundance, size distribution, and recruitment characteristics of predominant subtidal and intertidal clam populations in areas where sea otters have failed to recover from the EVOS with areas where sea otters apparently were not affected by the EVOS. Based on available information regarding clam-sea otter interactions, we expect two general outcomes for the EVOS-affected area. If clam populations include high densities of large individuals (maximum shell lengths exceeding 5-7 cm), we will conclude that food is not limiting sea otter recovery in the area. If clam populations do not include numerous large individuals and densities are relatively low, then we will conclude that food supply may be limiting sea otter recovery. In the latter case, two causal mechanisms are possible, both of which will be evaluated by our studies. Chronic recruitment failure or foraging by invertebrate predators could limit clam population size. Alternatively, residual effects of the spill also may limit clam population size. In addition, effects of co-predators (sea ducks and sea stars) will be examined.

1.4.1.7 Invertebrates - Sea Urchins

Sea urchins are a favored food of sea otters. There is strong evidence that the increase in otter populations in Alaska in the 1970's, led to a general reduction in sea urchin abundance (Dayton 1975, Estes et al. 1978, 1989, Duggins 1980). There are no quantitative subtidal surveys of sea urchin densities in PWS prior to immigration of sea otters. However, surveys conducted prior to the EVOS in the mid 1970's (Rosenthal et al. 1977) as well as those conducted after the spill (Jewett et al. 1994) suggest that there were few urchins present within the areas examined in the Sound, and that the few urchins observed were small and lived in cryptic habitats (under cobbles and boulders).

There is some evidence that sea urchin populations may be increasing in parts of PWS that were heavily oiled and now have relatively few sea otters. Anecdotal observations suggest increases in some intertidal and shallow subtidal habitats within Bay of Isles in 1993. No such aggregations were noted in extensive subtidal surveys in PWS in 1989 through 1991, and there were no aggregations observed at any unoiled sites in 1993. We suspect that such increases may result from reduced predation by sea otters. If the pattern of increased urchin abundance in oiled areas is documented, this would provide evidence that recovery of sea otters is limited by factors other than food availability.

Proposed assessments of sea urchins will include collection of abundance, size distribution, growth rate, and recruitment data at unoiled sites with large numbers of sea otters, and at oiled sites with few sea otters.

1.4.1.8 Invertebrates - Crabs

Crabs can make up a significant portion of the diet of sea otters (Calkins 1978). Following the immigration of sea otters into Prince William sound in the early 1970's, Dungeness crab population densities within the Sound declined markedly, presumably as the result of sea otter predation (Garshelis 1983). These and other cancer crabs are now rarely seen within the Sound. The helmet crab, *Telmessus cheriagonus*, is now the most abundant crab in the nearshore zone within the Sound (Jewett et al. 1994) and can make up a sizable fraction of the sea otter's diet (Doroff and Bodkin 1994). Helmet crabs were less abundant at oiled than at unoiled sites within shallow subtidal habitats following the EVOS, and populations had not fully recovered by 1993 (Jewett et al. 1994).

We will assess the abundance of all crab species at oiled (low otter density) sites and unoiled sites within the Sound.

1.4.1.9 Invertebrates - Mussels

Mussels are commonly eaten by sea otters in PWS, and generally represent a much higher proportion of the diet of juvenile sea otters than adults (Johnson 1987; Doroff and Bodkin 1994). Because mussels occur in the intertidal zone and require little effort to capture, they can be obtained readily by sea otters (Estes et al. 1981; VanBlaricom 1988). However, their caloric content is relatively low and they are not considered to be as valuable as many other sea otter prey (Garshelis 1983). Mussels also are important prey for a number of sea duck species (Koehl et al. 1982, Sanger and Jones 1982, Vermeer and Bourne 1982, Patten 1994).

Mussels have been the subject of a number of studies in PWS. However, extensive surveys of mussel abundance have been conducted only after the EVOS. Two major studies conducted after the EVOS included an examination of mussel populations in PWS. Houghton et al. (1993b, 1993c, 1993d, and 1993e) estimated abundance of *Mytilus* along with other epifauna at 21 locations in western PWS in 1991-92. Houghton et al. (1993b, 1993d) found no overall difference in abundance of *Mytilus* at unoiled beaches compared to beaches that had been oiled during the EVOS or oiled and subsequently cleaned with a hot-water wash treatment, although mussels suffered high mortality at certain stations that received high-pressure hot-water-wash treatment. Houghton et al. (1993c) present size-frequency data for *Mytilus* at 10 locations in PWS in May, July, and September 1991. Length-weight analysis of these mussels indicated that those at oiled sites did not appear to spawn in 1991. Mussels at oiled sites which were subsequently cleaned may have delayed spawning and spawned fewer times than mussels at unoiled sites (Houghton et al., 1993b). Houghton et al. (1993b) found that mussel populations in PWS exhibited a large amount of variation in the rates of growth of individuals.

VanBlaricom (1987, 1988) also found significant variation in growth rates and size distributions between populations of mussels at three locations in PWS prior to the oil spill. However, differences in growth rates could not account for the differences in size distributions between mussel populations. VanBlaricom (1987, 1988) concluded that mussel size distributions at his study sites were affected by sea otter predation.

Highsmith et al. (1993) estimated abundance and biomass of *Mytilus* at nine sites in PWS in late summer/early fall 1989 and in spring/summer 1990 and 1991. They found that *Mytilus* abundance at control sites exceeded that at oiled sites depending on habitat and tidal height (Highsmith et al. 1995). The size-frequency distribution of mussels was studied after the spill at three pairs of sites in Herring Bay by Institute of Marine Science biologists, but analysis of the data from that study is not complete (S. M. Saupe, pers. comm.).

Other studies of *Mytilus* that have been conducted in PWS have measured concentrations of petroleum hydrocarbons in mussel tissues before and after the EVOS (Karinen et al. 1993, Babcock et al. 1994). Neither study examined mussel abundance or size frequency distributions. Babcock et al. (1994) identified ten oiled mussel beds within the geographical areas proposed for the present study. Shigenaka and Henry (1994) compared hydrocarbon uptake by mussels with that by a semipermeable membrane device at a heavily oiled and extensively treated site on Smith Island. They concluded that sheens that had leached from subsurface deposits of residual oil, and particulate matter to which hydrocarbons were adsorbed were apparently more important exposure pathways than hydrocarbons dissolved in water. Keiser (1978) studied reproductive phenology, settlement, and growth in *Mytilus* in Port Valdez. She found that growth was seasonal with the most growth beginning in May after spawning and during the period when gametogenesis had ceased.

This component of the study will compare abundance and size-distribution of mussels in oiled areas where sea otters have failed to recover after the EVOS (e.g. northern Knight Island) with those in unoiled areas where sea otters were not appreciably affected by the EVOS (e.g., northwest Montague Is.). Food availability may be limiting recovery of sea otters in western PWS if three conditions are observed: (1) large mussels are reduced in abundance; (2) size frequency distribution of mussels is similar to that observed at areas where sea otters have not suffered reductions in abundance; and (3) alternate prey are not available, especially to young sea otters and females with dependent pups. If food availability is not limiting recovery of sea otters in PWS then large mussels should be abundant in western PWS. Abundance and size distribution of mussels in Barrow's goldeneye (*Bucephala islandica*) and white-winged scoter (*Melanitta fusca*) diets will be determined to understand the role of predation by these sea ducks in structuring mussel populations, with implications for interpretation of above-mentioned relationships between sea otters and mussels.

1.4.1.10 Pigeon Guillemot and River Otter Prey - Fishes

Both river otters and pigeon guillemots feed primarily on small benthic fishes common in the intertidal and shallow subtidal regions. Thus, assessing abundance of these fishes is necessary for understanding the role of food limitation is constraining recovery of these predators.

River otters in coastal Alaska have a broad diet consisting of a number of marine fishes and invertebrates common in the intertidal and shallow subtidal regions. Studies of river otters in PWS after the EVOS indicate that nearly 150 prey taxa are present in otter diets, with demersal fishes dominating in importance (Bowyer et al. 1994). The most commonly taken fishes are of the orders Gadiformes (Pacific cod, *Gadus macrocephalus*; Pacific tomcod, *Microgadus proximus*; walleye pollock, *Theragra chalcogramma*), Perciformes (searcher, *Bathymaster signatus*; crescent gunnel, *Pholis laeta*; Pacific sand lance, *Ammodytes hexapterus*), and Scorpaeniformes (greenlings, Hexagrammidae; sculpins, Cottidae; and poachers, Agonidae). Other marine food groups of lesser importance include gastropods, bivalves, and crabs. Diets of river otters from oiled areas changed after the EVOS (Bowyer et al. 1994). Fewer species were present in the diets of otters in oiled areas after the spill. Prey taxa that showed significant declines in the diets of otters at oiled sites relative to unoiled sites after the spill included perciform fishes (searcher, crescent gunnel, and Pacific sand lance) and Archaeogastropoda (keyhole limpets and the snail *Margarites* spp.). Bowyer et al. (1994) hypothesized that the change in diet may have resulted in reduced body mass that was noted in otters from an oiled area relative to an unoiled site (Duffy et al. 1994b).

They also speculated that oil in food items may have been responsible for toxicological effects in otters, as manifested by increased haptoglobins noted in otters from oiled areas (Duffy et al. 1994b).

Numerous investigations have revealed that the fish brought to the nesting pigeon guillemots chicks by the adults are primarily intertidal and nearshore bottomfishes (e.g., gunnels, sculpins) and nearshore schooling fish (e.g., sand lance) (Thoresen 1958; Drent 1965; Kuletz 1983; Emms and Verbeek 1991). In 1979-81 chicks in Prince William Sound were mainly fed sand lance, gunnels, pricklebacks and cottids, although a variety of other fishes were also taken (Kuletz 1983). Further south, along coastal British Columbia, the majority of fishes delivered to the chicks in 1984 and 1985 were either blennies (gunnels) or sculpins; sand lance and other fishes were less common (Emms and Verbeek 1991). In winter, after the chicks fledge, a substantial portion of the pigeon guillemot population leaves PWS and disperses throughout coastal Gulf of Alaska (D. Roby, R. Day, Pers. Commun., 1995).

Pigeon guillemots feed in the nearshore zone and eat a variety of fishes. The most common prey items that were brought to guillemot nests on Naked Island in 1994 were predominantly juvenile gadids, followed by pricklebacks, gunnels, sculpins and sand lance (D.L. Hayes, unpubl. data). The diet composition of guillemot nestlings on Naked Island has not always been dominated by juvenile gadids. In the late 1970's and early 1980's, the dominant prey types were sand lance, blennies (including pricklebacks and gunnels), sculpins and herring/smelt (Kuletz 1983).

There have been no studies on the availability or condition of pigeon guillemot or river otter prey that would allow one to make direct links between the effects of oil on prey and subsequent impacts on the predators. However, there are some data from independent studies in PWS that suggest that the abundance of some prey items in the diets of pigeon guillemots and river otters were reduced by oiling. Jewett et al. (1994) noted that gunnels were generally less abundant at oiled sites in 1990 and 1991, but did not differ significantly among treatments (oiled vs. unoiled).

There is also some evidence to suggest that prey items, especially intertidal ones, may be contaminated with oil, and may serve as a pathway of contamination of river otters. Gunnels collected in the shallow subtidal from oiled sites in 1993 had evidence of hemosiderosis in their tissues, an indicator of exposure to oil (Jewett et al. 1994).

Proposed studies of fish prey will include estimates of abundance at oiled and unoiled sites, and levels of cytochrome P450 within selected prey species.

1.4.2 General Approach

Our overall intent in this proposed study is to examine the status of recovery of nearshore vertebrate predators. As discussed above (section 1.3) the three factors most likely to be limiting recovery are intrinsic demographic constraints, continued hydrocarbon exposure, and food limitation (Figure 3). Demography will be examined by comparing population densities and parameters affecting population growth rates between oiled and unoiled sites. The question of continued exposure to oil will be assessed by comparing indicators of exposure to oil and individual health between oiled and unoiled sites. Food limitation will be considered by examining population densities and size class structures of dominant prey species. Concurrently, these studies will provide information regarding the status of recovery.

1.4.2.1 Demography

Analysis of change in vertebrate populations can be approached from several perspectives (Caughley 1977), including estimates or indices of abundance. Population abundance data provide evidence of direction and rate of change in numbers of individuals, but offer little insight into underlying processes responsible for any observed change. Data on measures of fecundity, survival, or dispersal enhance the identification of processes significant to changes in abundance.

Abundance of nearshore vertebrate predators will be measured at oiled and unoiled sites to compare recovery between these areas. In addition, we will measure demographic parameters (e.g., growth, survival, reproduction) in selected species to assess population health and also to determine if recovery of injured resources is proceeding at a rate that would be expected in the absence of continued oil toxicity or food limitations related to the effects of oil.

To assess whether recovery is proceeding as quickly as possible, considering no oil related limits to population growth rates, we will measure demographic factors of vertebrate predators and determine whether population growth rates and demographic parameters are consistent with models predicting growth rates in the absence of oil or food limitation effects. Studies of demographic factors also may provide insight into mechanisms of constraints on recovery, and to possible linkages between a lack of recovery and impacts of oil toxicity or food limitation. As an example, poor survival of pigeon guillemot chicks at oiled sites, coupled with a lack of preferred food items being brought to the nest at these sites, and a limited supply of these food items in oiled foraging areas would lend strong support to the hypothesis that food is limiting to pigeon guillemot recovery.

Demographic parameters to be measured will differ among nearshore vertebrate predators due to logistic and ecological considerations. For example, reproductive success can be effectively assessed only for sea otters and pigeon guillemots. However, overwinter survivorship is an appropriate measure of population health for harlequin ducks, because survival is thought to have a greater influence on population growth than annual reproductive success (Goudie et al. 1994) and numbers of harlequin ducks increase substantially in PWS during winter.

1.4.2.2 Population Health

Health of predator populations and the related issue of continued oil exposure will be assessed using a variety of measurements. These will allow for an assessment of the status of recovery of injured populations that is independent of measures of recovery based on population abundance or demographic data. This independent assessment of recovery may also provide a view of potential for recovery and long term population health that can not be evaluated by abundance or demographic characteristics. Measurements to be collected include assays of immune function, conventional hematology, cytochrome P450 levels (an enzyme indicative of continuing exposure to aromatic hydrocarbons), hydrocarbons, body condition and morphometrics.

Focusing on biological responses overcomes many limitations that plague chemical analysis of the environment (Payne et al. 1987). Measurement of tissue hydrocarbon burdens has been an important aspect of previous oil spill studies on top predators. However, potential advantages of measuring biomarkers include: (1) they may provide evidence of exposure to compounds that do not bioaccumulate or are rapidly metabolized; (2) they integrate the toxicological interactions resulting from exposure to complex mixtures of contaminants; (3) they present a biologically relevant measure of the cumulative adverse effect; and (4) they measure early responses of organisms to toxicant exposure and serve as short-term predictors of long-term adverse effects.

Over the past decade, the immune system has been increasingly investigated as a target organ system for assaying toxic damage (Luster et al. 1988, 1992). The immune system is an active and complex process dependent on the interaction of a diverse group of cell types and soluble factors orchestrated into a functional response. These inherently active and complex processes make the immune system especially sensitive and susceptible to toxic damage. Toxicity may occur either as a direct effect on immune function or as an indirect effect through an aberrant or abnormal immune response in the form of a hypersensitivity or allergic reaction. In those instances in which the immune response is a direct target, the result is most often expressed as an increased susceptibility to infections. Additionally, the direct effect also may be expressed as an autoimmune disease or neoplasia.

General methods to evaluate the mammalian immune system have been established and are available for most species. Assays are typically divided into those that evaluate the overall function of the immune system and those that evaluate specific components of the immune system (Luster et al. 1988). To document an effect on the immune system, the initial focus is on tests to detect gross effects. Tests in this category include: (1) conventional hematology; (2) serum immunoglobulin quantitation; and (3) in vitro lymphocyte proliferation assays. Most immune abnormalities are characterized as a suppressed response, although in some instances a hyper-response may be noted. Based on the results obtained in screening tests for gross effects on the immune system, specific functional tests can be performed to determine the exact parameter (organ system, cell or soluble factor) that is responsible for the noted abnormal response. A number of these specific tests have been adapted to or are being validated for the species we propose to evaluate, and could be utilized if warranted based on initial results of overall immune function tests.

The cytochrome P450 assays directly address the question of continued exposure to oil. Cytochromes P450 are a group of enzymes that metabolize a wide variety of endogenous and xenobiotic compounds (Appendix 6.2). One subgroup of these enzymes, the P450-1A family, is specifically induced by planar aromatic or chlorinated hydrocarbons, and thus its presence serves as a bioindicator of hydrocarbon exposure. While we can assess the exposure of predators to oil directly by measuring hydrocarbon levels in prey, the use of biomarkers may provide a more sensitive indicator to exposure via oil-contaminated prey, as well as indicating exposure via other routes (e.g., ingestion from grooming oiled pelage). Hydrocarbon levels in prey species are highly variable in time and space, and estimation of hydrocarbon levels in a small sample of available prey may not reflect true levels of exposure. In addition, vertebrate predators quickly metabolize hydrocarbons so that it may not be practical to measure exposure by measuring hydrocarbons in the predators' tissues.

Tissue samples from harlequin ducks collected in oiled and unoiled areas of PWS in 1993 showed differences in levels of P450 induction (R. Spies, pers. comm.). We will apply P450-1A assays to tissue samples collected from the four predator species, and in selected fish species that are prey to both pigeon guillemots and river otters. An additional measure of oil contamination, through ELISA assay for external oil on pelage or plumage (J. Mazet, pers. comm.), will be evaluated.

Body composition provides another assessment of health, as poor body condition may result in depression of population growth rates through affects on survival or reproductive effort. Exposure to contaminants can result in poorer body condition (e.g., Peakall et al. 1980, Hohman et al. 1990) and, even if immediate effects are not lethal, cause a reduction in subsequent rates of survival and reproductive success. Thus, we will examine variation in body composition as measures of the health of harlequin duck and pigeon guillemot populations.

1.4.2.3 Evaluation of Food Availability

The hypothesis that food availability may be limiting recovery of nearshore vertebrate predators will be addressed primarily by examining abundance of major prey items in oiled and unoiled areas. As indicated previously, there is strong evidence to suggest that at least some prey species may be less abundant at oiled sites. These include mussels, limpets, and littorines (Houghton et al. 1993b,d, Highsmith et al. 1993) which are food for both sea otters and harlequin ducks (Calkins 1978, VanBlaricom 1987, 1988, Patten 1994). Two favored foods of sea otters are *Protothaca staminea* and *Saxidomus giganteus* (Calkins 1978, VanBlaricom 1987, 1988). Houghton et al. (1993b,d) found fewer *P. staminea* at oiled and high-pressure hot water washed sites than at control and oiled sites; Jewett et al. (1994) found fewer *S. giganteus* at oiled sites. Evidence for an adverse effect of oil on fish species is less compelling although possible reductions in gunnels, a prey of both river otters and pigeon guillemots, have occurred within some oiled habitats.

Evaluation of abundance and size distribution data for prey items also will be useful for providing additional indirect evidence for a lack of recovery of some predator species. For example, it is well documented that sea otters prefer sea urchins as prey and that in the presence of strong predation by sea otters, both the abundance and average size of sea urchins is reduced (Figure 4).

However, evidence of lack of recovery of predators based on differences in abundance and/or size of prey may be confounded by several factors. First, many of the prey species serve as food for more than one predator. For example, mussels are prey of sea otters as well as sea ducks and sea stars (*Pycnopodia helianthoides* and *Evasterias troschelii*), and mussel size class distributions overlap in all of their diets. Second, differences in abundance of prey among sites may be due to differences in either recruitment or growth of prey, as well as predation. To account for these factors, it will be important to assess the relative impact of various predators on prey items, and to assess both recruitment and growth of the prey at the oiled and unoiled sites.

While not the primary focus of our efforts here, information obtained in assessing food limitation of nearshore vertebrate predators also will shed light on the question of "what structures nearshore benthic invertebrate communities?". While competition for space, rather than for food, broadly limits sessile filter-feeding invertebrates (Branch 1984), evidence has accumulated suggesting that predation frequently surpasses competition in structuring marine intertidal and shallow subtidal invertebrate communities (O'Clair and Zimmerman 1987). For example, the invertebrate predatory sea star has been the focus of considerable study as a structuring agent (Menge 1982, Paine et al. 1985; see review in O'Clair and Zimmerman 1987). Similarly, the vertebrate sea otter is also well documented as a force in structuring the organization of the nearshore benthic community (see review in O'Clair and Zimmerman 1987). For example, Estes and Palmisano (1974) compared the nearshore communities between areas with and without sea otters and focused on the preferred prey of sea otters, the sea urchin (*Strongylocentrotus*). Sea urchins, themselves, can cause large-scale kelp bed destruction (VanBlaricom and Estes 1988). In the presence of sea otters, Estes and Palmisano (1974) and Palmisano and Estes (1977) found urchins (a preferred prey item) were reduced and smaller (Figure 4). This reduced urchin biomass was accompanied by extensive kelp beds; mussels, barnacles, limpets and other invertebrates were reduced and ichthyofauna increased in abundance. Alternatively, in the absence of sea otters, they found larger and more abundant sea urchin populations, reduced kelp beds and more abundant mussels.

Other predators, such as sea ducks, also may structure invertebrate populations, although there are fewer data addressing this than for sea otters. For example, Bourne (1984) estimated that a flock of 200 scoters could consume 5.3 to 15.9 tons of clams during winter, and Faldborg et al. (1994) suggested that sea ducks were responsible for a dramatic decline in intertidal mussel populations in Denmark. Given the high number of sea ducks in PWS (Agler et al. 1994) and their reliance on benthic invertebrate prey, it seems likely that they may be having important effects on prey community structure.

2.0 Project Descriptions

2.1 Objectives - General

General objectives of the study are stated as follows:

A. Determine status of recovery of injured populations of nearshore vertebrate predators.

A.a. Determine if there are differences in abundance or indices to abundance between oiled and unoiled areas.

A.b. Determine if there are differences between oiled and unoiled areas with respect to demographic characteristics of nearshore vertebrate predator populations.

A.c. Determine if there are differences between oiled and unoiled sites with respect to measures of health of nearshore vertebrate predator populations.

A.d. Determine if there are differences in abundance or size distribution of prey between oiled and unoiled sites.

B. Determine if recovery of nearshore vertebrate predators is constrained by demographic factors unrelated to oil toxicity or food supply.

C. Determine if recovery of nearshore vertebrate predators is constrained by continued oil toxicity.

C.a. Determine if there are differences between oiled and unoiled sites with respect to bioindicators of exposure to oil in nearshore vertebrate predators.

C.b. Determine if bioindicators of exposure to oil differ between prey collected from oil and unoiled sites.

C.c. Determine if hydrocarbon levels in prey species differ between oiled and unoiled sites.

D. Determine if recovery of nearshore vertebrate predators is constrained by food availability.

We will address all major objectives for each of the 4 predators selected for study. Methods are detailed in sections 2.3 to 2.8.

2.2 General Study Design, Methods and Study Areas

The generalized study design calls for comparing predator abundance, demographic measures, health, indicators of oil exposure, and prey abundance within a selected oiled area and a selected unoiled area (Table 3). We are constrained to using selected areas, rather than a random sample of all potential oiled and unoiled areas for several reasons. First, the mobility of nearshore vertebrate predators makes it difficult to clearly define subpopulations of these species within PWS. For example, sea otters can range up to 40 km, making it difficult to select clearly defined replicate "oiled" subpopulations. Second, habitats within PWS are extremely diverse, making it difficult to segregate effects of oiling from other environmental factors, especially in cases where habitats in oiled and unoiled areas are clearly different. For example, it would be difficult to examine the effects of availability of sea urchins on sea otter abundance by comparing sea urchin density in the oiled area around Knight Island with an unoiled area from the extreme western portion of PWS because of potentially significant differences in exposure, oceanography, and geomorphology. The extreme western portion is heavily influenced by glacial runoff, and the resulting low salinity in this region likely would preclude establishment of sea urchins even in the absence of otters. Third, the areas representing the total of all oiled and unoiled areas are extremely large, and it would be impossible to effectively sample from the entirety of these areas given reasonable monetary constraints.

In using selected sites, we are restricted to making statistical inferences to these sites only, and not to the oiled and unoiled areas as a whole. Extrapolation of results to the broader oiled and unoiled parts of the sound will therefore rely on "best professional judgement". However, given the alternative of what would assuredly be an unworkable experimental design, we feel this is the only reasonable approach.

Study sites will be within generalized "oiled" and "unoiled" areas. The oiled area is identified as the Naked Island-Northern Knight Island group (Figure 5). Oiling was heaviest here, and population levels of sea otters were much lower here than at unoiled sites in PWS (Table 4). Harlequin duck densities also appear to be lower in this area. The unoiled sites will be along the northwestern shore of Montague Island (for sea otters and harlequin ducks) and around Jackpot Island (for river otters and pigeon guillemots). The unoiled sites are on the periphery of oiled areas.

More specific study locations will be selected from within each generalized area. For sea otters and harlequin ducks, we will focus on an oiled area on Naked and Northern Knight Island (area N, Figure 5) and an unoiled area on Montague Island (area M, Figure 5). These represent areas where we have estimates of population density for both harlequin ducks and sea otters, and are areas representative of foraging grounds for oiled and unoiled subpopulations of sea otters and harlequin ducks within the Sound.

The selected oiled area for sea otter and harlequin duck studies is composed of two, non-contiguous sites: one in Herring Bay and the other in Bay of Isles. We have chosen these two sites, rather than one contiguous site on either the eastern or western sides of Knight Island for several reasons. First, studies of sea otter abundance suggest that most sea otters occur within these bays rather than on more exposed coasts outside of the bays. Second, by including both bays, we believe that the extent of different intertidal and subtidal habitats will be comparable among oiled and unoiled areas. Soft sediment habitats are extensive at the Montague site, but relatively rare in oiled areas. Areas outside of the bays on Knight Island are generally sharply sloping rock faces, habitats not well represented on Montague. By restricting sampling to one contiguous oiled site, we suspect that available habitat for sampling of some otter prey, especially soft-sediment dwelling clams, would be severely limited. Finally, inclusion of the Herring Bay and Bay of Isles sites will provide a strong historical data base on the populations of both predators and prey. These are among the most extensively studied oiled sites within PWS.

For pigeon guillemots, selected study locations include approximately 10 km of shoreline which are feeding grounds for the birds. These are within a 4 km radius of two known areas of nesting for pigeon guillemots: one is an oiled area on Naked Island, and the other is an unoiled site near Jackpot Island (Area J, Figure 5).

For river otters, the selected study locations include an approximately 25 km section of shoreline in Herring Bay (oiled) and a 25 km section of shoreline near Jackpot Bay (unoiled). These both represent reasonable river otter habitat areas with old growth forest to the water's edge. The Herring Bay site was selected because there are historical data here for otters (Bowyer et al. 1994, Testa et al. 1994).

We have selected sites to maximize sampling efficiency from a logistical perspective as much as possible. For example, sea otter and harlequin duck study sites overlap completely and oiled study sites for river otters overlap with a part of oiled study sites for sea otters and harlequin ducks. However, complete overlap was not possible because no one site had appropriate habitat for all predator species.

The following sections describe methods that are general to several of the sudy species (e.g. various health and oil exposure methods, and habitat characterizations) as well as species specific methodologies. Detailed standard operating procedures are on file and available upon request.

2.3 General Methods for Determining Health and Exposure to Oil

2.3.1 Rationale

As indicated in section 1.4.2.2, we will examine a common suite of biomarkers for each of the nearshore vertebrate predator species to determine the health and oil exposure of oiled and unoiled populations. Health will be evaluated through hematology and immune function assays as well as morphometrics (weights, lengths, etc.) and, for harlequin ducks and pigeon guillemots, body composition measurements. Oil exposure will be evaluated by measurements of cytochrome P450-1A's, enzymes that are specific indicators of exposure to aromatic hydrocarbons (Appendix 6.2). P450 assays will be done for the four predator species and on vertebrate prey (selected fish species). Additional tests of oil exposure will include ELISA assay of pelage or plumage swabs and, if warranted based on outcome of P450 assays, analysis of hydrocarbon levels in tissue samples. A list of the assays to be performed, laboratory or location of the work, and candidate species are given in Table 5.

General methods for assessing health and oil exposure are presented below. Methods specific to each species will be addressed in sections 2.5 to 2.8.

2.3.2 Methods

2.3.2.1 Collection of Blood Samples

Samples will be collected at capture from sea and river otters (30 ml) by standard jugular venipuncture techniques, and from pigeon guillemots (1 ml) and harlequin ducks (2 ml) by brachial or jugular venipuncture. Blood volumes collected on sea and river otters will be sufficient to conduct conventional hematology, immune function and cytochrome P450 assays. For harlequin ducks and pigeon guillemots, because blood volumes will be limiting, the primary focus will be on conventional hematology.

Because Barrow's goldeneyes and white-winged scoters will be collected, primarily for assessments of sea duck predation pressure on bivalves (section 2.5.2.8), we also will be able to compare of bioindicators of health and exposure across study sites for these species. Tissue samples and blood will be taken immediately upon collection.

2.3.2.2 Conventional Hematology

For the CBC's (complete blood cell counts), WBC's (white blood cell counts) and serum chemistries, one EDTA tube, one serum tube and two blood smears from each animal will be prepared in the field. The EDTA sample, a portion of the serum and one blood smear will be sent to Corning Clinical Laboratories for the sea and river otter samples, and to a laboratory specializing in avian hematology for the bird samples. The remaining blood smear is to be sent to Purdue University. The remaining serum will be divided into aliquots for UAF and Purdue and frozen.

At UAF, agarose gel electrophoresis of total serum proteins will be performed as described by the manufacturer using a high resolution electrophoresis kit (Helena Laboratories, Beaumont, Texas, USA). Electrophoresis will be used to resolve the protein pattern into multiple zones. Two microliters of serum will be applied to the agarose gel, which will be subjected to electrophoresis in a cooled chamber at 100 volts for 1 hr. The agarose gels will be stained with Coomassie blue and individual zones will be quantified using a Beckman Model R-112 densitometer (Beckman, Palo Alto, California, USA) (Jeppson et al. 1979; Tilley et al. 1989). Serum protein levels will be determined using the Bio-Rad protein assay with bovine serum albumin as a standard (Bradford 1976).

Haptoglobins in serum will also be measured at UAF. Haptoglobins (Hp) are alpha glycoproteins that stoichiometrically bind free hemoglobin (Hb) in a haptoglobin-hemoglobin complex (Gordan and Koj 1985). Excess hemoglobin will be added to the serum sample in a 1 part of a 10% hemoglobin suspension to 20 parts of undiluted serum, and allowed to mix for 5 min. Two microliters of the sample mixture are then electrophoresed on agarose gels at 100 volts for 1 hr. After fixing the protein complex with 7.5% trichloroacetic acid, gels will be stained for hemoglobin using o-dianisidine, as described by the manufacturer (Helena Laboratories Technical Bulletin Number 5445). The Hp-Hb complex, which migrates in a different region from hemoglobin, is quantified by densitometry and results are expressed as mg of hemoglobin binding capacity per 100 ml of serum as described by the manufacturer (Helena Laboratories Technical Bulletin Number 5445; Valeri et al. 1965).

Samples for IL-6 will be analyzed at UAF using an immunochemical assay (Quantakine ELISA). Samples will be run in duplicate on a microtiter plate coated with a monoclonal antibody for IL-6. After washing away any unbound protein, an enzyme-linked polyclonal antibody for IL-6 will be used to detect IL-6 levels.

At Purdue, the serum samples from sea and river otters will be batch tested for serum electrophoresis (SEP) and immunoglobulin quantitation using standard methodologies. Serum protein electrophoresis offers information on relative protein distribution and allows for the calculation of absolute values (Melvin 1987). Many disease states may alter the electrophoretic pattern (Turnwald 1989). Acute phase, complement, immunoglobulin and coagulation proteins can all be assayed using SEP.

2.3.2.3 Immune Function Assays

From sea and river otters, a total of 20 ml of blood collected with 40U of preservative-free heparin/ml as the anticoagulant will be used to isolate buffy coat leukocytes. Blood samples will be processed using a technique modified from Truax et. al. (1993) on cryopreservation of buffy coat cells. Briefly, the blood will be centrifuged (800 xg, 20 minutes) to separate the sample into plasma, buffy coat, and RBC layers. Two ml of plasma will be removed from each sample and placed into a sterile tube. The remaining plasma will be removed, alliquoted and frozen for additional analyses. The buffy coat layer will be removed and resuspended in 2 ml of autologous plasma. Dimethylsulfoxide (DMSO) will be added to the cell suspension to a final concentration of 10% (v/v). The cell suspension will be divided equally into two cryovials. The cell suspensions will be kept on ice for 1 hour then transferred to a freezer overnight, and stored in liquid nitrogen until needed.

Frozen cells for analysis will be thawed rapidly in a 37°C water bath and immediately placed on ice. The sample will then be transferred to a 15 ml centrifuge tube and diluted to 10 ml with Hank's balanced salt solution (HBSS) containing 40 U of heparin/ml. The sample will then be layered over 4 ml of a ficoll gradient and centrifuged at 1600 x g for 30 minutes. The cells at the interface will be collected and washed 3 times in HBSS. Following the final wash the cells will be resuspended in RPMI 1640 medium supplemented with 10% (v/v) fetal clone, 2 mM L-glutamine, 25 mM 2-mercaptoethanol and antibiotics. Enumeration and viability will be assessed using trypan blue dye-exclusion. Lymphocyte proliferation assays will be performed using the mitogens PHA, Con A and PWM in 5 day cultures. All assays will be done in triplicate. Proliferation will be assayed by adding tritiated thymidine to the cultures at 16 hours prior to harvesting. Results will be recorded as counts per minute (cpm). Control wells will contain medium only.

2.3.2.4 Cytochrome P450 Assays

Three approaches will be taken to evaluate cytochrome P450 levels:

1) Immunohistochemistry (J. Stegeman, Wood's Hole Oceanographic Institution):

The induction of cytochrome P4501A (CYP1A) in tissues of the predator species will be evaluated by immunohistochemistry. Candidate tissues to be used include skin punches from flipper of sea otters and from ear of river otters; liver from sea ducks (sample at collection of Barrow's goldeneyes and white-winged Scoters; biopsy at surgery from Harlequins); foot web biopsy from captured harlequin ducks and pigeon guillemots; and liver from demersal fishes (sample at collection). Tissue samples will be preserved in 10% neutral buffered formalin immediately after collection and will be shipped to Wood's Hole Oceanographic Institute for analysis. Background information on CYP1A as a marker of hydrocarbon exposure and detail on the immunohistochemistry methods are presented in Appendix 6.2.

2) Immunochemical using Western Blotting (L. Duffy, UAF):

Western blotting is the process of immobilizing proteins on a solid membrane support (following a gel electrophoresis separation stage) and analyzing them using immunodetection. The blotting procedure reproduces the relative spatial arrangement of the proteins in the initial electrophoretogram. The immunodetection technique offers specificity through the use of an antibody specific for the blotted proteins.

Following blotting the membrane is treated with a blocking reagent to prevent nonspecific binding of the immunodetection reagents to the blotting membrane. The immunodetection procedure for otters utilizes an anti-rat cytochrome P450 IA1 (primary) antibody raised in rabbit which binds specifically to the immobilized cytochrome P450 IA1 isoenzyme. This antibody is also expected to work for birds. Validation of this is currently underway. The membrane is then detected with an anti-rabbit Ig-biotinylated species-specific (secondary) antibody. This in turn is detected with a streptavidin-horseradish peroxidase (HRP) conjugate which binds to the biotinylated secondary antibody and the molecular weight protein markers. After each incubation stage, any unbound antibodies or striptavidin-HRP conjugate are removed by washing with Tris buffered saline-Tween™20 solution. Detection using ECL detection reagents utilizes the bound horseradish peroxidase to catalyze the oxidation of luminol, in the presence of hydrogen peroxide (H_2O_2) and an enhancer. Following oxidation, the luminol is in an excited state which decays to the ground state via a light emitting pathway. This method has been validated for mammal liver samples. Currently, skin and foot pad biopsy samples are being evaluated.

3) Quantitative RT-PCR to measure cytochrome P450 (P.W. Snyder, Purdue University):

The purpose of this study is to use an established method (quantitative polymerase chain reaction) to measure cytochrome P450 expression in peripheral blood lymphocytes. The expression of genes encoding xenobiotic enzymes have been used as endpoints for investigating potential biomarkers for compounds that are known to activate the enzymes in question. In reference to hydrocarbons, induction of the cytochrome P450 isoenzymes is known to occur and thus support the idea that these enzymes may be biological markers of exposure. The lymphocytes will be isolated from blood samples drawn from animals captured from oiled and non-oiled sites. The method to be used will be adapted from the published method (Vanden Heuvel et al. 1993). Advantages of this technique are: (1) the use of peripheral blood samples for analysis; (2) the small sample size required for detection and (3) increased sensitivity as compared to other methods. Total RNA will be extracted from isolated peripheral blood lymphocytes and a reverse transcriptase-polymerase chain reaction (RT-PCR) assay will be used to quantify cytochrome P450 levels.

2.3.2.5 Hydrocarbon Analyses

Due to negative results from past studies on hydrocarbon contamination of clams (Doroff and Bodkin 1994) and sea otter tissues (Ballachey and Mulcahy 1993), we do not plan to assay for hydrocarbon levels *unless* other indicators of oil contamination (P450 assays) demonstrate continued exposure to hydrocarbons. However, we will collect and archive tissue samples from sea ducks and prey species (both demersal fishes and invertebrate prey) in the event that later analyses are warranted.

2.3.2.6 Assays of External Oil

Personnel at the CA Dept. of Fish and Game have recently adapted an ELISA assay to detect oil contamination of pelage under field conditions (J. Mazet, CDF&G, pers. comm). Controlled tests of the procedure show sensitivities in the range of less than or equal to .7 parts per million. To sample the pelage (or plumage), a 4x4 guaze swab is saturated with isopropanol and applied to the fur for 15 seconds. These swabs can then be assayed immediately (ELISA field kit) or frozen for later analysis. We intend to sample pelage or plumage of all captured sea otters, river otters, harlequin ducks and adult pigeon guillemots; however, ELISA analyses will be limited to a subset of the collected samples. If initial ELISA results are positive for contamination, or if the P450 assays indicate continuing hydrocarbon contamination, the remaining samples can be tested to evaluate external contamination as a route of oil exposure.

2.3.2.7 Body Composition

Body composition of pigeon guillemot fledglings and molting harlequin ducks will be used to assess population health in oiled and unoiled sites in PWS. Body composition can be measured directly, by collection and proximate analysis of the carcasses (Esler and Grand 1994), or it can be predicted using models that serve to index condition, once those models have been created based on collected individuals. We will use a number of methods to assess body composition for this study. Specific details are outlined in sections 2.6 and 2.7.

Body composition of pigeon guillemots and harlequin ducks will be estimated using nondestructive condition indices that incorporate body mass, morphometrics, and measures of total body electrical conductivity (TOBEC; Walsberg 1988, Roby 1991). The TOBEC method relies on the major difference in conductivity between lipids and other body constituents to estimate total lean body mass (Pethig 1979; Van Loan and Mayclin 1987). The difference between total body mass, as determined by weighing, and lean body mass, estimated by TOBEC, provides an estimate of total body fat. A major advantage of the technique is that measurements can be obtained rapidly and repeatedly without harm to the subject. Also, validation studies to date indicate that the accuracy of the technique can be high ($r^2 = 0.996$) (Bracco et al. 1983, Walsberg 1988, Roby 1991) if subjects are positioned consistently within the measurement chamber and plumage is dry. The TOBEC analyzer (SA-3000 Small Animal Body Composition Analyzer, EM-SCAN Inc., Springfield, IL) can be used in the field and powered from a 12 volt battery, so the subjects can be analyzed and released within a matter of minutes.

Although the TOBEC technique is nondestructive, it must be calibrated by sacrificing a sample of subjects of each species for proximate analysis of body composition. Collections for calibrations for pigeon guillemot fledglings will be conducted in Kachemak Bay during 1995, as part of a separate study. A sample of 25 harlequin ducks will be collected as part of this study (see section 2.6.2.3). Calibration curves for each species will be produced by regressing TOBEC value against lean body mass for the sample of subjects, and 95% confidence intervals for estimates of total body fat from TOBEC alone will be determined by the inverse regression procedure.

2.4 General Methods for Habitat Evaluation

2.4.1 Rationale

As part of studies of food availability, it will be necessary to estimate habitat type distribution within study sites. Habitats will be described by levels of exposure (either exposed or sheltered) and substrate type (rocky, boulders/cobble, gravel/sand/mud). These designations will be used in two ways. First, they will be used to direct sampling programs of prey species that are stratified by habitat type. In some cases, we know that some prey species occur only in specific habitats. For example, clams occur only where there are fine sediments (gravel/sand/mud). As a result, we need to know the distribution of these habitats so that we can randomly select sampling sites from appropriate habitats for clams within each area. Second, we will use habitat distribution data to determine abundance of prey items within each study area. Most studies of prey abundance will employ a stratified random sampling design, with stratification by tidal height (for intertidal prey species) or depth (for subtidal prey) as well as habitat type. Mean densities within each habitat type will be multiplied by the areal extent of each habitat type in order to determine the abundance of prey within each habitat. Total abundance within each area will be obtained by summing abundances from all habitats.

2.4.2 Methods

Distribution of habitat types within intertidal regions will be determined using a pre-existing Environmental Sensitivity Index GIS (Geographic Information System) database that lists geomorphological habitat types for shorelines throughout PWS (Gundlach et al. 1983). Shoreline types in this database will be verified by a visual census of all shorelines within our study areas conducted from a small boat. Shoreline type verification will be carried out in conjunction with side-scan-sonar surveys of subtidal habitats, described below.

There are no existing data on subtidal habitats, and it is impossible to determine subtidal habitat type from shoreline habitat data. Therefore, we will census all subtidal habitats within our study areas using side-scan sonar to define substrate types. The EG&G Model 260-TH system consists of a graphic recorder, digital processor and the dual frequency (100 & 390 kHz) shipboard selectable Model 272-TD sonar fish.

The sonar fish has two sets of linearly focused transducer arrays - one array on each side of the towed fish. Circuitry inside the towed fish energizes the transducers, causing them to project high intensity, high frequency bursts of acoustic energy at 100 (or 390) kHz in fan-shaped beams, narrow in the horizontal plane and wide in the vertical plane. These acoustic beams (sonar signals) project along the sea bed on both sides of the moving vessel. Objects, topographic features, and substrate changes on the sea bed reflect the signal back to the towed fish where it is received by the transducers, amplified, and sent up the tow cable to the graphic recorder on the ship.

The EG&G Model 260-TH digital thermal recorder produces a continuous permanent graphic record of the sea floor (analogous to a photograph) by electronically processing and then printing the information (line by line) to produce the sonar image of the sea floor. Signal synchronization is achieved by the recorder generating a trigger pulse and sending it to the towed fish and then waiting for the reflected signals. This system has a third channel that displays the depth of the water column beneath the towed fish that is used to digitally correct the image.

The range of the side-scan-sonar system can be selected from 12.5 meters up to 700 meters on each side of the ship. A 100 meter range scale has been selected for the described mapping system, using 100 kHz transducers. This combination provides the best compromise between resolution and mapping efficiency. A typical recording, with descriptive titles, is shown in Figure 6.

Mapping precision depends on the accuracy of vessel positioning during a survey. Accurate positioning will be provided using a differential Global Positioning System (GPS) interfaced with a navigation computer. The navigation computer provides a permanent record of the ranges, line and shot number updating, real time, and other related features. Data are stored on the computer hard drive and printed on paper and downloaded on 3.5" disk for backup. The actual path of the boat, or "vessel track" is later post-plotted from the date stored on the floppy disk by using a 36" X-Y plotter.

A single boat track will be run along the shore, with the boat positioned along the 4-10 m depth contour. The depth range covered by the sonar record will depend in part on the slope on the seabed at each location. However, it is anticipated that coverage of the sea floor will generally extend from depths of 12 m to the intertidal zone (0 m).There are no existing data on subtidal habitats, and it is impossible to determine subtidal habitat type from shoreline habitat data. Therefore, we will census all subtidal habitats within our study areas using side-scan-sonar to define substrate types. The side scan sonar system consists of a graphic recorder, digital processor and towed sonar fish. The sonar fish has two sets of linearly focused transducers - one set on each side of the towed fish. Circuitry inside the towed fish energizes the transducers, causing them to project high intensity, high frequency bursts of acoustic energy at 100 kHz in fan-shaped beams, narrow in the horizontal plane and wide in the vertical plane. These sound beams (sonar signals) project along the sea bed on both sides of the moving vessel. Objects, topographic features, and substrate changes on the sea bed reflect the signal back to the towed fish where it is received by the transducers, amplified, and sent up the tow cable to the graphic recorder on the ship.

The digital graphic recorder produces a continuous permanent graphic record of the sea floor by electronically processing and then printing the information (line by line) to produce the sonar image, as well as data from the water column. Signal synchronization is achieved by the recorder generating a trigger pulse and sending it to the towed fish and then waiting for the reflected signals.

Printing is accomplished by a high speed thermal printer in which each individual dot is digitally interpreted in order to produce 16 distinct gray shades on 43.2 cm (17.0") wide graphic recorder paper.

A single boat track will be run along the shoreline, with the boat positioned along the 6 m depth contour. The depth range covered by the sonar record will depend in part on the slope of the seabed at each location. However, it is anticipated that coverage of the sea floor will generally extend from depths of 12 m to the intertidal zone (0 m).

2.5 Specific Methods for Sea Otters

2.5.1 Rationale

2.5.1.1 Demographic Measures

Abundance of sea otters in area N (Figure 5) was less than 50% of pre-spill estimates in 1994 (Table 4). An aerial survey methodology recently developed by the National Biological Service and the U.S. Fish and Wildlife Service provides unbiased estimates with improved precision. The 1994 survey estimated 9,092 (se=1,422) sea otters in all of PWS excluding Orca Inlet. However, the point estimate for area N, because sea otters are relatively rare, is based on a small sample size and lacks precision. We propose to conduct an aerial survey of western PWS in July 1995. Available data on sea otter abundance are restricted to summer months and seasonal estimates in distribution are necessary to confirm the observed pattern of limited recovery throughout the year. The purpose of these surveys is to provide data on the seasonal distribution of sea otters in area N (including surrounding areas) with the objective of describing future change.

Skiff surveys along shoreline transects will be conducted in order to estimate the proportion of independent to dependent sea otters in a population. Reproductive rates are key variables in defining the rate of change in large mammal populations. Previous studies were unable to detect differences in the ratios of independent to dependent sea otters between oiled and unoiled areas of PWS (Bodkin and Udevitz 1991). However, their treatment area included portions of the spill area where there is little evidence of lack of recovery (lightly oiled as well as heavily oiled areas). We propose to limit our treatment (oiled area) to area N, where surveys suggest recovery is not occurring.

2.5.1.2 Health Measures and P450 Induction

Specific concerns over the health of sea otters in oiled areas persist due to differences between oiled and unoiled areas in juvenile survival and blood parameters. Survival rates of juvenile sea otters in western PWS were significantly lower than in non-oiled areas in both 1990-91 and 1992-93 (Rotterman and Monnett 1991; NBS unpublished data); however, survival rates for both areas were improved in 1992-93 compared to 1990-91. Pup weights at capture tended to be lower in oiled areas. In 1992 (and in previous post-spill collections), levels of blood serum enzymes indicative of liver disorders (ALT, GGT), and white cell counts (basophils, eosinophils) were elevated in both adult and juvenile sea otters, suggesting chronic or recurrent infections perhaps related to continued oil exposure. The increased levels of serum enzymes are consistent with changes observed in oiled otters exhibiting kidney and liver pathologies at the rehabilitation centers. No further blood samples have been collected since 1992. Sea otter studies proposed in the NVP project will evaluate animal condition (weights, lengths) and health (blood and immune measures). The inclusion of the P450 assays in the NVP will allow us to directly address the question of continuing exposure to oil as a factor in differences observed between sea otters oiled and unoiled areas.

2.5.1.3 Prey Availability

As identified in the introduction (section 1.4.2.3), sea otters have a well documented structuring effect on many of the nearshore marine invertebrates on which they prey. It is under this premise that we have developed one of the three principal avenues for evaluating those processes that are constraining recovery of nearshore vertebrate predators, in this case the sea otter. Based on previous food habits data from PWS, clams, mussels, and crabs are predominate prey items, comprising up to about 95% of the sea otters diet (Estes et al. 1981, Garshelis 1983, Johnson 1987, Doroff and Bodkin 1994). Additionally, observations by marine ecologists (Jewett et al. 1994) studying effects of the spill have identified increasing numbers of green sea urchins in at least one portion of northern Knight Island. Sea urchins are a favored prey of sea otters elsewhere. For these reasons we have selected clams, mussels, crabs, and urchins as potential measures of the effects of reduced sea otter predation on their prey, and thereby an indirect measure of the status of the sea otter population. However, other prey can be important in the diets of sea otters in PWS. These include the Dungeness (*Cancer magister*) and helmet crab (*Telmessus cheiragonus*) which may comprise up to 20% of the sea otter's diet. In addition, a wide array of other invertebrates are utilized by sea otters and are potentially valuable components of their diet, as well as potential indicators of predation pressure. These include snails, limpets, octopus, and sea cucumbers. The purpose of the estimation of sea otter diets is to validate findings of the invertebrate studies and to provide estimates of the relative importance of other prey items, which also may be indicative of community level changes in the nearshore ecosystem. Large changes in species composition of sea otter prey, either over time or between areas, may suggest potential mechanisms constraining recovery, as well as provide indirect evidence of the status of recovery.

The availability of major prey items will be assessed by conducting stratified random sampling surveys of prey density within each area. In addition, diets of sea otters will be verified by foraging surveys that indicate the types and numbers of prey items taken within each study area. The availability of several prey items (clams, mussels, and sea urchins), also will be assessed by measuring the size distribution of prey in oiled and unoiled areas. It is well documented that sea otter predation often results in prey populations having fewer, smaller individuals (Figure 4). This pattern has been observed for a number of prey species in a number of different habitat types (VanBlaricom and Estes 1988).

Interpretation of prey abundance and size class distributions is generally described in Figure 7. In terms of abundance, fewer prey at oiled sites would suggest that the recovery of predators in oiled areas could be food limited. There are a number of possible outcomes with respect to the size distribution of prey items. However, there are only two that seem likely. The first is one in which only small individuals are represented in subpopulations at both oiled and unoiled areas, size distributions of otter prey being strongly skewed toward smaller size classes if larger prey are missing from unoiled areas, but not oiled areas. The second likely outcome is one in which only small individuals are present in unoiled areas, but both large and small individuals are present in oiled areas with few predators (Figure 7). This would suggest that food is not limiting recovery at the oiled site. This outcome would suggest that recovery may be limited by food, especially if the density of prey is lower at oiled sites.

The interpretation of the abundance and size distributions of prey items is potentially confounded by several factors including the growth rate of prey, the recruitment of prey, and predation by other organisms whose diets overlap those of sea otters (principally sea ducks and sea stars). This is illustrated in Figure 8. We envision the processes of recruitment and post-recruitment predation as filters which influence the supply of invertebrate prey populations to sea otters and sea ducks. By influencing both the number and size distribution of prey, the various filters influence significantly the supply of prey to top-level carnivores. Thus, an understanding of the characteristics of each filter will be necessary for understanding constraints on recovery of injured populations of sea otters, as well as sea ducks.

The first filter in our model represents the recruitment process. Recruitment in benthic invertebrate prey is known to be strikingly variable among years, among seasons within years, and among locations on a number of scales. Variation results from changes in reproductive success of invertebrates and from spatial and temporal differences in processes which affect the transport and survival of planktonic larvae. Thus, characteristics of the recruitment filter change over time and among locations. In some situations the filter will allow no juveniles to pass, effectively shutting off the supply of individuals that would ultimately serve the nutritional needs of predators. In other situations the filter will have a few "openings," allowing low rates of recruitment, and in still other cases the filter will be "wide open," allowing for major recruitment events and the appearance of a dominant cohort in the benthic population. An improved understanding of recruitment filter characteristics will allow determination of the extent to which recruitment processes influence food supply to sea otters and sea ducks, thus affecting their status with regard to recovery from EVOS injury.

The other three filters in the model represent predation by invertebrate predators, sea ducks, and sea otters, respectively. Although we have displayed these filters sequentially for purposes of illustration, we suggest that they operate with some overlap in both space and time. The invertebrate predator filter probably primarily affects individual prey at the low end of the size spectrum of prey useful to sea ducks and sea otters (e.g., Paul and Feder 1975) (see Figure 7). However, there likely will be some overlap in utilization among all predators, especially for mussels and urchins. In our view, the invertebrate predator filter is functionally similar to the recruitment filter, influencing the supply of prey to sea ducks and sea otters. Characteristics of the invertebrate predator filter will vary to some degree by season and location because of changes in metabolic needs of the predators, changes in prey availability as influenced by the recruitment filter and local differences in predator density.

Characteristics of the sea duck filter will vary by season and location. Populations of sea ducks are considerably higher during winter (Agler et al. 1994) and fidelity to wintering sites may exist (Limpert 1980). Variability in features of the sea otter filter should be less dramatic than for sea ducks, although the foraging patterns of sea otters clearly can change by season and year and among locations as a result of population growth, distributional shifts, reproductive status, and changes in the range of available prey.

Specific prey individuals pass through the recruitment filter only once in their lives. Thereafter, however, they may pass through predation filters repeatedly. Multiple exposures to particular filters can be envisioned as feedback loops in the filter diagram, leading a particular range of prey abundance and size to be continuously modified by the effects of various filters. We have not included feedback loops in the diagram to minimize clutter, but feedback and multiple filtration are important conceptual elements in our model.

Our studies will seek an understanding of the qualities and variability of each of the filters indicated in Figure 8. We will test hypotheses regarding filter behavior and measure the structure of prey populations in the field. At the same time we will integrate existing knowledge and hypotheses about the relationships of predation and prey population structure and dynamics, producing a range of expected prey population characteristics. Expected population patterns will reflect differing emphases on factors that could be constraining prey densities and size distributions. Comparison of field data with hypothetical population patterns will provide improved understanding of food-related factors that could constrain the recovery of sea otters and sea ducks.

2.5.2 Methods

2.5.2.1 Aerial Surveys of Sea Otter Abundance

The aerial sea otter survey methodology we will employ is fully described in appendix C. The survey design consists of two components: (1) strip transect counts and (2) intensive search units.

1) Strip Transect Counts

Sea otter habitat is sampled in two strata, high density and low density, distinguished by distance from shore and depth contour. Survey effort is allocated proportional to expected sea otter abundance by adjusting the systematic spacing of transects within each stratum.

Transects with a 400 meter strip width on one side of a fixed-wing aircraft are surveyed by a single observer. Transects are flown at an airspeed of 65 mph (29 m/sec) and an altitude of 300 feet (91 m). The observer searches forward as far as conditions allow and out 400 m, indicated by marks on the aircraft struts, and records otter group size and location on a transect map. A group is defined as one or more otters spaced less than three otter lengths apart. Observation conditions are noted for each transect and the pilot does not assist in sighting sea otters.

2) Intensive Search Units

Intensive search units (ISU's) are used to estimate the proportion of sea otters not detected on strip transect counts. For adequate statistical power in calculation of the correction factor, each observer needs to obtain a preset number of ISU's. To arrive at this goal in an unbiased manner, observers pace themselves so ISU's are evenly distributed throughout the survey area.

ISU's are flown at intervals dependant on sampling intensity, throughout the survey period. An ISU is initiated by the sighting of a group and is followed by five concentric circles flown within the 400 m strip perpendicular to the group which initiated the ISU. The pilot uses a stopwatch to time the minimum one minute spacing between consecutive ISU's and guide the circumference of each circle. ISU circle locations are drawn on the transect map and group size and behavior is recorded on a separate form for each ISU. Number observed on the strip count and number observed during the circle counts are recorded for each group.

2.5.2.2 Estimation of Annual Production of Sea Otters

Estimates of annual reproduction, as indicated by ratios of independent to dependent sea otters, and patterns of habitat use will be obtained from small boat surveys. Surveys will be conducted in July and August each year.

Sample units will correspond to coastline transects established by Irons et al. (1988) and will extend offshore out to the 100 m depth contour or 1/2 the distance to the opposing shoreline, whichever is less. A subset of sample units will be randomly selected to be surveyed in each of the study sites (M and N; Figure 5).

The survey vessel will maneuver about 200 to 300 m offshore, and out to the offshore boundary as necessary to observe and classify all otters within each selected sample unit. Boat speed will be maintained at less than 15 mph. Surveys will be conducted only when viewing conditions are considered good or better (calm to light winds, sea state less than Beaufort 2).

Surveys crews will consist of two observers, including the boat operator. Crews will use high resolution binoculars. Otters will be classified as either dependent or independent. Dependent otters will be defined as sea otters smaller than, and in close association with, an adult. This definition includes, but is not limited to, pups in close physical contact, nursing, receiving food from, swimming with or being groomed by an adult sea otter. Independents will be defined as all other sea otters. Crews will record the number of dependent and independent sea otters found in each sample unit.

Each sample unit will be classified by coastline physiography and bathymetry into one of six categories. Coastline physiography will be categorized as protected bay, open coast, or island. Bathymetry will be categorized as either shallow (less than 31 m deep for more than 50% of the sample unit's length, 200 to 300 m offshore) or deep (greater than 31 m deep for more than 50% of the sample unit length). Depth determinations will be based on navigational charts and fathometer readings taken during the survey.

Ratios of independent to dependent sea otters will be obtained for each stratum and for each habitat type by summing over all sample units within each stratum or habitat type. Proportions of dependent sea otters will be calculated for each transect. Kruskal-Wallis tests will be used to evaluate differences in proportions among areas.

2.5.2.3 Beach Surveys of Sea Otter Mortality

Patterns of sea otter mortality will be determined by estimating age class structure of sea otters dying in PWS. By searching beaches each spring, samples of sea otter skulls will be obtained. A premolar tooth will be extracted the age of the animal at death will be estimated. Data collected in western PWS in the 1970's described a small proportion of prime age (ages 2-9) sea otters dying each year. Following the EVOS, in years 1990 - 1992, the age structure of dying otters in western PWS consisted of more prime age otters than would normally be expected. This is one of the findings that suggested that injuries to sea otters resulted not only from immediate mortality, but resulted in longer term, chronic injuries to the population. Data from 1993 and 1994 suggest that mortality may be returning to pre-spill patterns in western PWS. The purpose of this component of the study is to continue collecting carcasses in western PWS on an annual basis as a measure of the status of sea otter populations relative to recovery.

Mortality patterns, based on age distributions of the dying portion of the population, will be evaluated through recovery of beach-cast sea otter carcasses in western PWS. Beaches in the Green Island area of western PWS, surveyed for carcasses in 1976-84 by Johnson (1987), and again in 1990-94 (Monson and Ballachey 1994), will be surveyed in 1996. In addition, a limited number of beaches on Knight, Naked, and Montague Islands will be surveyed in 1996. Beaches will be surveyed once during late April or early May after snow melt but prior to summer revegetation, which may hide carcasses washed high on the beach by winter storms.

Surveys will consist of crews of two people walking along selected beaches searching for carcasses between the water line and the storm tide line. At least one member of each crew will have experience in beach surveys from previous field seasons. Generally, the search effort will focus on the high tide line and the storm tide line where skeletal remains often are found, while the lower beach is scanned for fresh carcasses. Efforts will be made to check behind large beached logs and other objects which can easily trap carcasses as waves wash over them.

Data recorded for each carcass will include: (1) relative location of carcass on the beach, (2) relative condition and completeness of carcass, (3) position of remains relative to previous year's vegetation, (4) relative age (adult, subadult, pup), (5) sex, and (6) specimens collected (e.g., entire carcass, skull, baculum, none). Skulls (when present) will be taken from all carcasses and a tooth extracted for aging (Garshelis 1984). Any fresh carcasses collected will be necropsied as soon as possible and tissue samples collected for potential toxicology and histopathology studies.

Otters will be categorized in three age classes: 1) juvenile, ages 0 and 1, 2) prime, ages 2-8, and 3) older, ages 9 and above. The distribution of age classes of all recovered carcasses will be determined for each area (eastern PWS and western PWS), and compared with the distribution obtained in other post-spill collections (1990-92) and pre-spill collections (1976-84), using Fisher's Exact Test (2-tailed).

2.5.2.4 Indicators of Health and P450 Induction

Sea otters will be captured in the 1996 and 1997 summer field seasons, with 60 animals captured each year (30 each at Area N and Area M). Capture will be done with either tangle nets, hand-held dip nets or under-water diver-held traps, all methods which have been used routinely in previous capture efforts. Sea otters will be sedated with a combination of fentanyl and diazepam and will be reversed with naltrexone following collection of data and samples. Sea otters will be tagged with unique color/number coded polyethylene tags in their hind flippers, and a coded transponder chip will be implanted subcutaneously in the right groin area. Flipper tags are often lost, so the transponder chips provides a permanent identification in the event that the animal is recaptured or recovered. Both methods of tagging have been used routinely in previous studies of sea otters, without deleterious effects. Morphometric data collected will include age class, sex, length, weight, girth, canine width and baculum length (in males). Morphological characters will include head color and tooth wear. The mouth will be checked for oral lesions, and if observed they will be surgically biopsied and preserved in formalin. A premolar tooth will be removed for age estimation.

A blood sample of up to 30 cc will be collected by jugular venipuncture from each sea otter and processed as described in the general methods section; conventional hematology (2.3.2.2), immune function assays (2.3.2.3) and cytochrome P450 assays (2.3.2.4) will be done. A skin punch is removed from the webbing of the flipper when inserting the flipper tag; this punch will be preserved in formalin for P450 assays (section 2.3.2.4). While sedated, the pelage of the sea otter will be sampled for external oil contamination (section 2.3.2.6).

2.5.2.5 Sea Otter Foraging

Sea otter prey will be determined at both study sites. The primary method of data collection will be observational, following standard operating procedures (Appendix C). Observations will be made from shore with the aid of high resolution telescopes (Questar Corporation) and 10X binoculars. Data will be collected at both locations within a six week period during the months of June, July and August, beginning in 1996. Data recorded will include sex, age class of focal animal (adult or juvenile), number of prey and relative prey size (A: < 2 cm, B: ≥ 2 to < 4 cm , C: ≥ 4 cm to < 8 cm, D: ≥ 8 to < 12 cm, and E: ≥ 12 cm), dive time, surface time, success rate and prey item to lowest taxon. Prey size will be visually estimated based on a mean forepaw width in sea otters of 4.5cm. Repeated dives will be recorded for a focal animal until a maximum of 50 identifiable prey items are observed per individual or until the animal is lost or discontinues foraging. Focal animal selection, when more than one otter is feeding at an observation site, will be random. A minimum of 500 identifiable prey items will be recorded at each of the two selected geographic areas. An attempt will be made to distribute foraging observations from all vantage points within each study area. Compiled foraging data will be compared to the invertebrate data collected, particularly as it pertains to species composition and size class composition. Adult animals will be categorized as male, independent female or female with a pup. Juveniles will be identified as small dark-headed otters estimated to be less than 24 months of age. Dependent otters will be classified as such. Data will be collected only during daylight hours, during all tidal cycles. Tidal state will be recorded for all observation periods.

2.5.2.6 Availability of Subtidal Clams

We will determine abundance and size structure of existing subtidal clam populations in nearshore habitats of PWS. Taxa to be evaluated will include, but will not be limited to: *Saxidomus giganteus*, *Protothaca staminea*, *Tresus capax*, *Clinocardium* spp., *Mya* spp., *Macoma* spp., and *Serripes groenlandicus*.

Based on results of the sidescan sonar habitat survey, we will select the two most prominent unconsolidated substratum types as sample strata. Within each stratum in each study area (i.e., Montague Island and Knight Island; Figure 5) we will sample at two depths, 6 and 12 m, in five replicate sites chosen from within each of the defined strata. Site selection initially will be random, but arbitrary adjustments may be necessary to ensure that site environmental attributes (e.g., exposure, current velocity) are comparable among the two study areas. A complete sample set will consist of 2 study areas x 2 strata x 5 sites x 2 depths = 40 samples. We will collect complete sample sets during summer months of 1996 - 1998. During 1995 we will complete the sidescan sonar survey, identify the strata, and if possible gather preliminary samples. Preliminary sampling will be done to: (1) verify the effectiveness of sampling techniques, and (2) gather preliminary population data necessary for calculations of minimum acceptable sample sizes for studies of abundance and size distribution.

Individual samples will be gathered by scuba divers. A temporary 50 m transect line will be placed at a pre-determined sample site. Individual sample frames (0.25 m^2 surface area) will be placed at random locations along the line and at random distances (5 m maximum) from the line. Numbers of frames sampled will be determined on the basis of preliminary studies. For obvious clams within each frame, calibrated rods will be placed in siphon holes to determine depth of individual clams below the sediment surface. Each sample will include a small sediment core taken prior to suction for subsequent determination of grain size distribution and organic carbon content. Each frame will be cleared by suction to a depth of at least 50 cm. The depth will be adjusted as necessary, based on preliminary sampling and rod probing, to ensure collection of all large clams within the frame. Suction will be done with a venturi dredge, with output filtered through a bag with mesh of approximately 0.5 cm. Bags will be brought to the surface and live clams will be sorted by hand from debris. Clams will be sorted by species and measured (maximum shell length, to nearest mm) with machinist's Vernier calipers. Clam count and size data will be recorded on standardized pre-printed data sheets. Data will be archived according to the NVP data management plan.

Samples of sediment and tissues from the three most abundant clam species will be archived for possible future analyses for hydrocarbon residues (see also section 2.5.2.7). Two sediment samples of 50 g each will be collected near the first location for suction sampling for each site on each date of sampling. After appropriate measurements are recorded, two tissue samples of 50 g each will be taken, for each of the three most abundant clam species, from suction samples. all samples of sediment and clam tissue will be frozen in the field and transported to laboratory facilities of the National Biological Service, Anchorage, Alaska, for archiving. Should biochemical measures of health in sea otters indicate the presence of a source of hydrocarbon contamination, sediment and tissue samples will be sent for appropriate hydrocarbon analyses to the Auke Bay, Alaska, Laboratory of the National Marine Fisheries Service, national Oceanic and Atmospheric Administration.
Clam data will be analyzed by species to determine mean and variance of density and size per site. Based on results of tests for normal distribution, mean density and size will be compared among replicate sites within study areas, and between study areas, using an appropriate parametric or nonparametric analysis of variance. Clam size data also will be analyzed with an appropriate cohort analysis to determine interannual variation in recruitment intensity.

We will determine the rate and pattern of recruitment to natural substrata in study sites as indicated above. We will use small diver-deployed coring devices to sample for newly-settled clams. Cores will be approximately 0.01 - 0.02 m^2 in surface area, sampling to a depth of 10-20 cm. Exact protocols will not be established until completion and analyses of preliminary samples. Numbers of cores necessary to support statistically meaningful contrasts also will be calculated based on preliminary sampling. Preliminary samples will be collected in 1995. A. sample will consist of 2 study areas x 4 sites = 8 samples (see section 2.5.2.8).

Individual cores will be located in the same way as sampling frames for suction samples. Cores will be capped with fine mesh screening and inserted gently, by hand, to minimize loss of organisms due to surface disturbance. Once in place, cores will be contained and extracted, and carried to a surface vessel. Cored sediments will be gently washed through a screen (0.5 mm square mesh) with filtered seawater. Retained materials will be fixed, stained with Rose Bengal and preserved for laboratory sorting.

In the laboratory, stained samples will be sorted for juvenile clams and for empty shells of juvenile clams. Only empty shells that are clearly fresh and intact will be retained. Clams will be categorized to the lowest possible taxonomic level and counted. Counts will be the sum of live clams and intact empty shells (the latter divided by two to avoid double-counting of individual clams). Data will be recorded on standard data sheets and archived as indicated above. Density data by taxonomic category will be compared within and among study areas in a manner analogous to suction samples, described above. An appropriate time series technique will be employed to assess interannual differences in recruitment intensity.

We will examine correlations of recruitment intensity of clams with habitat and oceanographic variables assessed in other EVOS-related projects. Completion of this task will rely on cooperation of investigators working on oceanographic characteristics and planktonic ecology during the time period of our study. If, as we expect, our data suggest significant variations between year or between locations in recruitment intensity (as indexed by densities of newly-recruited clams as described above), we will search for covarying physical or biological water-column processes such as current pattern, density and temperature fields, or primary productivity that might explain observed variation. The emergence of significant covariation will suggest models for constraints on clam recruitment that may be linked to constraints on recovery of nearshore vertebrate predators.

2.5.2.7 Invertebrate Co-Predators

We will determine densities and diets of predatory invertebrates in nearshore habitats of PWS that may be important competitors of sea otters for food. Initial efforts will focus on sea stars (*Pycnopodia helianthoides* and *Evasterias troschelii*), crabs (*Telmessus cheiragonus* and *Cancer* spp.), and snails (*Nucella* spp.). Predatory species of interest may be added or deleted from the above list depending on the results of literature review and preliminary field work. Two study areas, Montague Island and Knight Island (Figure 5) will be utilized. Within each area this project will use the same study sites at the same depths as indicated for the subtidal clam assessments. Sampled transects will be placed in adjacent non-overlapping positions to ensure that sampling effort for one project will not be disruptive to the other. In addition, data will be gathered from intertidal soft-substratum sites in the vicinity of subtidal sites. To the maximum possible extent, intertidal sampling sites will be done in or near sites selected for the intertidal clam study. Thus a complete subtidal sample will consist of 2 study areas x 2 subtidal strata x 2 depths x 5 sites = 40 samples. A complete intertidal sample will consist of 2 study areas x 5 sites = 10 samples.

Subtidal invertebrate predator data will be collected during scuba dives. A temporary 50-m transect line will be placed on the bottom. The line will be divided into 10 m segments. Within each segment, a random point on the line will be chosen. A 10-m line will be extended perpendicularly from the random point in one of two randomly chosen directions. Invertebrate predator species within 1 m of either side of the 10-m line will be counted, measured, and examined for dietary information. Thus each 50-m transect will provide five separate random subsamples of 20 m^2 each. Sea stars and snails will be located by simple visual survey. Crab counting methods will be determined during preliminary field work. If visual survey is found to be ineffective, crabs will be flushed by dragging a rake with close-set tines through the sediment, then counted and collected (see below).

Sea star size will be indexed by measuring the distance from the center of the mouth to the tip of the longest ray. Crab size will be indexed by measuring the maximum carapace width.

Snail size will be indexed by measuring the maximum shell dimension. Data on transect counts, body size indices, and size of prey items (see below) will be recorded on standardized, pre-printed data sheets. All data for the entire study (all objectives) will be managed and archived according to NVP program protocols and procedures.

Diet will be determined by direct examination during dives for sea stars and snails. *Pycnopodia helianthoides* swallows prey whole, requiring manual probing of the stomach to extract and identify prey. *Evasterias troschelii* and snails process prey externally, thus prey items can be easily removed from the mouth area. Prey items will either be identified and measured (maximum shell dimension) during sampling dives, or returned to the surface for later examination. If preliminary work indicates insufficient diver bottom time to complete all sampling tasks, collected predators will be carried to the surface for processing, and later returned alive to the bottom. All crabs located in samples will be transported to the surface and later dissected to remove stomach contents. Because crabs typically crush hard-shelled prey during ingestion, laboratory examination of stomach contents will be necessary to identify and enumerate prey.

Intertidal density data will be gathered for sea stars and crabs by counting all predatory invertebrates within 1 m on either side of a 50-m line placed parallel to shore at the tidal datum. Counts will be recorded on preprinted data sheets in 1 x 10 m segments (n = 10 segments per transect). Snails will be counted by searching 0.25 m^2 frames placed along the 50-m line. The minimum number of frames necessary for an adequate sample will be determined after preliminary field work during 1995. Diets will be assessed using the same methods as for subtidal samples (see above).

Complete samples will be gathered in winter 1995-96 and summer 1996. Preliminary work will be done during summer 1995 and will include testing and refinement of sampling techniques and determination of minimum sample sizes as indicated above.

During sampling for density and diet all observed individual predators will be scored for activity, as follows:

Sea stars:	Scored active if moving, excavating or ingesting prey, or digesting prey extraorally. Otherwise scored inactive.
Snails:	Scored active if moving or attacking prey. Otherwise scored inactive.
Crabs:	Scored active if moving or feeding. Otherwise scored inactive.

During preliminary studies in summer 1995, we will compare proportions of predators active during day and night dives, and during day and night low tides. If preliminary data indicate significant day/night differences, additional activity surveys will be done at night. If night surveys are necessary, data collected will be limited to activity indices only for those predators with a significant day/night difference in activity. Some crab species are visually sensitive to approaching objects, and may flee during sampling. Location and activity will be scored from the point at which individual crabs are first seen, to minimize bias against inactive individuals.

2.5.2.8 Availability of Intertidal Clams

Spawning by hard-shelled clams like littleneck and butter clams takes place in PWS primarily during June (Feder et al. 1979, H.M. Feder pers. comm.) followed by a 3 week planktonic larval stage (Chew and Ma 1987) before settlement to the benthos. Maximum densities of littleneck clams in PWS tend to occur near the 0.0 m tidal height (mean lower low water) (Paul and Feder 1973, Paul et al. 1976, Houghton et al. 1993b). Poor survival during the first winter has been identified as a limiting factor for PWS littleneck clams (Paul and Feder 1973). We will examine populations of intertidal clams (primarily littleneck and butter clams, but also other common clams utilized by sea otters) at study sites M and N (Figure 5).

A reconnaissance survey will be conducted in the summer (presumably July or August) of 1995 along these coastlines to determine the extent of potential clam beaches (mixed sand/gravel). This survey will occur concurrent with the side scan sonar survey designed to distinguish subtidal habitats adjacent to shore. Additional shoreline information will be obtained from records compiled from the 1989 shoreline surveys. Four beaches will be randomly selected from each of the two treatment areas.

From 1996 - 1998, assessment of recruitment from the previous season's spawning, as well as size and age structure, will be conducted during June. Four 0.25 m^2 samples will be randomly collected from each beach along a 30 m transect at the 0.0 m tidal height. The 30 m transect will randomly be placed at the 0.0 m tidal height on the beach. The sediment in each sample will be removed to a depth of 30 cm and first hand-sorted to remove larger bivalves. This sediment depth is necessary to obtain the deep-dwelling butter clams. Sediment will be washed through a series of screens, the smallest of which is 1.5 x 1.5 mm mesh, to obtain smaller clams. Seawater used for the washing process will be furnished by a portable pump. The sediment retained by the finest screen will be returned to the laboratory and examined for small specimens under a 2x lens and measurements on small clams will be conducted at the Institute of marine Science, University of Alaska Fairbanks. All larger clams will be identified, counted and measured, in the field and returned to the area when they were sampled. All sampling will occur during the low tide series in June 1996. A total of 16-0.25 m^2 samples will be examined for intertidal clams in each treatment area in 1996. All clam identifications, counts, measurements and aging will be conducted at the Institute of Marine Science, University of Alaska Fairbanks.

Samples of sediment and littleneck and butter clams will be archived for possible hydrocarbon analysis. Two 50 g samples of sediment will be collected adjacent to the first two 0.25 m^2 quadrants on each beach. Therefore, a total of eight sediment samples will be collected from each of the two treatment areas. Two 50 g samples of littleneck clams and butter clams will be collected adjacent to the 0.25 m^2 quadrants on each beach. Therefore, a total of eight 50 g tissue samples of the two clam species will be collected from each of the two treatment areas. The total sediment and clam samples that will be archived for hydrocarbon analyses in 1996 are 16 and 32, respectively. All hydrocarbon samples will be frozen in the field and stored at the National Biological Service facility in Anchorage. If various measures of health (e.g., P450 assay) for sea otters or sea ducks indicate presence of oil then the clam and sediment samples will be sent to the NOAA/NMFS Auke Bay facility for hydrocarbon analyses. This information may identify a potential mechanism of primary oil transport to predators.

2.5.2.8 Predation on Bivalves by Sea Duck Competitors

Sea otter and sea duck diets overlap broadly, especially with respect to bivalves. To assess predation pressure of sea ducks on populations of selected bivalves (mussels and sub- and inter-tidal clams) and possible confounding effects on interpretation of sea otter effects (see section 2.5.1.3 and Figure 8), models including diet, duck numbers, and estimates of caloric needs will be derived to estimate numbers, biomass, and size classes of invertebrate prey. In concert with data documenting invertebrate prey abundance and size class and sea otter diets, we can determine the extent of structuring by sea duck predation and its potential confusion with sea otter structuring.

Diets of Barrow's goldeneyes and white-winged scoters will be determined by collecting birds on the invertebrate study sites. Collections will occur at three periods during winter (November, January, and March) beginning in 1996. Approximately 50 birds of each species will be taken. Birds will be shot from foraging flocks. Immediately after collection, the esophagus, proventriculus, and gizzard will be tied off separately, removed as a unit, and injected with alcohol to halt digestion. Samples will be removed from the digestive tract the same day and stored in alcohol. Diet analysis will consist of sorting and identifying samples and quantifying: length, width, and wet mass of each item and wet mass, volume, and dry mass of each taxa per sample.

We will conduct complete counts of sea ducks within the Knight and Montague Island study sites (Figure 5). Sea duck counts will occur in November, January, and March, and will be replicated within a week if weather allows. Two observers will conduct the counts in a skiff following standard boat survey methods for marine birds. Methods will be consistent with those used by Klosiewski and Laing (1994) and Agler et al. (1994). During counts observers will collect information on species, gender, habitat, and foraging activity of all ducks observed.

2.5.2.9 Availability of Sea Urchins and Crabs

Sea urchin and crab abundances will be estimated from the Montague and Knight Island study sites (Figure 5). We have little prior data describing habitat preferences of urchins, and crabs appear to be widely distributed among habitats (Jewett et al. 1994). As a result, it will be necessary to sample within all habitats (at least during our initial year of sampling).

Extent of each habitat will be determined and divided into 200 m segments. We will then randomly select 6 sampling sites from each habitat and area. Each site will have a minimum of 200 m of contiguous habitat. Sampling will be conducted at a minimum of 4 sites per habitat. More sites will be sampled if it is possible to do so within the allotted cruise time.

We will sample sea urchins and crabs within two depth strata, 0 to 3 m and 3 to 6 m. Previous surveys as well as anecdotal observations indicate that both sea urchins and *Telmessus* in PWS are found in relatively shallow water. Jewett et al. (1994) noted much higher densities of *Telmessus* in shallow (less than 11 m) stations than at deeper sites, and noted highest densities of sea urchins in very shallow water (less than 3 m). Evidence from Cook Inlet and Kodiak Island, Alaska suggests that green urchins are more abundant in shallow waters. In the absence of otters, urchins are generally found in higher densities at depths less than 6 m (Dames and Moore 1976, Zimmerman et al. 1979, Lees and Driskell 1981). Dayton (1975) noted higher densities of green sea urchins in somewhat deeper water (greater than 18 m) in Amchitka Alaska, where sea otters were abundant. He attributed the lack of urchins in shallow water to greater foraging efficiency of otters at the shallower depths. Thus, while occasionally found in deeper waters, shallow populations of sea urchins appear to be the most important for otters. The sampling depths at each site will be randomly selected from the 0 to 3 and 3 to 6 m strata.

At each depth, divers will count sea urchins and crabs within a 100 to 200 m long transect that is 1 m in width. Divers will turn algal blades and smaller cobbles to find cryptic sea urchins. In addition to counting sea urchins and crabs, divers will also note the predominant substrate type (mud, sand, gravel, cobble, boulder, reef), the dominant vegetation type (none, eelgrass, *Laminaria, Agarum*, etc.), and the density of dominant sea stars (*Pycnopodia helianthoides* and *Dermasterias imbricata*). The sea stars will be counted because these are potential competitors of sea otters for some food items, especially clams and sea urchins (Duggins 1981, 1983).

The length of the transect will be measured in one of two ways. First, if it proves feasible, the transect length will be measured using differential GPS. Divers will enter the water at a starting buoy and then proceed along a compass course for a specified period of time. The time will be that generally considered necessary to cover about 200 m. The positions of the start and end point of the dive will be noted using differential GPS and the length of the transect will be determined. Differential GPS correction transmitters are now operational in the Sound, allowing for about 10 m accuracy in positioning. However, if is not certain whether clear reception of this signal will be available in all parts of the Sound. In the event that we are unable to use differential GPS, divers will determine transect lengths by moving a 2 m long measuring stick along the transect.

The size and average density of urchins will be determined for any aggregations that are noted along the transect. An aggregation will be defined as any 1 m^2 area in which there are 5 or more urchins. When aggregations are encountered, we will determine the size of the aggregation by marking the boundaries of the aggregation along two axes, onshore-offshore, and longshore. The positions of these boundaries will be noted using GPS, or meter tapes. We will then count the number of urchins within 9, 0.25 m^2 quadrats that are uniformly spaced along the axes of the aggregation.

We will determine the size (test diameter) of the first 100 urchins observed at each site. In addition, we will tag a minimum of 200 urchins from each aggregation found. The urchins will be collected and measured, and all within a size range of 15 to 18 mm will be tagged by placing them into a solution of calcein dye overnight (see also section 2.5.2.10). This has proven to be an effective method of marking animals for latter retrieval and determination of growth rates (based on marks left by Calcein in their skeletal material; Dixon et al. 1992). The urchins will be released into the same area from which they were collected. In fall, 1995 we will conduct preliminary sampling to test survey methods including GPS locating systems. Initial full scale sampling will be conducted in 1996.

The sampling plan for 1996 may be modified (if necessary) based on preliminary 1995 reconnaissance results. For example, some habitats or depth strata may be eliminated if they prove unsuitable for urchins and crabs. Otherwise, it is anticipated that comparable methods as described for sampling in 1996 will be used in year 3 estimation of abundance. Size distributions will be determined as in year 2, and a total of 200 urchins will be collected form each aggregation from which animals were collected and tagged in the previous year. These animals will be returned to the laboratory where they will be measured and the presence of a tag determined by viewing under a florescent microscope.

If we note differences in density among oiled and unoiled areas in 1996, we also will measure recruitment of urchins in 1997 (see also section 2.5.2.9). This will be done using nylon bristle brushes as larval collectors (Ebert et al. 1994). Brushes will be placed at each of 5 sites per area. Eight replicate brushes per site will be put out in April and collected and replaced by new brushes at monthly intervals through August of that year. The brushes will be returned to the laboratory where they will be washed, and the number of small urchins per brush will be counted.

2.5.2.10 Availability of Mussels

Within the Montague and Knight Island study areas (Figure 5) mussel abundance will be estimated using stratified random sampling with proportional allocation. Each length of coast will be initially divided into five strata based on shoreline type as characterized by the EVOS Damage Assessment Geoprocessing Group: 1) exposed rocky, 2) sheltered rocky, 3) gravel, 4) sheltered tidal flats, and 5) mixed sand and gravel. Four shoreline segments will be sampled in each stratum. A 30 m transect will be laid parallel to shore at the median tidal level of mussel distribution at randomly selected mussel beds in each randomly selected segment. Mussel densities will be estimated using 500 cm^2 quadrats. The quadrats will be placed randomly along each transect. The number of transects and quadrats will depend on the distribution of the mussel beds and mussel density in each bed as determined during preliminary sampling. A preliminary estimate of total sample size is 2 study areas x 5 strata x 4 shoreline segments x 15 replicates = 600 samples. The contents of each quadrat will be collected and subsequently washed over a 0.5 mm sieve. Mussels retained by the sieves will be counted. Small mussels (size range, 0.5-5mm) will be separated from organic detritus and sediment with a combination of flotation and elutriation in a sodium polytungstate solution.

In a subset of ten quadrats from each randomly selected mussel bed mussels will be collected and the maximum shell length of each mussel will be measured to the nearest 0.1 mm with a digital caliper connected to a portable data recorder. Lengths of smaller mussels will be obtained with an image analysis system. Mussels will be dried at 60°C and weighed at 24 h intervals to the nearest 0.001 g on a precision balance. This procedure will continue until mussel weights have stabilized. Subsequently, mussel tissue will be digested in 10% potassium hydroxide and the remaining shell dried to a constant weight. Tissue dry weight will be obtained by subtracting shell dry weight from mussel dry weight.

If differences in the size-frequency distributions of mussels are observed between areas M and N then individual mussels from each stratum in each area will be tagged with calcein to measure growth. The calcein solution will be prepared as described in Houghton et al. (1993b). Mussels will be held in the calcein solution for 24 h. Mussels will be tagged and released at intervals of three months. Tagged individuals will be retrieved at the end of each three month period, the periostracum will be removed and the increment of shell laid down after the calcein band (observed under an ultraviolet light) was incorporated into the shell will be measured using an image analysis system.

Mussels will be collected for tissue hydrocarbon analysis immediately adjacent to a subset of the randomly placed quadrats used for density estimates. Three composite samples of mussels will be collected from oiled and unoiled mussel beds at each study site. Samples will be placed in coolers with ice immediately after collection and will be frozen within an hour. Appropriate blanks will be collected at each site.

Analysis of variance will be used to compare mussel abundances between study areas. A nonparametric anova will be substituted if the data do not meet the assumptions of the parametric anova and standard transformations do not normalize the data and stabilize variance. Size-frequency distributions will be compared using the chi-square statistic after decomposition of the distributions to be compared into subpopulational nodes. Growth curves of mussels will be compared using analysis of covariance following curvilinear regression.

2.6 Specific Methods for Harlequin Ducks

2.6.1 Rationale

2.6.1.1 Demographic Measures

Sound-wide abundance estimates for birds are generated periodically by boat-based surveys (Agler et al. 1994). We propose to use previously collected boat survey data combined with an existing shoreline-type data set to answer three more specific questions. First, which shoreline-types, if any, are selected by harlequin ducks? Second, are densities of harlequin ducks in the oiled zone lower than expected based on habitat availability in the oiled zone and patterns of selection of those habitats in the unoiled area of PWS? The third question focuses on the heavily oiled Area N, which was selected as a study site because sea otter and harlequin duck densities appear to be unusually low there; do shoreline types in Area N contain fewer harlequin ducks than expected based on patterns of habitat selection in the unoiled area? Evidence of avoidance of apparently suitable habitat in the oiled zone would indicate oil-related causes of lack of recovery.

Demographic data will be collected to assess harlequin duck population health between study sites, in the form of studies of overwinter female survival. For long-lived species with relatively low annual productivity, like harlequin ducks, female survival is a primary determinant of population trends (Goudie et al. 1994). Sex ratios of nearly all ducks are skewed towards males (Bellrose 1980), i.e., fecundity is not limited by numbers of available males. In this study, both adult and subadult females will be marked. Adult female survival is particularly influential on population growth rates, while subadults may be more susceptible to mortality factors and, thus, provide indications of limiting factors as well as perturbations to the system.

2.6.1.2 Health Measures and P450 Induction

Bioindicators of harlequin duck health will be compared between study sites, including blood and tissue analyses described in sections 1.4.2.2 and 2.3. Body condition of molting harlequin ducks also will be compared between sites. Body condition can have critical influences on survival and reproduction, and thus is a good indicator of overall population health. For example, the waterfowl literature documents instances in which survival of wintering ducks varied with condition (Conroy et al. 1989, Longcore et al. 1991, Bergan and Smith 1993). Harlequin ducks may be particularly sensitive to body condition effects because of severe weather encountered in northern wintering areas (Goudie and Ankney 1986). Body composition affects reproduction through initiation date and clutch size effects (Esler and Grand 1994) and may affect breeding propensity of harlequin ducks. Exposure to contaminants in winter can influence waterfowl body weights or composition (Hohman et al. 1990), subsequently affecting survival or reproduction. Barrow's goldeneyes and white-winged scoters collected for diet assessment (section 2.5.2.8) also will be available for analyses of tissue, blood, and body condition.

2.6.1.3 Trophic Interactions

Harlequin ducks feed primarily on lacunid snails, limpets, chitons, mussels, and littorine snails (Goudie et al. 1986, Patten 1994) that live in the lower intertidal and shallow subtidal zone; however, foraging ecology relative to available food resources has never been addressed. There is evidence that some harlequin duck foods (e.g., limpets, mussels and some littorines) were injured following the EVOS (Highsmith et al. 1993). There is also evidence that sea duck distribution and abundance, including that of harlequin ducks, may be affected by foraging opportunities (Stott and Olsen 1973, Goudie and Ankney 1986). In this study, we will assess whether food availability differs between oiled and unoiled areas, and if so, whether food may be limiting recovery of harlequin ducks in oiled areas. As discussed in introductory remarks (section 1.4.2.3), a lack of preferred food items at oiled sites indicates possible inhibition of recovery in oiled areas as a result of food limitation. As a corollary, abundant food in oiled areas may well provide additional evidence for a lack of recovery, and will suggest that factors other than food (e.g., continued toxicity of oil or demographic constraints) may be limiting recovery.

2.6.2 Methods

2.6.2.1 Analysis of Harlequin Duck Distribution and Habitat

We will examine habitat use relative to Sound-wide availability using an existing shoreline-type data set of PWS (Research Planning Institute 1983) which was transferred to a computer GIS format after the spill (GIS Technical Group 1991). During the Damage Assessment phase of the spill, this data set was overlaid (B. Boyle, pers. comm.) on transects from boat surveys conducted over the last 20 years (Klosiewski and Laing 1994), and the linear distance of each shoreline type in a given bird survey transect was compiled (B. Boyle, pers. comm.).

For this project, we will place each transect in PWS in a category based on its dominant shoreline-type. To answer the first question discussed in 2.6.1 above, densities of harlequin ducks in each transect randomly sampled in boat surveys will then be compared statistically among shoreline-types to model expected densities by habitat. We will address the second question by comparing, by shoreline-type, predicted harlequin duck densities to densities in the oiled area. We will answer the third question by making a similar comparison specific to Area N.

2.6.2.2 Harlequin Duck Survival

Harlequin ducks will be captured during late August and early September by driving molting flocks into traps. Molting flocks will be located from a support vessel cruising slowly along shorelines. When molting flocks are located, a crew will be sent ahead to set the trap wings and pot at an appropriate site. When the trap is set, kayakers will slowly herd the flock into the trap. These methods have been successfully applied in British Columbia (Goudie, pers. comm.).

One hundred females will be outfitted with radio-transmitters each year, beginning in 1995. Fifty birds each will be marked in oiled and unoiled study sites. Samples will be evenly allocated between adults and subadults. The focus will be on females because their survival largely dictates population dynamics (Goudie et al. 1994). Capturing and marking birds will be conducted cooperatively with Alaska Department of Fish and Game investigators monitoring harlequin duck populations (EVOS project 95427).

Transmitters will be equipped with mortality switches. Transmitter life will be at least 210 days. Transmitters will be implanted in the body cavity with an external antenna. Implanted transmitters have been successfully used in waterfowl studies (e.g., Olsen et al. 1992, Haramis et al. 1993) and are less disruptive than backpack transmitters (Pietz et al. 1993, Rotella et al. 1993), especially for diving ducks (Korshgen et al. 1984). Surgeries will be conducted by a certified veterinarian experienced in avian implant surgeries, following procedures outlined in Alaska Science Center, National Biological Survey standard protocol.

These procedures have been used successfully for radio implants in spectacled eiders and common murres (Mulcahy, pers. comm.).

Radio telemetry flights will be conducted weekly through winter. Flights will detect each marked individual and note status and general location. For birds indicated as dead, the carcass will be recovered by boat or float plane as soon as possible. Collected carcasses will be examined for causes of mortality.

Data will be analyzed using a Kaplan-Meier staggered entry design (Pollock et al. 1989). Effects of oiling history, age, and condition (as estimated by condition indices described in section 2.6.2.3 below) will be examined with log-rank tests.

2.6.2.3 Health Measures and P450 Induction

A condition index for molting harlequin ducks will be derived to allow an accurate and nonlethal assessment of body composition for captured harlequin ducks. Condition will be modeled with a combination of morphological measures and measurements of total body electrical conductivity (TOBEC), which provides an accurate indication of total lean and lipid mass (Roby 1991). In 1995, a sample of 25 molting harlequin ducks will be collected in eastern Prince William Sound, where harlequin duck populations were not believed to have been injured. Collected birds will be captured during molting drives, treated similarly to other captured birds (see below), and then collected by injection of euthanasia solution intravenously or in the trachea. Carcass analysis of collected birds will be conducted following standard methods (Esler and Grand 1994). Models will then be created, using morphology and TOBEC measures, to predict body composition. Condition indices will be extremely valuable for estimating condition of molting harlequin ducks for assessments of (1) effects of condition on survival of radio-marked females (see above), and (2) differences in body condition between study sites (see below).

Harlequin ducks captured during molting drives will have blood drawn from the jugular or brachial veins for blood assays (section 2.3). A 3 mm foot web biopsy will be used as a nondestructive tissue sample for P450 measures (section 2.3). Morphology of each bird will be measured including body weight, tarsus, culmen, and wing length from the wrist notch to the end of the longest primary. Each bird will be passed through the TOBEC analyzer a minimum of six times to insure an accurate reading. Birds will be restrained with a nylon stocking to insure a common position for all birds during TOBEC analysis.

Stage of molt will be indexed by primary length. Linear models describing body condition variation through molt will be derived; slopes and intercepts will be compared between oiled and unoiled sites for each age and sex cohort.

2.6.2.4 Harlequin Duck Prey Abundance

During the first year of our study (summer 1995), we will census subtidal habitat types within oiled and unoiled areas regions of the Sound, and produce habitat maps (section 2.4). The following winter (November 1995-March 1996), we will assess population densities of harlequin ducks in these same areas, and determine the location (within approximately 30 m) of each duck or flock of ducks (section 2.5.2.8) Habitat and harlequin duck distribution maps will be overlaid to define habitats and areas with high duck densities.

During the fall of the following year, we will assess abundance of the 5 primary prey items within 12 randomly selected sites within high harlequin duck use areas: 6 in the oiled area and 6 in the unoiled area. A second duck survey conducted during the winter of 1996/1997, will confirm continued use of selected habitat. A second invertebrate survey of the same sites sampled in fall 1996 will be sampled again in spring 1997, after overwintering ducks have left the PWS.

Invertebrates will be sampled at 6 randomly selected 1 m^2 quadrats within the intertidal and shallow subtidal zone (from +1 m to -2 m MLLW) at each of the 12 sites. All vegetation from each quadrat will be removed by divers using SCUBA and will be placed in a small mesh bag underwater. All remaining epifauna will then be scraped from rocks and sampled using an airlift. Samples will be sorted in the laboratory and the number, size classes, and biomass (dry weight) of each of the 5 major prey items will be determined.

We will compare the mean density and biomass at each of the two areas (oiled and unoiled) in both fall (before duck foraging) and spring (after foraging) surveys using a two-way ANOVA.

2.7 Specific Methods for Pigeon Guillemots

2.7.1 Rationale

Guillemots have served as subjects in previous studies to assess the effects of ingested crude oil on marine birds (Peakall et al. 1980). Nestling black guillemots (*Cepphus grylle*), a very closely-related species of the pigeon guillemot, were fed single doses of weathered South Louisiana crude oil (WSLC) and subsequently monitored in their natural nest site where they were cared for by their parents. These experiments demonstrated that single doses of as little as 0.1 ml WSLC resulted in declines in growth rates, increases in plasma sodium levels and increases in nasal and adrenal gland masses. The effects of the single dose were not transient, as nestlings that were dosed at roughly two weeks post-hatch were 20% lighter than controls at five weeks of age (just prior to fledging). Such persistent sublethal effects may have serious consequences for post-fledging survival. Peakall et al.'s (1980) study clearly demonstrates that guillemot nestlings living normally in their chosen habitat are tolerant of handling and disturbance associated with assessing pollutant toxicity.

We will monitor blood parameters in pigeon guillemots breeding at Naked Island (oiled area) and Jackpot Island (unoiled area), PWS. Data on population size, reproductive success, prey composition and provisioning rates of breeding guillemots will be collected at these same sites as part of an on-going research project conducted by the Fish and Wildlife Service and directed by Dr. David Irons. Collection of blood samples from nestling and adult guillemots will be coordinated closely with Dr. Irons' field crew. Naked Island supports the highest breeding densities of guillemots in PWS (Sanger and Cody 1993) and a breeding population that is adequate for the proposed research (Oakley 1981, Kuletz 1983). The following parameters will be measured at accessible guillemot nests, in coordination with Dr. Irons' studies, as indices of parent-offspring productivity: 1) chick feeding rates; 2) chick meal size; 3) taxonomic composition of chick diets; 4) biochemical composition of chick food items; 5) chick growth rates and body composition; 6) nestling survival; and 7) fledging age, body mass, and body composition. Productivity will be compared with blood parameters used to monitor contaminant exposure. Nondestructive indices to stress induced by petroleum hydrocarbon ingestion will be used, such as levels of selected plasma immunoglobulins, blood plasma proteins, cell counts, and interleukin levels in blood of adults and chicks, body mass and body composition of adults and chicks, chick growth rates, and fledgling mass. These data will then be used to evaluate the factors that limit guillemot productivity. The results of this research project will provide us with the background necessary to use guillemots as avian indicators of nearshore ecosystem health in PWS.

2.7.2 Methods

2.7.2.1 Indices of Abundance and Health

Field studies will be conducted during the 1996 and 1997 (with options for 1998) breeding seasons in PWS. Fifty active and accessible nests will be located and marked during early incubation at an oiled (Naked Island) and an unoiled (Jackpot Island/Icy Bay) study site in each of the three breeding seasons. Field work will be coordinated with on-going U.S. Fish and Wildlife Service studies of factors limiting recovery of pigeon guillemots in PWS (D. Lindsey Hayes, PI), as part of the Seabird/forage Fish Project (95163). Active and accessible nests will be closely-monitored until the young fledge or the nesting attempt fails.

An attempt will be made to locate, identify, and map all active guillemot nest sites on Jackpot Island and on the western and northern shores of Naked Island. Active nest sites will be identified during the chick-rearing periods (regardless of whether the nest site is inaccessible) because active nest sites can be readily identified by the presence of adults transporting fish in their bills. Trends in the numbers of active nest sites, as well as nest site and colony abandonment rated, will serve as indices to population trends at each study site. Differences in trends of numbers of breeding pigeon guillemots at unoiled (Jackpot Island) and oiled (Naked Island) sites will be used as a demographic indicator of potential effects of the spill. In addition, guillemot adults that are captured at active nests for blood sample collection will be banded with USFWS leg bands for future identification. Pigeon guillemots are highly philopatric and usually return to breed in the same nest crevice each year, or one in close proximity. Consequently, mark-recapture rates can be used to estimate adult survivorship at the two study sites.

Differences in reproductive success (number of fledglings produced per nesting attempt) at the unoiled and oiled sites will be measured as an indicator of effects of the spill on population productivity. Reproductive success in pigeon guillemots can be subdivided into several components: (1) the proportion of breeding age birds that produce a clutch, (2) size of clutches (one or two eggs), (3) the proportion of laid eggs that successfully hatch, (4) the proportion of chicks that successfully fledge, and (5) the proportion of fledged young that survive the post-fledging period. Variable (1) and (5) are extremely difficult to measure, although fledgling body fat reserves can be used as an index to post-fledgling survival. Variables (2), (3), and (4) can be estimated in an unbiased manner (by employing the Mayfield method), if active nests are checked regularly after they are found. Active and accessible guillemot nests will be checked every four days during incubation to determine status, every other day during the hatching period to determine hatching success, and every four days during the nestling period to determine nestling survival rated, and to weigh and measure chicks for monitoring growth and development. The following parameters will be measured at accessible nests as indices of parent-offspring condition; (1) growth rates of body mass, wing length, and primary feathers in nestlings, (2) accumulation of fat reserves in fledglings, (3) total mass (corrected for body size) and body composition of adults during the chick-brooding period, and (4) fledging age and body mass. Clutch size hatching success, fledging success, and overall reproductive success will be compared between the oiled and unoiled study sites. Recent work on pigeon guillemots nesting on Naked and Jackpot islands (D. L. Hayes, unpubl. data) ensures that an adequate sample size of guillemot nests will be found shortly after laying.

Data on age-specific body mass, wing length, and primary feather length of nestlings will be separated by year and study site, and fit to Gompertz sigmoidal growth models. Growth constants (K), inflection points (I), and asymptotes (A) of fitted curves will be statistically analyzed for significant differences among years and study sites. Total body fat of chicks at 20 and 30 days post-hatch will be estimated by noninvasive (nondestructive) measurement of total body electrical conductivity (Walsberg 1988, Roby 1991). The SA-3000 Small Animal Body Composition Analyzer (EM-SCAN, Inc., Springfield, IL) will be validated for measuring body fat in guillemot chicks using a sample of chicks collected in Kachemak Bay, Alaska. Body mass, wing length, length of primary feathers, and TOBEC measurements will be used to develop a condition index for each chick at 20 and 30 days post-hatch.

To more accurately assess the health of individuals and potential effects of oil exposure, we will collect blood from guillemots at the oiled and unoiled study sites. We will use blood sampled from nestlings and adults to determine levels of acute phase blood proteins, such as haptoglobin, albumin, and metalothionine, that are indicative of exposure and tissue damage. We also will measure cytokines such as IL-1 and IL-6 and liver enzymes such as AST. We will supplement our blood molecular work with cellular studies, such as red cell volume, hematocrits, and immune functions (Heinz bodies will be looked for in guillemot blood samples). Differences in biomarker levels of blood collected from oiled and unoiled sites will be used to evaluate the effects of the spill on contaminant levels in the food supply.

Blood samples (1 ml) from guillemot nestlings will be collected by brachial vein puncture at ages 20 and 30 days post-hatch (guillemot chicks normally fledge at 30-40 days post-hatch). Blood samples will be collected in heparinized tuberculin syringes, transferred to Eppendorf centrifuge tubes for transport to the base camp, and centrifuged to separate plasma and cells. Plasma and cells will be frozen separately in propane freezers at the base camps. Blood samples will be collected using SOPs developed by us during the *Exxon Valdez* spill studies to preclude sample contamination. In the lab, plasma and blood cell samples will be analyzed for molecular and cellular biomarkers (e.g., characteristic morphological lesions of red blood cells associated with hemolytic anemia caused by oil ingestion [Leighton 1985]). A panel of biomarkers, including leukocyte counts, macrophage function, electrophoretic measurements of serum immunoglobins, and ELISA assays of interleukins will provide data on the health status of individuals and permit comparison of study sites. At UAF, we will perform haptoglobin assays, IL-1 and IL-6 assays, and immunoglobin typing assays for the blood samples collected from guillemots. Cell counts will be performed by a NBS contracted lab and macrophage function assays will be developed. Results from biomarker studies will be used to test biostatistical models that predict population health.

The impact of potential contaminant exposure on breeding adults will be monitored using a combination of direct and indirect methods. Attentiveness of adults will be monitored during the incubation period. Frequency of chick meal delivery and meal size will be determined during the chick rearing period by a combination of monitoring adult nest visitation rates and periodic weighing of chicks. Individual variation in exposure of adults (and nestlings) to petroleum hydrocarbons will be monitored by periodically collecting food samples from adults as they return to the nest site to feed nestlings and by collecting prey samples at sea (section 2.7.2.2). In the lab, samples of nestling food will be analyzed to determine levels of aliphatic and aromatic hydrocarbon fractions using a Iatroscan MK-5 TLC/FID Analyzer System. During the chick-brooding period (0-7 days post hatch), adult guillemots will be captured in the nest crevice, banded for later identification, and blood samples (1 ml) collected from the brachial vein. Blood samples will be analyzed for molecular and cellular biomarkers of contaminant exposure using the same techniques applied to nestling blood samples. These measurements will allow us to monitor the impact of various levels of contaminant exposure on physiological condition of nestlings and foraging efficiency of adults.

2.7.2.2 Prey Abundance

Surveys to assess abundances of nearshore demersal fishes that comprise a major proportion of guillemot diets will be conducted at the oiled study site (area N, western Naked Island) and the unoiled study site (area J, Jackpot Bay; Fig. 5). The target fishes include a variety of blennies, sculpins, and sand lance, because guillemots feed their young a diverse array of fish prey (Kuletz 1983).

During 1985, results from side-scan sonar surveys (section 2.4) will be used to define subtidal habitats. Fish sampling will be conducted from 1996-1988 and will be stratified, probably within four subtidal habitats. Within each habitat, six sites will be randomly selected and sampling will occur on 1 X 50 m transects parallel to shore at the 0-3 m depth stratum. A total of 18 transects will be sampled in each treatment area. Fishes will be identified and counted by SCUBA divers as they swim along the transect within 3 m of the bottom. For schooling fishes like Pacific sand lance, we will employ a variety of netting techniques. Twenty fish of each dominant taxa will be collected (be spearing, netting, and/or seining) from each area (oiled and unoiled) and archived for potential hydrocarbon analyses.

Prey availability will also be assessed from data on the provisioning rates of nestlings by parents. Active nests will be observed from blinds in order to measure chick meal delivery rates, as well as to estimate the taxonomic composition and size class distribution of nestling diets. Differences in parental provisioning rates, taxonomic composition, and size class distribution of nearshore demersal fishes fed to nestlings at unoiled and oiled sites will be used as an index to potential effects of the spill on prey availability. On-site estimates of nearshore demersal fish abundance will be compared with the rate and composition of prey delivered to nestlings in order to evaluate prey preferences in relation to availability.

2.8 Specific Methods for River Otters

2.8.1 Rationale

We will evaluate changes in population trends of river otters by examining the frequency of latrine site abandonment on oiled and unoiled areas. Kruuk et al. (1989) demonstrated a strong positive relationship between number of resident females and number of active holts (latrine sites) for European otters living in a marine environment. Likewise, Testa et al. (1994) showed that number of active latrines varied with estimated population size for river otters in PWS; however, too few areas were sampled to establish a regression line between these variables. Nonetheless, it is likely that abandonment of latrines provides a useful index to otter abundance, and can be used to evaluate trends in otter populations. Indeed, Duffy et al. (1994b) documented that river otters throughout oiled areas of PWS abandoned latrine sites at a rate over three times greater than did otters inhabiting unoiled areas. We will not be sampling all of the same areas we previously examined because of integration with other studies of vertebrate predators in the nearshore environment. If differences in oiled and unoiled areas still exist, it would be possible in subsequent years to evaluate the same sites that we sampled in 1991 to compare current values against that benchmark.

We previously developed a nonlethal method for evaluating the effects of marine pollutants (in this instance, crude oil) on the blood-enzyme chemistry of river otters (Duffy et al. 1994b). We first noted that blood haptoglobins (an acute-phase protein) were elevated in otters inhabiting areas where crude oil was prevalent one year following the oil spill (Duffy et al. 1993). Even two years after the oil spill and a major effort to clean oil-contaminated shores, we were able to construct a biostatistical model, using logistic regression, in which we classified > 86% of river otters correctly as having been captured in oiled or unoiled zones. This highly sensitive model used only blood values for haptoglobin, interleukin 6 (a cytokine), and AST (a liver enzyme). Our approach has already been extended for evaluating other marine mammals (Zenteno-Savin et al. 1993), and may be applicable to other vertebrates, especially marine birds. The strength of this line of research is that we have already developed the expertise necessary to live-capture river otters, have base-line data from oiled and unoiled areas throughout PWS, and have a predictive model that assesses the effects of oil contamination on otters, thereby providing an index to environmental health. This will provide a sensitive tool for examining the health of nearshore ecosystems.

2.8.2 Methods

2.8.2.1 Latrine Site Characteristics and Density

We will conduct searches of shorelines using the methods described in detail by Bowyer et al. (1994, 1995) and Testa et al. (1994). In 1996 and 1997 latrine sites will be characterized with respect to their topography, terrestrial vegetation (old growth, new growth, rock-grass-moss, or brush alder), intertidal substrate (sand, gravel, small rocks, large rocks, or bedrock) and distance from freshwater. Vegetation and intertidal substrate will be assessed for a 10-m arc with its pivotal point at mean high tide and extending in the appropriate direction (shore or ocean). This point will be aligned with the most obvious entrance to the latrine site. Relative cover of vegetation will be estimated visually; any category that does not compose 25% of the supratidal portion of the 10-m arc will be scored as 0. More abundant vegetational types will be assigned a rank of 1 to 4 (1 = 25%, 2 = 50%, 3 = 75%, 4 = 100% cover). This method will also be used to categorize intertidal substrates. Vegetated slopes will be measured from a point at mean high tide to a point 10-m distant toward the latrine site with a hand-held compass (nearest 5°). The tidal slope will be measured similarly from mean high tide to a point extending 10 m into the intertidal zone. Tidal state (high, incoming, outgoing or low) will be noted so that measurements can be corrected if necessary. The aspect of the latrine site will be recorded in eight compass quadrants, and exposure to wave action ranked into three broad categories from protected to exposed.

2.8.2.2 Morphometrics

Otters will be captured in 1996 and 1997 using Hancock live traps (Melquist and Dronkert 1987) placed on trails at latrine sites and monitored by means of a trap transmitter (Telonics, Mesa, Arizona, USA) that signals when a trap was sprung. We have used this method successfully in the past (Duffy et al. 1993, in press). The otter initially will be immobilized in the trap with a hand injection of ketamine hydrochloride (11 mg/kg estimated body weight, Sigma, St. Louis, Missouri, USA) and placed in a drugging box (Melquist and Hornocker 1983). Weights and measurements (see Duffy et al. 1993) will be taken and the blood sample drawn from the jugular vein. Sexes will be distinguished by the relative position of urogenital openings and palpitation of the baculum (Larson 1984). Age determinations will be based on tooth wear and overall size of otters (Stephenson 1977).

2.8.2.3 Biomarkers of Health and Cytochrome p450 Induction

During the past 15 years, xenobiotics have been shown to alter immune function (Fowles et al. 1993). Environmental chemicals interact with various parts of this complex system resulting in either suppression or hypersensitivity of immune activity and surveillance. A panel of biomarkers, including leukocyte counts, macrophage function, electrophoretic measurements of serum immunoglobins, and ELISA assays of interleukins will provide data on the health status of organisms and permit comparison of species.

At UAF, we will perform haptoglobin assays, IL-1 and IL-6 assays, and immunoglobin typing assays for the blood samples collected during this project. Cell counts will be performed by NBS contracted lab and macrophage function assays will be developed.

The following biomarker analyses will be performed on the samples (Fossi and Leonzio 1993): blood plasma protein and liver enzymes, cell counts and Heinz bodies, and interleukin levels. Haptoglobins, IL-6, and several blood enzymes have been used successfully as biomarkers for river otters (Duffy et al. 1993, 1994a, 1994b). We will continue using this productive approach.

2.8.2.4 Prey Abundance

Surveys to examine abundance and health of river otter forage fishes will be conducted as described in section 2.7.2.2.

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4.0 Tables

Table 1. Restoration strategies from the *Draft Restoration Plan*.

Biological Resources	Primary Restoration Strategy
Recovering Resources	*Primary Restoration Strategy*
Bald Eagle	• Rely on natural recovery
Black Oystercatcher	• Monitor recovery
Killer whale	• Protect injured resources and their habitats
Sockeye salmon at Red Lake*	
Resources Not Recovering	*Primary Restoration Strategy*
Common murre	• Conduct research to find out why these resources are not recovering
Harbor seal	• Initiate, sustain, or accelerate recovery
Harlequin duck	• Monitor recovery
Intertidal organisms	• Protect injured resources and their habitats
Marbled murrelet	
Pacific herring*	
Pigeon guillemot	
Pink salmon*	
Sea otter	
Alaska salmon (Kenai & Akalura Systems)*	
Subtidal organisms	
Recovery Unknown	*Primary Restoration Strategy*
Clams*	• Rely on natural recovery
Cutthroat trout	• Monitor recovery
Dolly Varden trout	• Protect injured resources and their habitats
River otter	
Rockfish	

* These resources are also important for subsistence or commercial fishing. For these resources, waiting for natural recovery may significantly harm a community or industry, and the strategies for subsistence or commercial fishing also apply.

Table 2. Injury and evidence for lack of recovery from the *Exxon Valdez* Oil Spill, 1989, in four top-level nearshore vertebrate predators as evidenced through demographic, bioindicator, and trophic factors.

Injured Resource	Injury to Nearshore Ecosystem and Lack of Recovery as Evidenced in Four Key Species	Status/ Recovery Strategy
Sea otters	**DEMOGRAPHIC** •Up to 4,000 acute mortalities	•Stable, not recovered
	•Various surveys suggest abundance of sea otters has not recovered to pre-spill numbers (Table 4) •Significant differences in juvenile survival between oiled and unoiled areas in 90/91 and 92/93. •Proportions of prime aged animals among dead different from pre-spill levels through 1991; however, returned to normal thereafter (Ballachey et al. 1994).	•Conduct research to find out why not recovering; hypotheses include continued hydrocarbon ingestion; spill-caused changes in benthic prey.
	BIOINDICATOR •Hemotological and serum chemistries suggest otters in oiled areas had higher incidence of inflammatory and/or infectious conditions. **TROPHIC** •Primary foods include mussels, clams, and urchins, as well as other subtidal organisms. Sea otters feed in the lower intertidal and subtidal areas, areas that were especially contaminated by oil spilled from the *Exxon Valdez* (Wolfe et al. 1994) and may still be exposed to hydrocarbons through their feeding (EVOSTC 1994a). •In areas where recovery has not occurred, increases in sea urchin densities (a preferred prey) have been observed (Jewett pers. comm.).	•Recovery judged when population abundance and distribution are comparable to pre-spill, and when all ages appear healthy

Injured Resource	Injury to Nearshore Ecosystem and Lack of Recovery as Evidenced in Four Key Species	Status/ Recovery Strategy
Sea ducks	**DEMOGRAPHIC** •1,000 acute mortalities in Harlequins •875 acute mortalities in other species •Populations of goldeneyes have increased more slowly in oiled vs unoiled areas in 1993 and 1994 (Agler et al. 1994, Agler pers. comm.). •Summer populations of harlequin ducks, which may be year-round residents, were lower than expected in the oiled area of Prince William Sound between 1989 and 1991 (Klosiewski and Laing 1994). **BIOINDICATOR** •Patten (1994) found hydrocarbon metabolites in sea ducks collected in oiled areas and also suggested that reproductive effort and productivity of harlequin ducks were lower in oiled areas. **PREDATOR/PREY** •Sea ducks rely heavily on mussels, clams, gastropods, urchins, and other subtidal and intertidal organisms that may continue to transport hydrocarbons through their food chain. They may also compete with other top predators for these prey. However, no specific assessment evidence of the potential for trophic-related constraints to recovery exists.	•Unknown •Conduct research to find out why not recovering; hypothesis related to oil-contaminated prey •Recovery judged for harlequins when breeding and postbreeding season densities and production of young return to pre-spill levels, or when no difference between spill and non-spill areas.

Injured Resource	Injury to Nearshore Ecosystem and Lack of Recovery as Evidenced in Four Key Species	Status/ Recovery Strategy
Pigeon guillemots	**DEMOGRAPHIC** •1,500-3,000 killed by EVOS in 1989	•Stable or continuing decline
	•Populations in PWS have declined from c.15,000 in the 1970s to c.3,000-5,000 in 1993 based on boat surveys. Declines have been greater in oiled vs unoiled areas of PWS (Klosiewski and Laing, unpubl. data; Sanger and Cody 1993). •Number of breeding pairs on Naked Island (largest guillemot breeding aggregation in PWS) have declined c.50% since the late 1970s and give no evidence of recovery (D.L. Hayes, USFWS, pers. comm.)	•Conduct research to find out why recovering; likely causes climatic /oceanographic, prey limitations and predation
	BIOINDICATOR •Average growth rates of chicks have declined since the spill (Oakley and Kuletz 1993) and remained lower at Naked Island (oiled) versus Jackpot Island (unoiled) during the 1994 breeding season (D.L. Hayes, USFWS, unpubl. data). •Fledging weights of guillemot chicks on Naked Island (oiled area) were lower than on Jackpot Island (unoiled area) in 1994 (D.L. Hayes, USFWS).	•Recovery judged by stable or increasing populations
	TROPHIC •No direct evidence collected. However, nearshore demersal fish, primary prey of this species, demonstrate a high incidence of hemosiderosis in oiled eelgrass beds of Herring Bay (Jewett et al. 1994). This suggests continued exposure to hydrocarbons. Nearshore demersal fish comprised ~half the diet of chicks on Naked Island. •Sandlance, a schooling fish that burrows in nearshore sandy sediments, formerly comprised c. a third of the diet of chicks on Naked Island. Since the spill, the proportion in the diet has declined.	

Injured Resource	Injury to Nearshore Ecosystem and Lack of Recovery as Evidenced in Four Key Species	Status/ Recovery Strategy
River otters	**DEMOGRAPHIC** •Although some were killed, there was no catastrophic mortality--river otters continued to live in areas that were heavily oiled through 1990 (Testa et al. 1994) •Initially modified their use of habitat by avoiding heavily oiled shorelines (Bowyer et al. 1995). Selected habitat differently on oiled verses unoiled areas by concentrating their activities on steeper tidal slopes and using areas with greater exposure to wave action (Bowyer et al. 1994), where oil was less likely to persist (Wolfe et al. 1994) •In 1990, home ranges in oiled areas were 2x those in unoiled areas, suggesting a loss of habitat on oiled sites (Bowyer et al. 1995) •Continued exposure has adverse health effects; lower body mass in oiled vs. unoiled areas (Duffy et al. 1993, 1994b). Lower body mass often related to lower reproductive output in large mammals (Docktor et al. 1987) •Throughout broad areas of PWS, latrine sites (an index of population density) were abandoned at a rate three times greater on oiled versus unoiled areas (Duffy et al. 1994a). **BIOINDICATOR** •Continued exposure has adverse health effects; higher haptoglobin (an acute-phase protein indicator of damage) levels than in otters from unoiled areas (Duffy et al. 1993). **TROPHIC** •Diets in oiled vs unoiled areas were similar through 1990, but differed markedly by summer 1991 (Bowyer et al. 1994). A number of taxa were absent from the diet in oiled areas. •Nearshore demersal fish, primary prey of this species, demonstrate a high incidence of hemosiderosis in oiled eelgrass beds of Herring Bay (Jewett et al. 1994). This suggests continued exposure to hydrocarbons.	•Unknown •Rely on natural recovery, indications of recovery are when habitat use, food habitats and physiological indices return to pre-spill conditions.

Table 3. Summary of methods for the NVP project, listed by species and approach.

APPROACH	SEA OTTERS	HARLEQUIN DUCKS	PIGEON GUILLEMOTS	RIVER OTTERS
DEMOGRAPHY	•AERIAL SURVEYS OF ABUNDANCE •SURVEYS OF ANNUAL REPRODUCTION RATES •CARCASS RECOVERY TO EVALUATE MORTALITY PATTERNS	•ASSESSMENT OF HABITAT USE AND ABUNDANCE IN OILED AND UNOILED AREAS •OVERWINTER SURVIVAL OF FEMALES	•CHICK GROWTH RATES •REPRODUCTIVE SUCCESS •ADULT ATTENTIVENESS TO CHICKS •MEAL DELIVERY RATES AND MEAL SIZE	•LATRINE SITE ABANDONMENT AS AN INDEX OF ABUNDANCE
HEALTH AND OIL EXPOSURE	•BLOOD AND IMMUNE FUNCTION ASSAYS •P450 ASSAYS •MORPHOMETRICS/CONDITION	•BLOOD ASSAYS •P450 ASSAYS •BODY COMPOSITION	•BLOOD ASSAYS •P450 ASSAYS •BODY COMPOSITION OF CHICKS	•BLOOD AND IMMUNE FUNCTION ASSAYS •P450 ASSAYS •MORPHOMETRICS
TROPHIC INTERACTIONS	•ABUNDANCE, DISTRIBUTION AND SIZE CLASS STRUCTURE OF CLAMS, MUSSELS, SEA URCHINS, CRABS •PREY SELECTION AND FORAGING SUCCESS •ASSESSMENT OF OTHER FACTORS AFFECTING PREY ABUNDANCE: VARIATION IN RECRUITMENT AND GROWTH OF INVERTEBRATE PREY; COMPETING PREDATORS	•ABUNDANCE AND SIZE CLASS DISTRIBUTION OF PRIMARY INVERTEBRATE PREY	•ABUNDANCE OF PREY (DEMERSAL FISHES)	•ABUNDANCE OF PREY (DEMERSAL FISHES)

Table 4. Abundance of sea otters in Area N, (north & east Knight, Disk, Eleanor, Naked and Smith Is., approx 400 km^2).

Pre/ Post Spill	Year	Survey Type	Population Estimate
Pre	1973	Helicopter survey	294 (minimum, not corrected)
	1984-1985	Boat survey	261 (minimum, corrected for visual bias, but coastal transects only)
Spill	1989	EVOS mortality	182 (carcasses and rehabs, not corrected)
Post	1992	Aerial Survey	132 (corrected for visual bias)
	1993	Aerial Survey	77 (corrected for visual bias)
	1994	Aerial Survey	108 (corrected for visual bias)

Table 5. List of assays and measurements for evaluation of health and oil exposure.

Assay or Biomarker	Laboratory or Location	Sea Otters	Harlequin Ducks[a]	Pigeon Guillemots	River Otters	Demersal Fishes
		n=60	n=100	n=75 nestlings n=25 adults	n=30	n=40
Blood - CBC, WBC	PML/ Purdue	X	X	X	X	
Serum Chemistry	PML	X	X	X	X	
Interleukin-6	UAF	X	X	X	X	
Haptoglobin	UAF	X	X	X	X	
Immunoglobulin Quantitations	Purdue	X	X			
Serum electrophoresis	Purdue/UAF	X	X		X	
Lymphocyte Transformation Assay	Purdue	X	X		X	
Cytochrome P450 Immunohistochemistry	Wood's Hole	X	X	X	X	X
Cytochrome P450 Western Blotting	UAF	X		X	X	
Cytochrome P450 Quantitative PCR	Purdue	X			X	
Hydrocarbons in tissues (GC-MS)	GERG	X Archive	X Archive	X Archive	X Archive	X Archive
External oil (ELIZA)	In field/ UAF/NBS	X	X	X (Adults only)	X	
Morphometrics (weights, lengths)	In field	X	X	X	X	
Body Composition	UAF/NBS		X		X	

[a]100 Harlequins for study of overwinter survival. Also taken will be 50 each of Barrow's Goldeneye and White Wing Scoters to be collected for analysis of food habits; tissue samples from these collections will be archived so that health and oil exposure assays could be performed later if warranted based on results from other species.

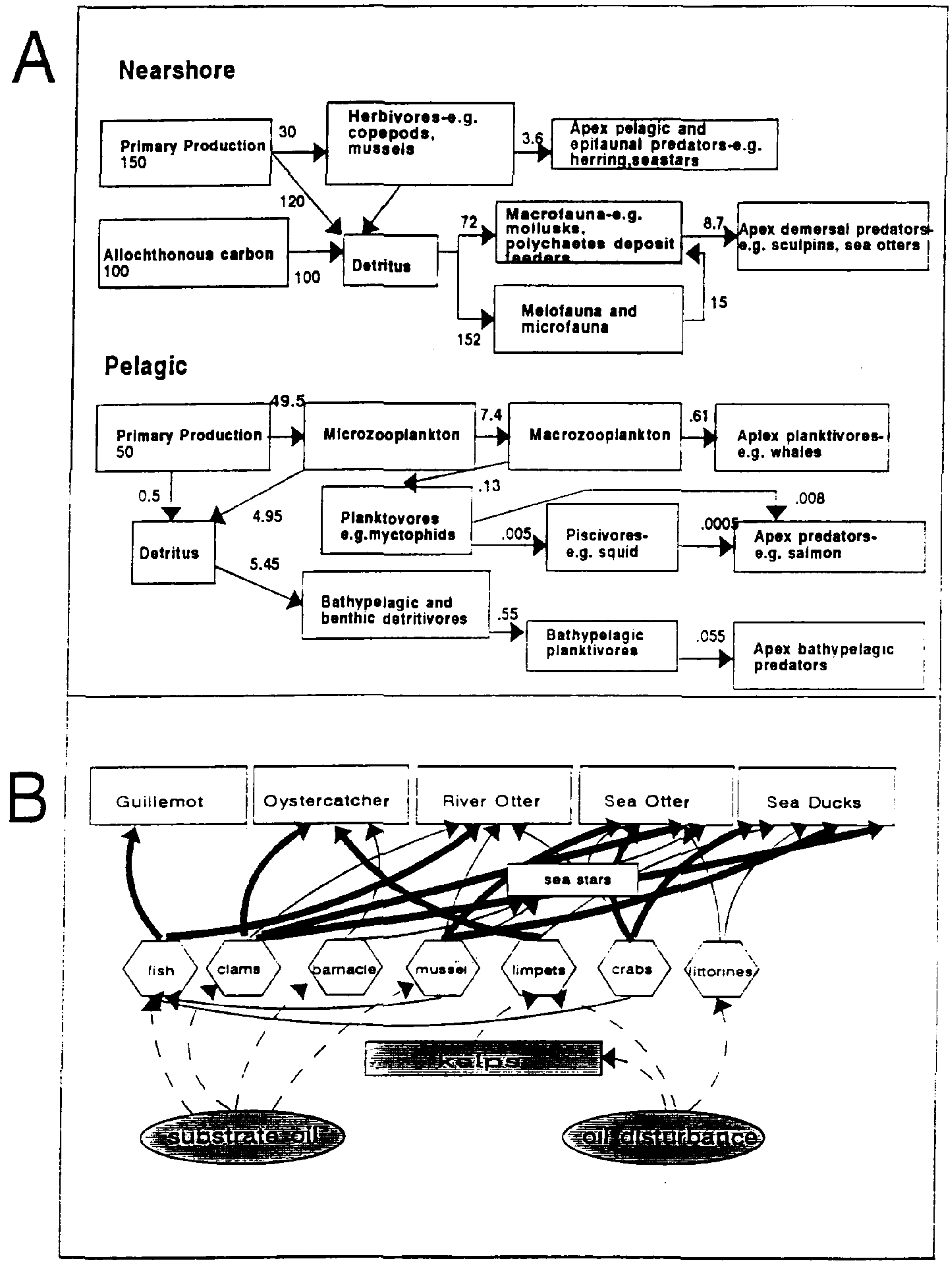


Figure 1. **A). Generalized energy flow based on organic carbon transfers in the nearshore** and pelagic ecosystem (modified from Parsons 1987, Figure 18-6). B). General trophic interrelations within the nearshore ecosystem (solid lines) and potential transfer or impacts from spilled oil (dashed lines).

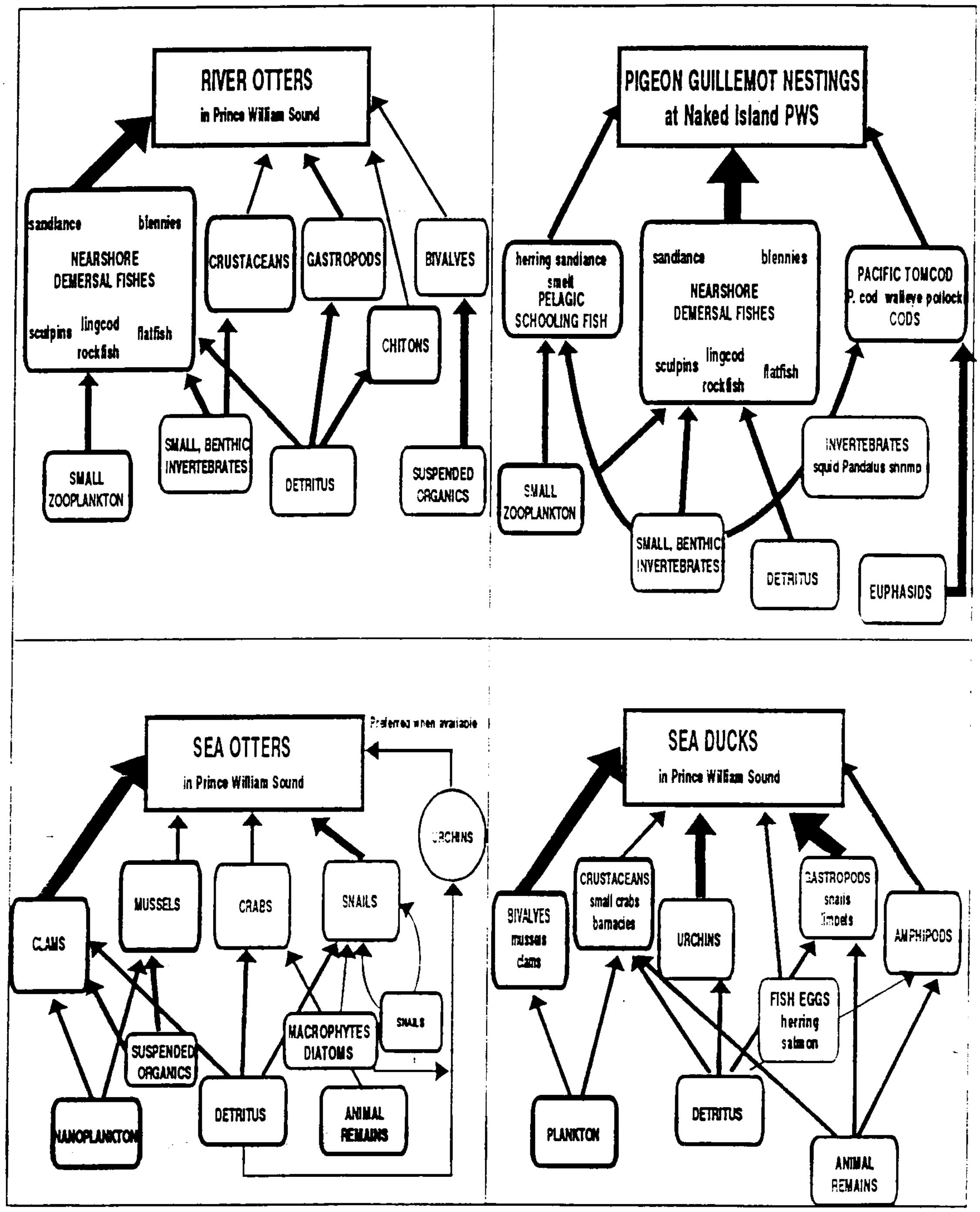


Figure 2. Food web of the four selected key species proposed for study under the Nearshore Vertebrate Predator 95025 package.

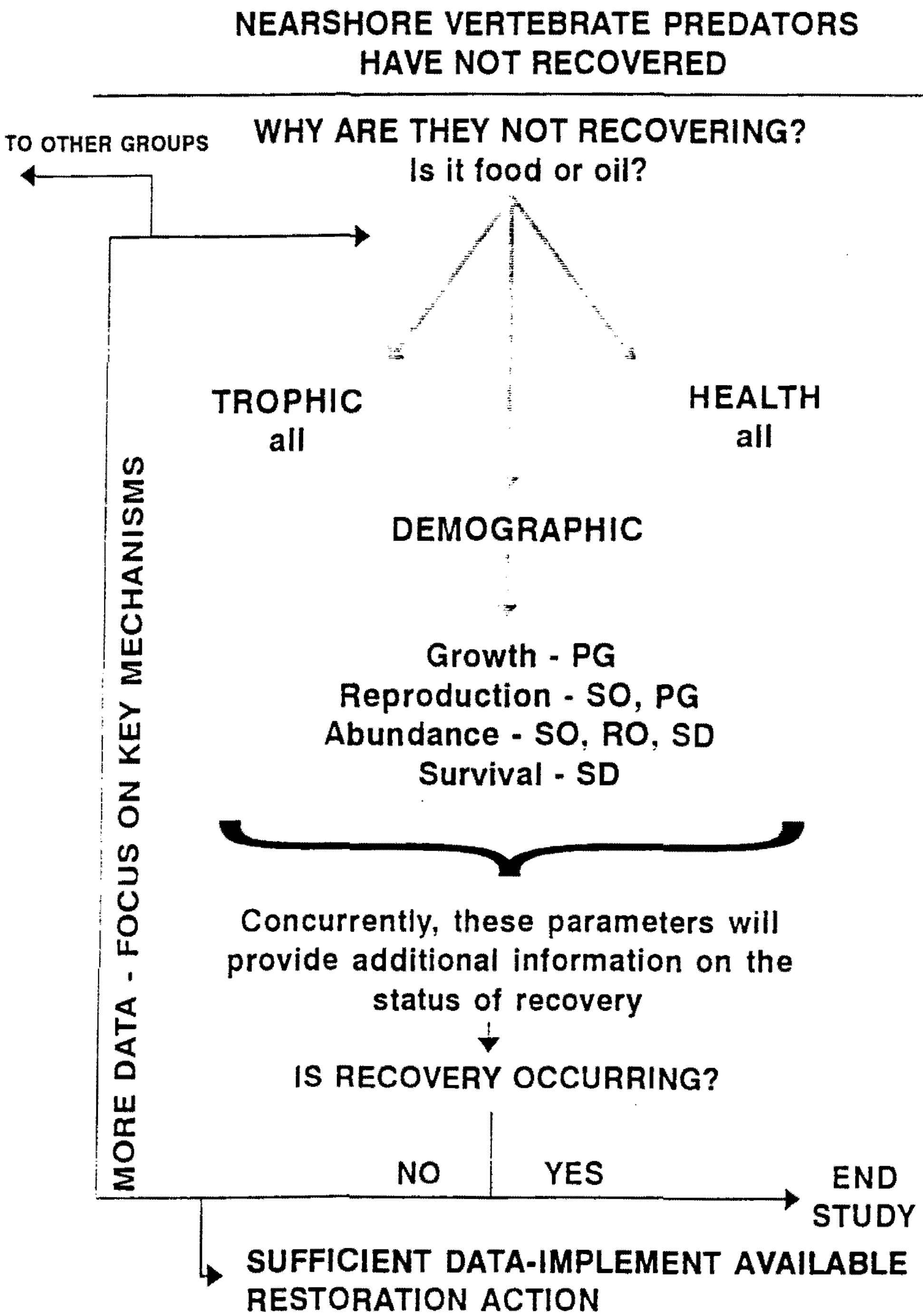


Figure 3. Approach to be taken in study.

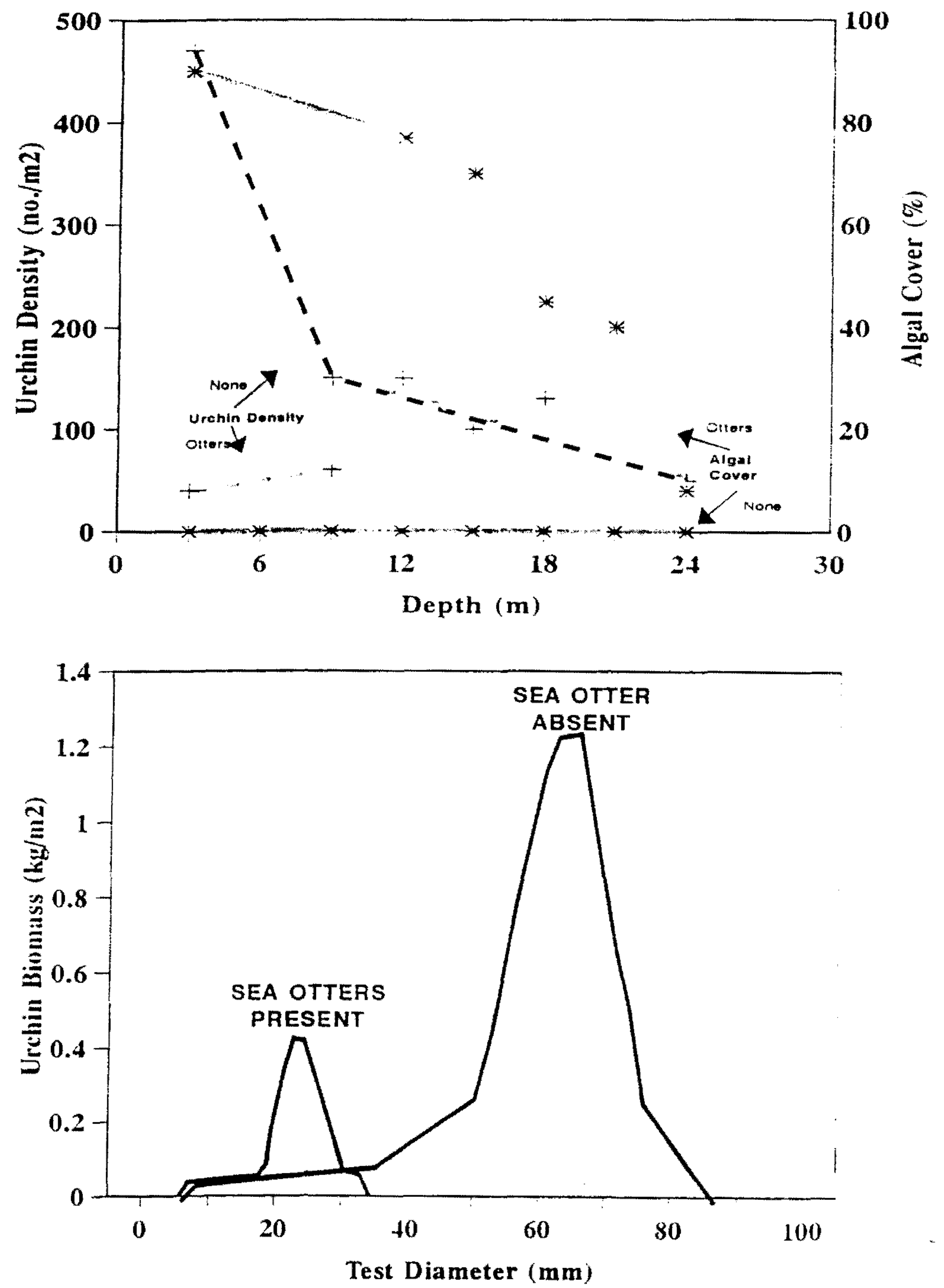


Figure 4. Comparative relationships of sea urchins population densities to algal cover and sizes of individual sea urchins to urchin biomass between Aleutian islands with sea otters (Amchitka) and without sea otters (Shemya). Modified from O'Clair and Zimmerman 1987, Figure 11-17, after Estes and Palmisano 1974.

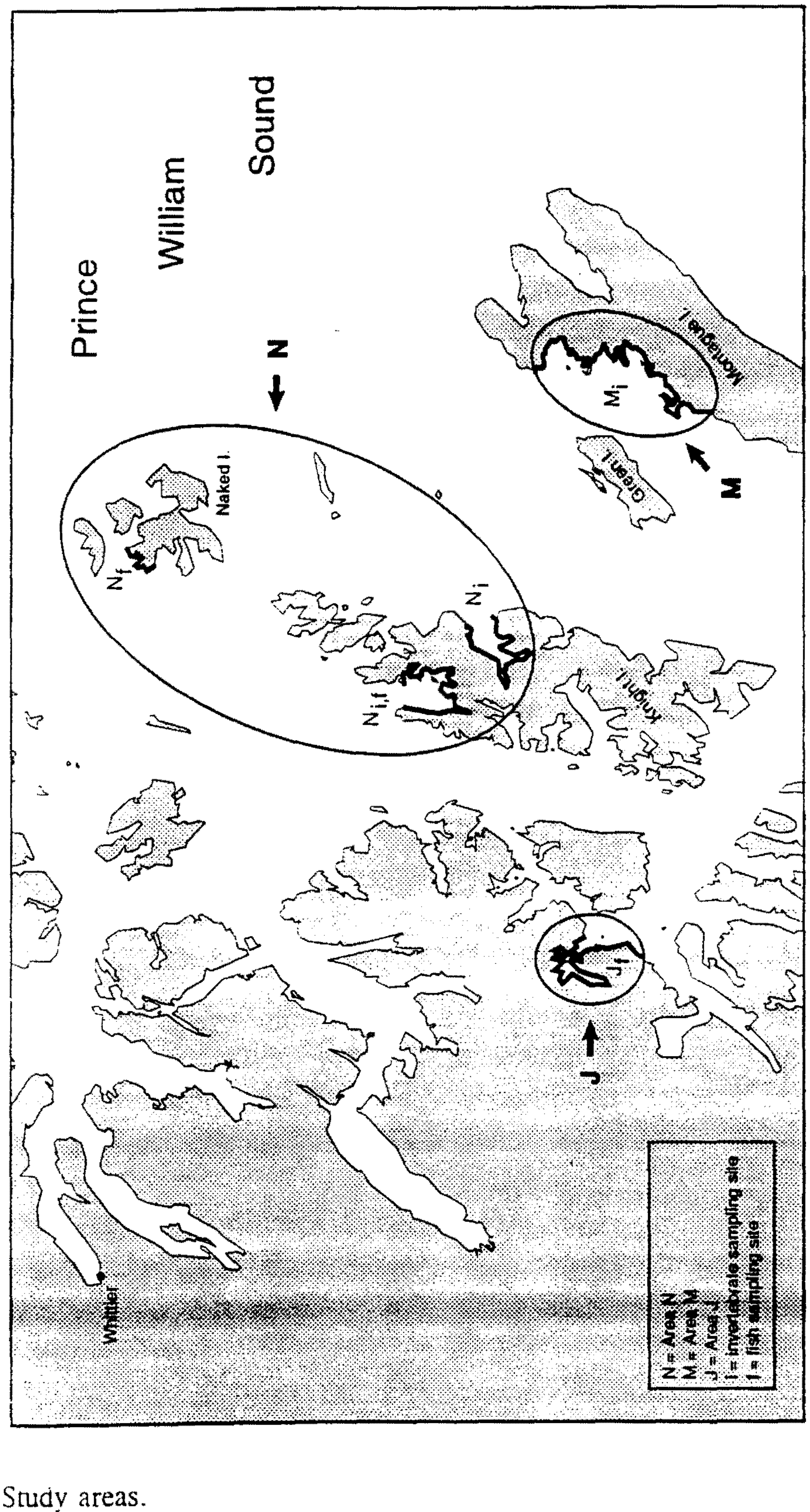


Figure 5. Study areas.

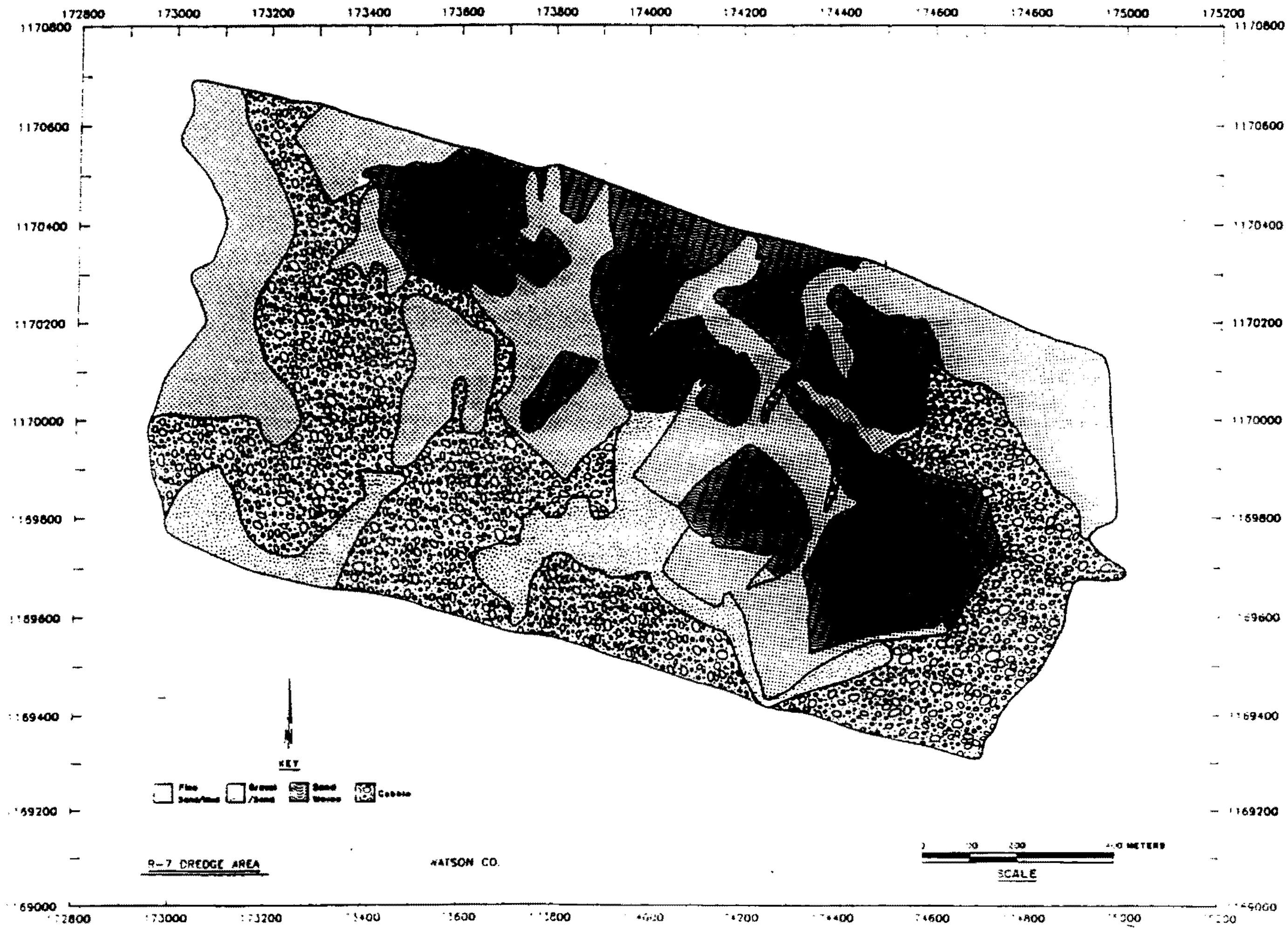
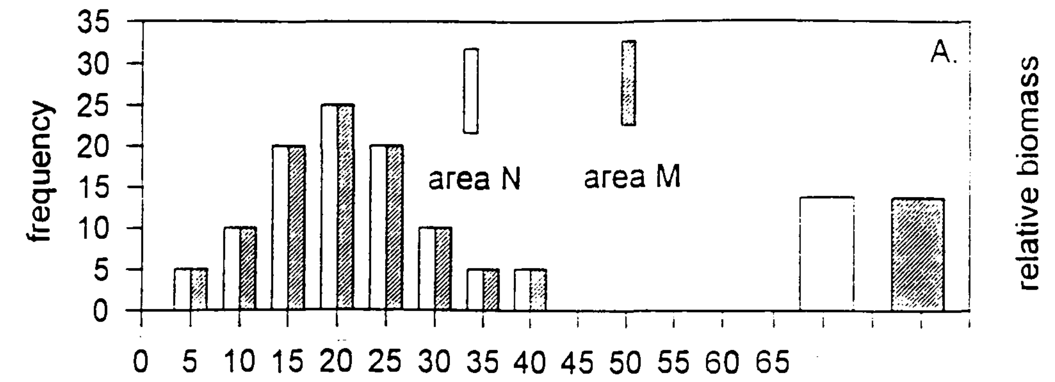


Figure 6. Example of a side-scan sonar record.

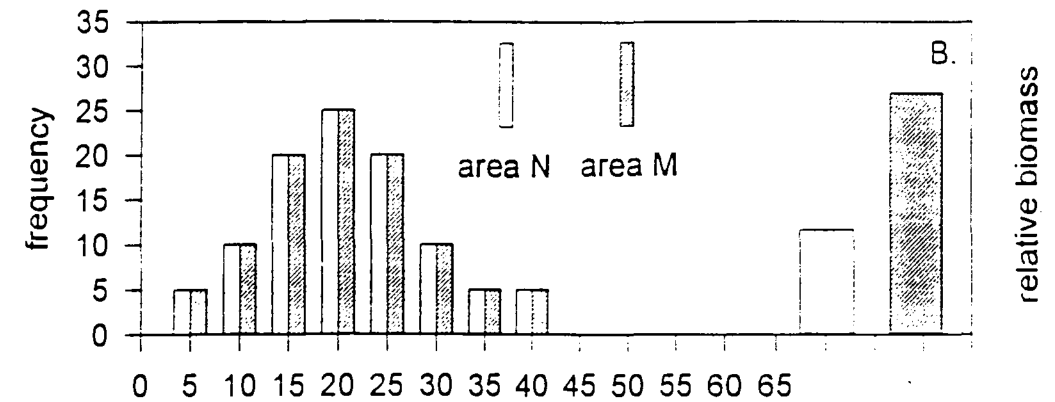
A. Size class structure of a "typical" invertebrate prey, in the presence of sea otters: assuming equal prey biomass among areas

<u>Conclusion</u>: predation pressures equivalent, recovery occurring



B. Size class structure of a " typical" invertebrate prey, in the presence of sea otters: assuming prey biomass is greater in area M

<u>Conclusion</u>: food is limiting, recovery uncertain



C. Size class structure of a "typical" invertebrate prey, in the presence (area M) and absence (area N) of sea otters: assuming prey biomass is greater in area N.

<u>Conclusion</u>: predation pressures not equivalent, recovery not occurring

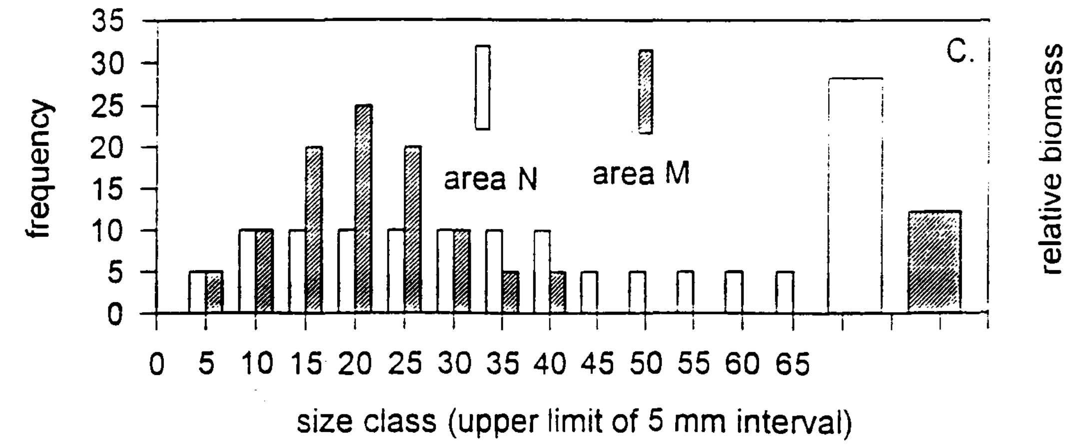


Figure 7. Three theoretical examples of how prey biomass and size class structure may be interpreted in relation to status of predator recovery and if food is at issue.

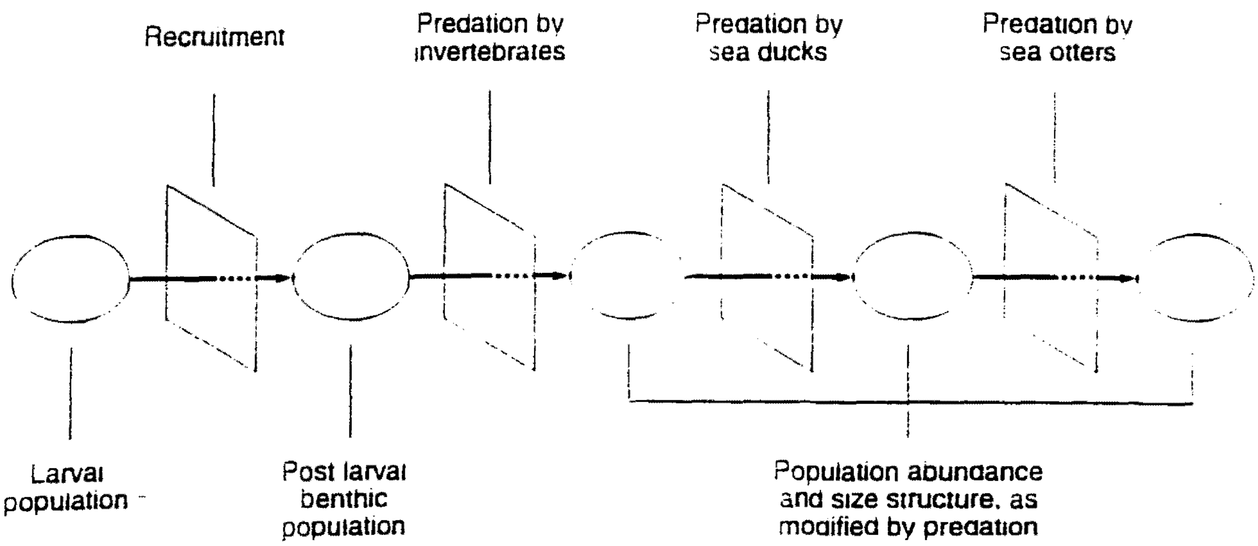


Figure 8. Theoretical "filters" that influence invertebrate prey size structure.

6.0 Appendices

6.1 General Hypotheses

Based on a wide variety of coordinated meetings including "Science for the Restoration Process" held April 13-15, 1994 (EVOSTC 1994b), a number of general hypotheses have been developed related to factors limiting recovery in the nearshore ecosystem:

1. *Involving Ecosystem Processes*

   1.a.Trophic Factors Hypotheses--

   1.a.i.The EVOS induced changes in populations of dominant competitors and resident predators in the nearshore region are limiting recovery of benthic communities;

   1.a.ii.EVOS induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators;

   1.a.iii.EVOS induced changes in top predators have influenced the recovery of EVOS injured benthic prey populations;

   1.b.Recruitment Hypothesis

   1.b.i.Recovery of nearshore resources injured by EVOS is limited by recruitment processes;

   1.c.Physical Limitations Hypothesis

   1.c.i.Physical processes limit the recovery of nearshore ecosystems.

2. *Involving Oiling From Initial or Continuing Exposure*

   2.a.Oil Toxicity/Contact Exposure Hypothesis

   2.a.i.Initial and/or residual oil in benthic habitats has a toxicological effect limiting the recovery of benthic communities ;

   2.a.ii.Initial and/or residual oil in benthic habitats and in or on benthic prey organisms has had a limiting effect on the recovery of benthic foraging predators;

6.2 Cytochrome P4501A Background and Methods

Provided by Dr. J. Stegeman, Woods Hole Oceanographic Institution

One of the most promising and revealing biomarkers of exposure to hydrocarbons is the induction of cytochrome P4501A. Numerous experimental studies confirm that in vertebrates selected HAH and PAH cause activation of genes classified in CYP gene family 1. These genes are further classified in gene subfamily 1A (hence, CYP1A) and subfamily 1B.

In terrestrial mammals there are at least two CYP1A genes, CYP1A1 and CYP1A2. The CYP1A1 is inducible in liver and extrahepatic organs. In birds there appear to be two CYP1A genes (Rifkind et al., 1994), not yet classified further. In fish there is clear evidence for induction of a P450 that may be orthologous to both the 1A1 and 1A2 forms (Stegeman, 1989; Morrison et al., 1995). In marine mammals there is at least one CYP1A, that is a CYP1A1-like protein (White al., 1994).

Studies with multiple species of fish, birds and mammals, from different parts of the world, have revealed close correlations between the levels of CYP1A and the levels of PCBs or PAH either in the organisms or in their immediate environment. Antibodies to the cytochrome P4501a from fish are now commonly used to demonstrate unambiguously that CYP1A forms are elevated in fish from contaminated regions. Studies in the flounder *Platichthys flesus* from Langsundsfjord, Norway (Stegeman et al., 1988), in starry flounder (*Platichthys stellatus*) from San Francisco Bay (Stegeman et al., unpublished), and in rattail (*Coryphaenoides armatus*) from the deep ocean (Stegeman et al., 1986) have all shown close correlation between the levels of induction of CYP1A in hepatic microsomes and the levels of total PCB residues. The content of CYP1A in the liver of birds correlates with the contamination by inducers (Rattner et al., 1993). In marine mammals there is close correlation between the amount of CYP1A in the liver and the content of toxic PCB residues on the blubber (White et al., 1994). The growing number of such studies provides a consistent picture, supporting use of the levels of a specific cytochrome P450 isozyme as a biomarker for levels of contaminants in the environment and/or in the organisms themselves. Thus, CYP1A induction can be a highly sensitive indicator or biomarker of the burden of toxic inducing compounds in vertebrate organisms, or their environment.

CYP1A Induction in Endothelial Cells

Most CYP1A induction studies have focused on the liver, a major site of metabolism of these compounds. However, extrahepatic organs are also prominent sites of CYP1A induction. We have used immunohistochemistry to detect induction in extrahepatic organs as a marker of exposure. A very significant site of induction established in general among the vertebrates is in the endothelial cells that line the blood vessel (Dees, Masters et al. 1982; Miller, Hinton et al. 1988; Stegeman, Miller et al. 1989; Smolowitz, Hahn et al. 1991). Endothelia form a barrier between blood and surrounding tissues in all organs. This gives it a potential role analogous to that of the skin or the intestinal epithelium, as a site at which xenobiotics can be intercepted before entering other functional cells of an organ. Xenobiotic metabolism in endothelial layers could influence strongly the identity and amounts of a compound distributed throughout the organism. As such, the endothelium could play an important role in pharmacokinetics. Processes determining the nature of the dose reaching target cells in other organs could also be a determining factor in, for example, toxic effects in the gonads, the brain and other key organs involved in reproduction. We also have examined the induction of CYP1A in mammalian endothelial cells in culture, establishing EC50 for induction by TCDD, 3,3',4,4'-tetrachlorobiphenyl and by benzo(a)pyrene (Stegeman et al. 1995).

The in vitro and in vivo studies suggest that the endothelium may be an ideal site for analysis of CYP1A induction. Examination of endothelium by immunohistochemistry or other techniques could make it possible to use small biopsy samples for analysis, avoiding destructive sampling of internal organs. The levels of CYP1A in endothelia could give an estimate of current and recent exposure not only of the organ in which the endothelium is examined, but of the organism in general. Thus, endothelial CYP1A expression in dermal endothelial cells present in the biopsy samples to be examined in this study should be predictive of exposure and induction in the endothelium in other organs, and possibly of other cell types where effects may be exerted. We are applying this approach to marine mammals (cetaceans).

Detection of Induction

Induction of CYP1A can be detected in several ways: 1) by catalytic (enzyme) assay, 2) by immunoassay, using antibodies to the CYP1A protein, or 3) by assay of the amount of the messenger RNA (mRNA) that codes for the protein. Catalytic assay, immunoassay and measurement of mRNA provide complimentary information, that can greatly amplify interpretations made in studies of CYP1A gene regulation (see for example, Kloepper-Sams and Stegeman, 1992). Specificity in detection is important.

(1) Few enzyme activities are known to be catalyzed only or primarily by CYP1A forms are known; the O-deethylation of ethoxyresorufin (EROD) appears to be such an activity. Analysis requires properly frozen or fresh material.

(2) Some of antibodies have been shown to cross-react widely with CYP1A proteins in species other than those from which the immunogen was purified. Monoclonal antibody 1-12-3 that we developed against a fish CYP1A1 (Kloepper-Sams et al., 1987) cross-reacts with CYP1A1 in every vertebrate species we have tested, more than 200 fish, birds, reptiles and mammals (Stegeman and Hahn, 1994). Species previously examined with this antibody include Harlequin ducks and pinnipeds (unpublished).

(3) Several groups have developed cDNA probes or specific oligonucleotide sequences, for use in hybridization procedures to detect CYP1A mRNA. The primers that we have designed for cloning and sequencing of CYP1A from fish (Morrison et al, 1995) appear to be universally applicable to vertebrate CYP1A genes. These may be tested for applicability in a quantitative reverse-transcriptase -PCR approach to measure the amount of CYP1A MRNA in the species of concern.

Proposed Analyses

We propose to analyze the expression of CYP1A in tissues of the sea otters, river otters, harlequin ducks and pigeon guillemots or other vertebrate species, using whatever approach appears to be most suitable for the type of tissue and the method of preservation. At minimum we propose to use immunohistochemistry on skin biopsies as well as any other tissues that may be obtained. Samples will be preserved in 10 volumes of 10% buffered formalin. If possible, we would propose to corroborate the IHC results with immunoblot analysis. We will use the MAb 1-12-3 described above.

We also would propose to collaborate with investigators who propose to use quantitative RT-PCR, for example on blood samples (Lorr et al., 1992), if the biopsy samples do not provide suitable results by immunoassay.

Immunohistochemistry

Prior to immunochemical staining, standard 5 μm sections are deparaffinated and hydrated in 1% bovine serum albumin/ phosphate buffered saline (BSA/PBS). During the hydration process, sections are incubated in 0.5% H_2O_2 in methanol for 45 minutes to block endogenous peroxidase (Polak and Van Noorden 1983). Hydrated sections are immunochemically stained using an indirect peroxidase stain (Universal Immunoperoxidase Staining Kit (Murine), Signet Laboratories, Inc., Dedham, MA) with MAb 1-12-3 to scup CYP1A as the primary antibody, as described below. Previous immunofluorescent studies have demonstrated the specificity of Mab 1-12-3 for CYP1A in tissue sections by immunoadsorption.

After hydration in 1% BSA/PBS, sections are incubated in normal goat serum (NGS) for 20 minutes to block any possible nonspecific attachment of the secondary antibody (goat antimouse IgG)(Polak and Van Noorden 1983). Sections are washed once for 5 minutes and then incubated in 1/24,000 dilution (1.7 5g protein/ml) of Mab 1-12-3 in 1% BSA/PBS for 18 hours (overnight). Incubation in primary antibody is followed by washing with 1% BSA/ PBS. This wash procedure follows all antibody incubations. Next, sections are incubated in a 1/200 dilution of goat-antimouse IgG for 20 minutes, washed and then incubated in a 1/600 dilution of peroxidase labeled nonspecific mouse IgG for 20 minutes. After another wash, sections are incubated for 30 minutes in 3-amino-9-ethylcarbazole (AEC) in acetate buffer to develop color. Sections are rinsed and then counterstained with Mayers hematoxylin, and mounted in glycerol (Smolowitz, Hahn et al. 1991). Two types of controls are used: (1)

Sections of liver from a fish (scup; *Stenotomus chrysops*) with high and one with low content of CYP1A (as determined by EROD activity and immunoblotting) are included in every stained group as controls for the staining method. (2) Matching serial sections of all tissues are stained using a nonspecific IgG (Purified mouse myeloma protein, UPC-10, IgG2A, Organon Teknika, West Chester, PA) at 1.5 5g protein/ml of 1% BSA/PBS (Polak and Van Noorden 1983).

Specific staining by MAb 1-12-3 will be evaluated by light microscopic examination of the stained sections. Cell types that stain and their associated occurrence and staining intensity will be recorded for each tissue section examined. At least two immunochemically stained sections will be examined from each sample. Comparative staining results for each sample will be described in relationship to whales from all samples, and reported as negative, mild, mild/moderate, moderate, strong or very strong. Quantitative comparisons will be made using the product of scaled values for intensity and occurrence.

Quantitative PCR and RT-PCR

RNA Isolation: We will initially apply quantitative RT-PCR methods to the analysis of pilot whale liver mRNA. We also will use samples of either scup or toadfish RNA as a procedural control, given that we have primers previously demonstrated to be effective with these species. Total RNA will be prepared as described above.

Amplification and Detection: Procedures will be those of (Gilliland et al. 1990) as modified by others (Vanden Heuvel et al. 1993). Eight or more equal aliquots of total RNA from a liver or skin sample, initially 0.1 5g RNA per aliquot, will be prepared and a dilution series of an internal standard will be added to the aliquots. A standard for the competitive PCR will be created by PCR reactions using CYP1A-gene specific primers. Conditions may vary but for example will be: 94 C for 1 min, 37 C for 1 min and 72 C for 90 seconds, 30 cycles. A PCR product of suitable size, e.g., about 170 bp, will be isolated and subcloned into a plasmid. Both the DNA plasmid construct and the cRNA transcript from the plasmid will be tested for utility as the internal standard for the competitive PCR. The amplified target sequence and internal standard will be resolved on 3% agarose gel, and visualized with ethidium bromide. Alternately, the bands will be detected by hybridization to a labelled cDNA probe.

The procedures for amplification will consider the sources of error as discussed by others (Foley, Leonard et al. 1993). The use of an internal control to minimize tube to tube variability is recommended, and has been used by (Vanden Heuvel, et al. 1993) who applied quantitative PCR to measure CYP1A1 in lymphocytes of humans (Vanden Heuvel, et al. 1993). However, in practice, Jefcoate et al have found that the internal control is not always necessary (Jefcoate, personal communication).

Immunoblot

Western blot analyses will be performed with microsomes prepared as previously described (Stegeman, Teng et al. 1990). 10-60 ug of microsomal protein will be run on SDS-PAGE gels and transferred overnight to 0.22 um nitrocellulose sheets (Scheicher and Schuell) at 4°C (BioRad transblot). Incubations of nitrocellulose will be carried out in the presence of 5% (w/v) dry milk in Tris-buffered saline (TBS) to block nonspecific reaction. Antibodies will be diluted in TBS/milk to 100 ug/ml and incubated with the nitrocellulose for appropriate times, 2 hours with MAb 1-12-3. The secondary antibody, alkaline-phosphatase conjugated goat anti-mouse IgG (BioRad) will be incubated with the sheets for 1 hour. Color will be developed by incubating the blots with 0.1 M NaHCO3, 1mM MgCl2 (pH 9.8) buffer containing 0.33 mg/ml nitroblue tetrazolium (BioRad) and 0.165 mg/ml 5-bromo-4-chloro-3-indoyl phosphate (BioRad), added in dimethylformamide as per the BioRad protocol for use with alkaline phosphatase. Alternately, we will use enhanced chemiluminescence. Antibody staining will be quantified densitometrically. Induced and uninduced scup liver microsomes will be used as controls.

Data will be analyzed using Abacus Concepts Statview®. Comparisons of means for CYP1A content or activity were made between groups from the various sites. A one way ANOVA using Fisher's protected least significant difference (PLSD) was used to establish significant differences between sites ($p < 0.05$).

Costs:

Costs for the proposed work are $140 per sample for analysis of CYP1A by immunohistochemistry, with a minimum of 100 samples. A sample is defined as one block of paraffin-embedded tissue. Cost will include preparation, processing, analysis and data reduction, and report writing, and will include technician and principal investigator time.

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7.0 Schedule

7.1 Proposed General Schedule

The NVP Project will begin in mid-summer 1995 with a program of primarily pilot efforts. These efforts will be used to establish final sample size and experimental design requirements for invertebrate sampling, validate a number of techniques and establish up-to-date sea otter population data prior to full study implementation in the spring of 1996. The investigators feel that these preliminary efforts will result in the most cost effective implementation of the full study design. In addition to these preliminary efforts, the sea duck component of the study will be initiated in full because of its fall/winter data collection needs. There will be full field seasons in 1996 and 1997. In December 1997, a full review of the first two years will be conducted to assess the status of species recovery and to allow for adaptive management options. Should all test species suggest recovery, the project would be recommended to move into final data analysis and report mode. It is most likely, however, that a full 1998 field season will be warranted or a modification to close out assessments that would focus on select components of the project with full analysis and project completion by October 1999. Because of this, only the FY 95-97 proposed schedules are provided below.

7.2 FY 1995 Draft Schedule

July
1. River otter/Pigeon Guillemot: Collection of tissue samples in Kachemak Bay (separate funding) to validate biomarker assays to be employed in 1996 and 1997.
2. Mussel/clam/urchin/fish and invertebrate predators: Side scan sonar to classify habitat types in Areas M, N, and J.
3. Mussel/clam/urchin/fish and invertebrate predators: Subtidal and intertidal reconnaissance survey of Areas M, N, and J to establish and test sampling methods and conduct test sampling required for conducting power analyses. Study site selection.
4. Sea otter: Aerial survey of western Prince William Sound.

August
1. Sea otter: Boat based surveys of sea otter reproduction.
2. Harlequin: Vessel charter for harlequin duck capture and collection.

September
1. Harlequin: Complete capture and collection, begin survival monitoring.

7.3 FY 1996 and 1997 Draft Field and Reporting Schedule

October
1. Harlequin: Continue survival monitoring.
2. Sea otter: Aerial survey of western Prince William Sound.

November
1. Harlequin: Continue survival monitoring and other sea duck skiff surveys.

December
1. Harlequin: Continue survival monitoring.
2. *All project components: Submission of brief field season summary reports.*
3. *Overall 95025 status report to EVOS Chief Scientist.*
4. *Project meeting to discuss field season outcomes and develop/revise proposed approach.*

January
1. Harlequin: Continue survival monitoring and other sea duck skiff surveys.
2. Invert. predator: Complete sampling of all study sites
3. *Reporting of project findings at Restoration Workshop*

Febuary
1. Harlequin: Continue survival monitoring.

March
1. Harlequin: Continue survival monitoring and other sea duck skiff surveys.

April
1. River otter: Live trapping for morphometrics and tissue sampling.
2. Sea otter: Beach-cast carcass survey.
3. *All project components (1996): Submission of 1995 Progress Reports.*
4. *All project components (1997): Submission of 1996 Progress Reports*

May
1. River otter: Live trapping for morpometrics and tissue sampling.
2. Pigeon Guillemot: Active nest surveys.

June
1. Pigeon Guillemot: Active nest surveys, blood sampling, prey sampling, and nest monitoring.
2. Sea Otter: Prey selection and foraging success.

July
1. Pigeon Guillemot: Active nest surveys, blood sampling, prey sampling, and nest monitoring.
2. Sea otter: Aerial survey of Prince William Sound, capture for morphometrics and tissue collection. Prey selection and foraging success.
3. Mussel/clam/urchin/fish and invertebrate predators: Vessel charter to sample Areas M, N, & J.

August
1. River otter: Latrine sites located, sampled, and monitored.
2. Pigeon Guillemot: Active nest surveys, blood sampling, prey sampling, and nest monitoring.
3. Sea otter: Boat based surveys of sea otter reproduction.
4. Harlequin: Vessel charter for harlequin duck capture.

September
1. Harlequin: Complete capture and collection, begin survival monitoring-96.

NOTE: Field sampling in 1997 will follow the 1996 schedule except for the addition of two winter mussel field sampling trips.

NOTE: All projects currently proposed are scheduled for comprehensive review at the end of FY 1997. It is possible that the results from fieldwork completed in 1995, 1996, and 1997 will indicate the need for modified, and/or additional fieldwork.

8.0 Existing Agency Program

The cooperating agencies under the Nearshore Vertebrate Predator Project 95025 have a variety of existing research programs related to the selected vertebrate predators and invertebrate prey under study. The Alaska Science Center has an extensive sea otter, sea bird, and coastal invertebrate program that has been involved in oil-spill related activities since 1989 as well as many complimentary research projects throughout coastal Alaska. The Center infrastructure is available to provide equipment, budget, and technical support to this effort. The University of Washington program personnel are active in the study of sea otters and invertebrates with a significant research history in Prince William Sound and the extensive University of Alaska coastal research program will serve to compliment the proposed research. Finally, the National Marine Fisheries Service actively participates in a number of oil-spill related studies and has extensive invertebrate expertise and equipment that will facilitate this effort.

9.0 Environmental Compliance

Study plans for this project are subject to approval by the Animal Care and Use Committee (ACUC) of the various cooperating agencies--the Alaska Science Center-National Biological Service (ASC-NBS), University of Washington (Washington Cooperative Fish and Wildlife Research Unit), University of Alaska-Fairbanks (Alaska Cooperative Fish and Wildlife Research Unit), National Marine Fisheries Service, and Alaska Department of Fish and Game, which are responsible for ensuring compliance with the provisions of the Animal Welfare Act. Documentation and currency of those reviews and approvals with be maintained the Program Chief Scientist, Dr. Leslie Holland-Bartels, ASC-NBS.

Many of the field work components of the study for vertebrates rely on observations and are non-intrusive. However, any capture activity is conducted under review of the above ACUC committees with final review of the Program Chief Scientist. Surgical implantation of transmitters will follow a standard protocol approved by the ACUC of the Alaska Science Center and will be conducted by or under the supervision of the ASC-NBS Research Veterinarian, Dr. Dan Mulcahy, PhD., DMV. The proposed Harlequin duck take will be reviewed and permitted under the following process: An application for the proposed collection will be submitted to the Division of Law Enforcement (LE), U. S. Fish and Wildlife Service (USFWS) and the Alaska Department of Fish and Game (ADFG). The USFWS will convene a panel of scientists to examine the application and research proposal for scientific merit and potential impact to populations and other research. A copy of the application is forwarded to the waterfowl coordinator, ADFG, who will provide an evaluation to LE. When the federal permit is issued it is submitted to ADFG, which initiates further review by headquarters staff before a state permit is issued. Federal and State permits must be in the possession of the permittee prior to any collection. Federal marine mammal permit for sea otter activities and general State collection permits are in possession or will be in place prior to initiation of any field work. The Program Chief Scientist will review permits for currency and keep documentation on file at ASC-NBS.

10.0 Performance Monitoring

This program is submitted by the Lead Agency Alaska Science Center, National Biological Service, located in Anchorage Alaska. Dr. Leslie Holland-Bartels, as Program Chief Scientist, NBS liaison to the Trustees, and Branch Chief for Marine Research for ASC-NBS will have both research and contractual oversight responsibilities for the program. Project personnel are either employees of the ASC-NBS or will function under contractual obligation to ASC-NBS through the Research Work Order Process (e.g. University of Washington and University of Alaska-Fairbanks) or are employees of other Trustee Agencies (e.g. USFWS, NMFS, ADFG).

Scientific and technical aspects of this study will be subject to internal review within the ASC-NBS, as the Program Manager. Cooperating agencies will provide regular internal review of their programs to the ASC in line with their established review processes. Work plans, study design, and final reports will be subject to the technical review of the Program

Statistician Dr. Lyman MacDonald and Program Chief Scientist Dr. Leslie Holland-Bartels, as well as the established internal review process of the ASC and the peer review process established by the Trustees Council and the EVOS Chief Scientist. Project dates/deadlines for products will be monitored by Leslie Holland-Bartels. Monthly teleconferences and semiannual project reviews will be held to ensure work is progressing on all components in a timely manner, and to identify and respond to specific issues or concerns. Significant findings presented in final reports will be submitted for publication in peer-reviewed scientific journals and presented at scientific meetings as they become available.

11.0 Coordination of Integrated Research Effort

This project was developed and submitted in cooperation among the National Biological Service, National Oceanic and Atmospheric Administration, U. S. Fish and Wildlife Service, Alaska Department of Fish and Game, University of Washington, and the University of Alaska-Fairbanks. Work conducted on the integrated Nearshore Vertebrate Predator Project will be coordinated among these agencies. Cooperation outside of the specified project participants includes coordination of field work and sharing of data with the monitoring efforts for pigeon guillemots under the Seabird/Forage Fish Interactions Project (Project 95163) to facilitate field operations and collection of common data. Many elements of the river otter and pigeon guillemot research is a parallel effort ongoing in Kachemak Bay (funded through the UAF Coastal Marine Institute) and will result in a broader examination of many of the bioindicator hypotheses forwarded in Project 95025. Harlequin duck molting drives are being coordinated with Dan Rosenberg of the Alaska Department of Fish and Game. Data from duck surveys and regarding duck condition and diets for populations at North Montague Island will be shared with Mary Anne Bishop of the Copper River Delta Institute. Oceanographic and existing invertebrate data specific to species under study for Project 95025 will be obtained through Project 95320, Prince William Sound System Investigation. Continuing information will be exchanged between this project and previous and ongoing nearshore efforts. Coordination through subject-specific workshops (e.g.Intertidal workshop planned for March 1995) and the annual EVOS Restoration Workshop will facilitate regular exchange of information and identification of further opportunities for economies through project collaborations.

12.0 Public Process

The project concept was developed as a result of the April 1994 "Science for the Restoration Process" workshop, a public forum. Continued discussion of the project occurred through the 1995 Work Plan and the initial project underwent public review through the Trustees Council process. Planning funds were approved by the Trustees in November 1994 at public meeting. Subsequently, a working meeting was held in November to discuss the framework for the project, also an open meeting. The Nearshore Vertebrate Predator Project was presented at January 1995 Trustees sponsored Restoration Workshop in Anchorage. Further opportunities for public input will be available at one March workshop and the Trustees meeting when the project proposal is presented.

13.0 Personnel Qualifications

Dr. Brenda Ballachey, Physiologist at the Alaska Science Center, NBS has been project manager and senior scientist for the damage assessment and restoration work on sea otters since 1990. She has over 15 peer reviewed scientific publications and was responsible for or author on 19 NRDA reports recently completed on sea otter issues.

Mr. Jim Bodkin, Research Wildlife Biologist, is the Project Leader for sea otter population research for the Alaska Science Center of NBS. He has over 18 peer-reviewed scientific publications and is involved in an active sea otter research program. He has actively studied and published on sea otter foraging ecology and community structuring since 1988 and has been principal investigator for sea otter survey methods development.

Dr. R. Terry Bowyer, Professor of Wildlife Ecology, University of Alaska Fairbanks. Dr. Bowyer has an extensive publication record (46). He has conducted extensive research on river otters and impacts of EVOS on this species.

Dr. Thomas A. Dean, is President of the ecological consulting firm Coastal Resources Associates, Inc, (CRA) in Vista, CA. He has over 20 years of experience in the study of nearshore ecosystems, and has authored over 20 publications, including several papers dealing with sea urchin and kelp interactions. He has extensive experience in long-term monitoring studies with marine plants and invertebrates. He has had a major role in both the shallow subtidal and intertidal EVOS investigations since 1989.

Dr. Lawrence Duffy, Professor of Chemistry and Biochemistry at the University of Alaska Fairbanks has been working in the area of toxicology for 15 years and is a member of the International Society of Toxicology. He has studied various bacterial and mammalian toxins. Since the *Exxon Valdez* oil spill, he has published four papers related to developing biomonitors. He is currently funded for two major environmental studies in Alaska. At the University, he teaches "Environmental Biochemistry and Biotechnology" and is a member of the Environmental Chemistry Program and Mammal Group.

Mr. Daniel Esler is a Wildlife Research Biologist for the Alaska Science Center, National Biological Service with a Master of Science in Wildlife Ecology, Department of Wildlife and Fisheries Sciences, Texas A&M University (Avian associations with hydrilla). He has worked primarily with aquatic birds, including extensive experience in Alaska. He has nine publications in national peer reviewed journals such as Wildlife Management, Wilson Bulletin, Journal of Field Ornithology, Condor and others.

Dr. Leslie Holland-Bartels, BS University of Massachusetts, MS Louisiana State University, Ph.D. Purdue University is the head of the Marine and Freshwater Ecology Research Program for the Alaska Science Center, NBS and directs research of 17 senior scientists in the areas of seabirds, marine mammals, anadromous fisheries, and associate habitat and population issues. She has 20 years experience in aquatic ecology and over 30 publications in national scientific journals on subjects ranging from contaminants, ecology of invertebrates, fisheries, water quality and aquatic ecology.

Mr. Stephen C. Jewett has been a Research Associate at the School of Fisheries and Ocean Science, University of Alaska Fairbanks, since 1975. During this time he has been involved in numerous benthic and intertidal investigations throughout Alaska that emphasize assessment and/or monitoring. He has authored more than 30 publications in scientific journals and books. He has been the coordinator of the federal/state EVOS shallow subtidal investigations in Prince William Sound (1989-1994).

Ms. Karen Laing, B.A. Stanford University, M.S. University of California, Davis, is a Wildlife Biologist for Migratory Bird Management, U.S. Fish and Wildlife Service, Anchorage, Alaska. Her research experience has focused on foraging ecology and population dynamics of waterfowl. Since 1991 she has designed, conducted and analyzed population surveys of waterfowl throughout the state. Earlier she was the Principal Investigator for Exxon Valdez Oil Spill Damage Assessment Bird Study No. 2, for which she conducted boat surveys of marine bird and mammal populations in Prince William Sound, Alaska. Her publications include Oil Spill Natural Resources Damage Assessment Bird Study No. 2. and publications in Condor, Applied Animal Behavioral Science, and Raptor Research.

Dr. Lyman MacDonald, B.S., M.S. Oklahoma State University, PhD. Colorado State University, is a biometrician with 25 years of comprehensive experience in the application of statistical methods to design, conduct, and analyze environmental and laboratory studies. He has designed and managed both large and small environmental impact assessment and monitoring programs.

Dr. Charles E. O'Clair, B.S. Zoology, 1963 University of Massachusetts, Ph.D. Fisheries, 1977, University of Washington. 1977-present: Fishery Biologist (Research), National Marine Fisheries Service, Auke Bay Laboratory, Juneau, Alaska. Research experience includes seven years of field and laboratory work on the effects of oil pollution and, later, the effects of logging on benthic invertebrates, eleven years of research on the ecology and behavior of Dungeness, king and Tanner crabs in relation to the management of these species, four years of research on the impact of the *Exxon Valdez* Oil Spill on subtidal sediments in Prince William Sound and the Gulf of Alaska and one year on the recovery of subtidal sediments in Prince William Sound.

Dr. Alan Rebar is Professor of Veterinary Clinical Pathology and Associate Dean for Research of the Department of Veterinary Pathobiology, Purdue University. He has been involved in EVOS clinical pathology studies of sea and river otters since 1991.

Dr. Dan Roby has conducted research on the physiological ecology and reproductive energetics of high latitude seabirds for the last 15 years. His field research on alcid reproductive biology has been in Alaska, Newfoundland, and Greenland, and he is currently conducting research on pigeon guillemots as bioindicators of nearshore ecosystem health in Kachemak Bay, Alaska. Dr. Roby's research on seabird reproductive energetics in the Arctic and Antarctic has been supported by the National Science Foundation. Roby is currently Assistant Unit Leader- Wildlife, Alaska cooperative Fish and Wildlife Research Unit, and is an Assistant Professor of Wildlife Ecology, Institute of Arctic Biology, University of Alaska Fairbanks. he has over 25 peer-reviewed scientific publication, 17 of them on topics in seabird ecology.

Dr. Paul W. Snyder is an Assistant Professor of Pathology and Immunotoxicology and Director of the Clinical Immunology laboratory of the Department of Veterinary Pathobiology, Purdue University. He is also a Diplomate of the American College of Veterinary Pathologists. his research interests are in the area of mechanism based studies on the pathology and immunology of xenobiotics on biological systems. He has an NIH-funded project related to the immunobiology of environmental contaminants.

Dr. Glenn R. VanBlaricom has conducted research on coastal ecosystems since 1970, and has been involved in research on sea otters and their ecosystems for 17 years. Dr. VanBlaricom studied relationships of sea otters and intertidal mussels in Prince William Sound from 1978 through 1986 and published papers on population size structure and individual growth rate of mussels, and effects of foraging by sea otters. Dr. VanBlaricom worked on sea otter rescue and rehabilitation in the immediate aftermath of EVOS, primarily in the Kenai region, and has published one paper on rehabilitation strategies. Currently Dr. VanBlaricom is Assistant Unit Leader (Wildlife), Washington Cooperative Fish and Wildlife Research Unit, and is Associate Professor of Fisheries in the School of Fisheries, University of Washington. He has 24 peer-reviewed scientific publications.

14.0 Budget

14.1 FY 1995 and FY 1996 Totals by Project

	FY95	FY96
River Otter/Pigeon Guillemot	51,595	173,528
Sea Otter	66,920	206,540
Harlequin Duck	175,120	336,930
Mussels	84,315	152,981
Subtidal Clams	38,810	69,796
Invertebrate Predators	35,077	98,511
Intertidal Clams	12,786	88,018
Urchins	33,841	183,074
Fishes	22,010	156,332
Harlequin Duck Prey	5,014	25,193
Side Scan Sonar	59,172	41,662
Project Management	11,550*	112,030
* $130K additional planning funds provided earlier		
Project Totals	**596,208**	**1,644,595**

The NVP Project FY 95 budget figures do not include approximately $30K in commodities and equipment that may be needed for project completion. These include computers and field supplies that may be in the EVOS equipment list. We will supply a list of needed items to the EVOS office.

14.2 Detailed Budgets for FY 1995

Salaries/Travel/Contractual/Commodities/Equipment/Administration

Salaries

River Otter/Pigeon Guillemot		
Scientist 1 mo.		5,974
Grad student Ph.D. (12 mo.)		12,500
Grad student M.S. (12 mo.)		0
Lab Tech. 150 hrs. @ 12.00/hr		3,020
Account. Tech. 40 hr @ 13.92/hr		1,114
Benefits (leave: staff acct: Lab Tech		4,426
student tuition		4,608
	Subtotal	31,642

Sea Otter		
Superv. WB GS-12 (.5 mo.)		2,400
Research WB GS-11 (3 mo.)		12,700
Bio. Technician GS-7 (3 mo.)		8,500
	Subtotal	23,600

Harlequin Duck		
Veterinarian (1 mo.)		6,000
Research WB (4 mo.)		19,300
Wildlife Biologist (2 mo.)		9,600
Training		3,000
Bio. Technician (3 mo.)		7,200
	Subtotal	45,100

Mussels		
Fishery Biologist (3 mo.)		20,040
Fishery Biologist (1 mo.)		4,108
Fishery Biologist (3 mo.)		13,854
Lab Technician (3 mo.)		10,681
Project Manager (1 mo.)		5,000
	Subtotal	53,683
Subtidal Clams		
Graduate student		6,858
Tuition		1,399
Benefits		549
Hourly diving assistants		2,400
Benefits		240
	Subtotal	11,446
Invertebrate Predators		
Graduate student		6,396
Tuition		1,399
Benefits		512
Hourly diving assistants		2,400
Benefits		240
	Subtotal	10,947
Intertidal Clams		
Scientist 1 mo.		4,745
Benefits		2,687
	Subtotal	7,432

Urchins/Crabs		
Scientist		2,373
Divers		3,508
Benefits Scientist		1,344
Benefits staff		1,844
	Subtotal	9,069
Fishes		
Scientist		2,373
Scientist		2,373
Benefits, scientists		2,688
	Subtotal	7,434
Harlequin Duck Prey		
Scientist		1,500
Benefits		673
	Subtotal	2,173
Side Scan Sonar		
Scientist		1,500
Benefits		899
	Subtotal	2,399

Project Management		
Chief Scientist		3,400
Program Asst.		2,900
Secretarial		2,700
	Subtotal	9,000

Travel

River Otter/Pigeon Guillemot		
FAI/ANC/FAI (9 trips @ $200		1,800
Per diem in Anc. 9 days @ $138		1,242
	Subtotal	3,042
Sea Otter		
ANC/Cordova/Anch (2 @ $250)		500
Per diem Cordova 20 days @ $141		2,820
ARR to Whittier 1 25' boat r/t		1,500
	Subtotal	4,820
Harlequin Duck		
ANC/BC/ANC		1,500
ANC/CDV/ANC 12 @ $250		3,000
Per diem		3,000
	Subtotal	7,500
Mussels		
JNU/ANC/JNU 4 @ $600		2,400
JNU/SEW/JNU 4 @ $720		2,880

	Subtotal	5,280

Sub-Tidal Clams

Field Work SEA/ANC/SEA 5 @ $360		1,800
ANC/Whittier/ANC 5 @ $100		500
Meeting SEA/ANC/SEA 2 @ $360		720
ANC/Whittier/ANC 2 @ $100		200
Per diem 20 days @ $211		4,431
	Subtotal	7,651

Invertebrate Predators

Field SEA/ANC/SEA 4@ $360		1,440
ANC/Whittier/ANC 4 @ $100		400
Meeting SEA/ANC/SEA 1 @ $360		360
ANC/Whittie/ANC 1 @ $100		100
Per Diem 14ays @ $211/day		2,954
	Subtotal	5,254

Intertidal Clams

Field FAI/CDV/FAI 1 trip		500
Per diem 3 d at 141/d		423
	Subtotal	923

Urchins/Crabs

FAI/CDV/FAI 1 trip		500
Per diem 3 d at 141/d		423
	Subtotal	923

Fishes

Santa Barbra/CDV/Santa Barbra		800
Per diem 3 d at 141/d		423
	Subtotal	1,223

Harlequin Duck Prey	Subtotal	0

Side Scan Sonar		
Fai/Anc/Fai I at 200		200
Per diem 3 d at 211/d		633
	Subtotal	833

Project Management	Subtotal	0

Contractual

River Otter/Pigeon Guillemot		
Duplication computer fees		200
ELISA analysis (oil on pelage)		1,500
IG analysis		1,000
HP analysis		500
Telephone		500
	Subtotal	3,700

Sea Otter		
80 hrs. Scout aircraft @ $200/hour		16,000
Warehouse space at Cordova w/ USFS		2,000
Preliminary blood analysis (Snyder)		7,000
	Subtotal	25,000

Harlequin Duck		
Vessel charter 30 days @ $1500/day		45,000
Blood assays (CBC, WBC, serum)		2,500
Aircraft 24 hours @ $275/hour		6,600
Radio telemetry		700
	Subtotal	54,800
Mussels	Subtotal	0
Subtidal Clams		
Shipping		400
Copying/postage		300
Telephone		400
	Subtotal	1,100
Invertebrate Predators		
Photocopying/postage		300
Telephone		200
Shipping		400
	Subtotal	900
Intertidal Clams		
Freight		300
Telephone/FAX		200
	Subtotal	500

Urchins		
Coastal Resources Associates		4,409
Telephone/FAX		200
Vessel Charter		12,500
	Subtotal	17,209
Fishes		
Coastal Resources Associates		4,985
Telephone/FAX		200
	Subtotal	5,185
Harlequin Duck Prey		
Coastal Resources Associates		2,005
	Subtotal	2,005
Side Scan Sonar		
Coastal Resources Associates		15,778
Side Scan Sonar contract		30,000
	Subtotal	45,778
Project Management	Subtotal	0

Commodities

River Otter/Pigeon Guillemot		
Interlukin assay kits 2 @ $550		1,100
P450 array kits 2 @ $260		520
Blood panel arrays 30 @ $33.33		1,000
Blood storage & sampling supplies		900
	Subtotal	3,520
Sea Otter		
Fuel 500 gal. @ $3/gal.		1,500
Food 25 days @ $20/day		500
Office/field supplies, misc.		500
	Subtotal	2,500
Harlequin Duck		
Fuel 166 gal. @ $3/gal.		500
Surgical supplies		9,000
	Subtotal	9,500
Mussels		
Hydrocarbon chemistry supplies		500
Field & lab chemicals		2,300
Field & lab supplies		4,200
Elec. calipers & digital recorders		5,600
Weight/measure supplies		1,200
Publication/presentation costs		500
Shipping, containers, equip.maint.		3,000
	Subtotal	17,300

Subtidal Clams		
SCUBA equipment		8,500
Sampling equipment		1,650
Protective clothing		500
Safety/first aid		500
Skiff fuel		150
Photographic film		200
Spare parts, outboards		300
Glassware and chemicals		800
Shipping supplies		250
Office supplies		200
	Subtotal	13,550
Invertebrate Predators		
SCUBA equipment		9,000
Sampling equipment		1,500
Protective clothing		500
Safety/first aid		500
Skiff fuel		150
Photographic film		200
Spare parts, outboards		300
Glassware and chemicals		800
Shipping supplies		250
Office supplies		200
	Subtotal	13,400
Intertidal Clams		
Field supplies		800
Portable pump and hoses		1,000
	Subtotal	1,800

Urchins	
Diving supplies	1,000
Subtotal	1,000
Fish	
Fish nets/spears and sampling equipment	4,500
Subtotal	4,500
Harlequin Duck Prey — Subtotal	0
Side Scan Sonar	300
Subtotal	300
Project Management	1,500
Subtotal	1,500

Equipment

River Otter/Pigeon Guillemot	
Clinical centrifuge	5,000
Subtotal	5,000
Sea Otter	
70 HP OB - OMC	4,000
Hand held VHF radios 2 ea	1,000

Subtotal	5,000

Harlequin Duck

Radio transmitter 100 @ $200 ea	20,000
Radio receivers 2 @ $2,400	4,800
TOBEC	9,500
Miscellaneous	8,000
Subtotal	42,300

Mussel	Subtotal	0
Subtidal clams	Subtotal	0
Invertebrate Predators	Subtotal	0
Intertidal Clams	Subtotal	0
Urchins	Subtotal	0
Fishes	Subtotal	0
Harlequin Duck Prey	Subtotal	0
Side Scan Sonar	Subtotal	0

Project Management	Subtotal	0

Note: 95 Field equipment needed through available EVOSTC equipment consists of

1. 2 Mark II (14-15') inflatable boats

2. 2 25 HP Outboard motors

3. 2 hand-held marine radios

Administration (OH)

River Otter/Pigeon Guillemot (10% of total direct)	4,690
Sea Otter (10% of total)	6,000
Harlequin Duck (10% of total)	15,920
Mussels (15% of salaries)	8,052
Subtidal clams	5,064
Invertebrate predators	4,576
Intertidal clams (20% TDC)	2,131
Urchins (20% TDC)	5,640
Fishes (20% TDC)	3,668
Harlequin Duck Prey (20% TDC)	836
Side Scan Sonar (20% of TDC)	9,862
Project Management	1,050

Totals by budget category

Salaries	213,923
Travel	37,449
Contractual	156,177
Commodities	68,870

Equipment	52,300
Administration	67,489
	596,208

Data Management Plan

Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

1.0 Introduction

The proposed study of injury to, and recovery of, nearshore vertebrate predators (NVPs) following the *Exxon Valdez* oil spill (EVOS) is a multidisciplinary project, involving scientists with varied areas of expertise representing several organizations. The success of the project (hereafter termed NVP) depends in large part on the exchange of information among scientists within the program, and between the NVP project and other projects sponsored by the *Exxon Valdez* Oil Spill Trustee Council. Effective communication of information can only be achieved through the use of a data management plan that provides a common language for the data gathered and a common means of information transfer.

The following provides an outline of the data management plan to be used by the NVP project and gives steps for implementation of the plan. The specific goals of the plan are to:

1. Ensure accuracy and maintain integrity of the data as gathered by each investigator.

2. Provide for an efficient exchange of information among investigators and between the NVP and other projects.

3. Provide a mechanism by which data and reports can be archived.

4. Provide a framework by which analyses presented in reports can be traced to the underlying data obtained during the initial data collection.

There are several keys to the successful implementation of such a plan. First, the plan must follow a written document. Second, there must be a management framework that clearly defines responsibilities for the plan's implementation. Third, all Principal Investigators and their staffs must be trained to ensure that all data are obtained and transferred as specified by the plan.

It should be stressed that the following is an outline for such a plan. This document will provide a framework by which a more complete plan can be produced and implemented. The complete plan will include Standard Operating Procedures, Field Data Sheets, Data Standards

Documents, and Data Dictionaries for each of the individual projects. Here we will give only examples of these products.

2.0 Project Management and Information Flow

The project organization is outlined in Table 1. Dr. Leslie Holland-Bartles will act as Chief Scientist for the NVP project. Her responsibilities with respect to data management, will include selecting a Data Manager and ensuring that all Principal Investigators adhere to the data management plan. All data collected by individual Principal Investigators will remain their intellectual property. However, it is also understood that all data will be accessible to each of the Principal Investigators and the Chief Scientist. After collection and timely review, all data files will be submitted by the Principal Investigators to a central data clearinghouse maintained by the NVP Data Manager.

It will be the responsibility of the Data Manager to maintain the central database, and to provide an updated index of the database to Principal Investigators and the Chief Scientist upon request. The Data Manager will also be responsible for dissemination of information in the database to the Chief Scientist or to other Principal Investigators upon request. Any use of the data from other Principal Investigators, either in presentations, reports, or publications will require the permission of the Principal Investigator who gathered the data. All such requests and subsequent approvals or denials for use will be routed through the Data Manager and reviewed by the Chief Scientist.

It will be the responsibility of each Principal Investigator to ensure that the data presented to the Data Manager is in an appropriate, pre-determined format, and is an accurate representation of the data as collected. The Principal Investigators will designate specific persons on her/his staff who have authority to submit data or request data from the Data Manager.

3.0 Written Documentation

Written documentation will primarily be provided in the form of Standard Operating Procedures (SOPs). An example of an SOP is given in Appendix A. All procedures, including field operations, laboratory analyses, data management, data distribution, report production, and the archiving of files will be provided. In many cases, SOPs will be project specific and will be provided by individual Principal Investigators. Other SOPs (eg. procedures for transfer of data files) will be generic to all projects and will be produced by the Data Manager.

All Standard Operating Procedures will contain the author's name, the draft number, the effective date of the SOP, a brief statement of its purpose, and the specific training required to use the SOP.

4.0 Training

Before an SOP can be used, all of those persons who will utilize the procedure must be trained. The level of training will be dependent on the procedure and will be at the discretion of the Principal Investigator. At a minimum, all users will be required to have read the SOP, and to have demonstrated their understanding of it. More elaborate training procedures involving hands on training and proficiency testing may be required in some instances.

5.0 Structure of the Data

5.1 Introduction

In order to maintain a common database and to ensure efficient dissemination of data, a common format of the data will be required of all individual projects. The following provides guidelines on the structure of files and their format.

5.2 Types of Files

There will be six types of files maintained (Table 2). These include:

5. Field or laboratory data files - Data as initially recorded on field sheets, lab notebooks, etc.

6. Raw data files - Computer file with the edited data from field or laboratory data sheets.

7. History files - Computer text files associated with each raw file that contains of history of when data were entered and/or edited, and a description of edits.

8. Analysis files - Computer files that are used to manipulate or provide summaries of statistical analyses of the raw data.

9. Ouput files - Computer output provided by analysis.

10. Report file - Computer word processing, spreadsheet, or image files that make up a particular report.

A brief description of these files and specifications for associated file names and file types are given in Table 3.

All files will be maintained by Principal Investigators. A copy of the raw data files and associated history files will also be placed in a common database maintained by the Data Manager.

5.3 Analysis Flow Charts

Any presentation of data in a report will be accompanied by an appendix containing a flow diagram that describes the steps taken in producing the table or figure (Table 4). This flow chart will allow one to trace the summary presentation back to field or laboratory data sheets. The diagram will indicate all the names of any intermediate databases used in the production of the final table or figure, as well as the names of all analysis files.

5.4 File Structure

An example of each file type represented in the flow diagram described above (Table 4) is given in tables 5 through 9. Accompanying each raw data file will be a data dictionary that gives the format, acceptable range, and a brief description of each variable in the file (Tables 10 and 11). The variables used in raw data files can be unique to a given project or can be more generic. In cases where the same variable is to be used by several projects, this variable will be described and its format defined in a data dictionary common to all projects (Tables 12 and 13). This is to ensure that all projects are consistent in their naming of variables, so that data can be easily shared among projects. Separate data dictionaries will be provided for all variables that are unique to a given raw data file.

In addition, there will be a single database that describes the location of all sampling sites, and an associated data dictionary (Tables 14 and 15). This "site location" database will list all sites sampled by each of the projects, and will describe the location of the sampling sites based on a coordinate system that is the same for all projects. This database is critical to future linking of information from separate projects. For example, it may allow for the efficient determination of prey abundance within a certain region for which we also have estimates of river otter abundance. In addition, this database will allow us to easily place all sampling sites on a common map.

6.0 A Time Line for Data Management Procedures

The following is a time line for critical events in the data management process.

- Chief Scientist selects Data Manager
- PIs select individual data managers for their project

- PIs and Data Manager write SOPs, including field/laboratory data sheets, raw data file structure, and associated data dictionaries
- Data Manager reviews and approves SOPs
- Field data collected
- Data from field sheets are entered into a raw data file
- The raw file is checked and edited if necessary
- A history file is produced
- The raw file and associated history file are submitted to the Data Manager
- At monthly intervals, the PIs submit newly created or edited raw files and history files to the Data Manager. If no new or edited files are available, the PI will supply the Data Manager with a short written statement to that effect.
- At monthly intervals, the Data Manager provides an index of all available raw data files to the PIs.
- PIs or their designees conduct analyses and prepare flow charts for same
- PIs write reports and submit to the Chief Scientist along with flow diagrams
- PIs archive field data, raw data files, history files, analysis files, and reports
- Data Manager archives raw data files, history files, analyses flow diagrams, and overall project report

Table 1. Flow chart for data management of the Nearshore Vertebrate Predator Project.

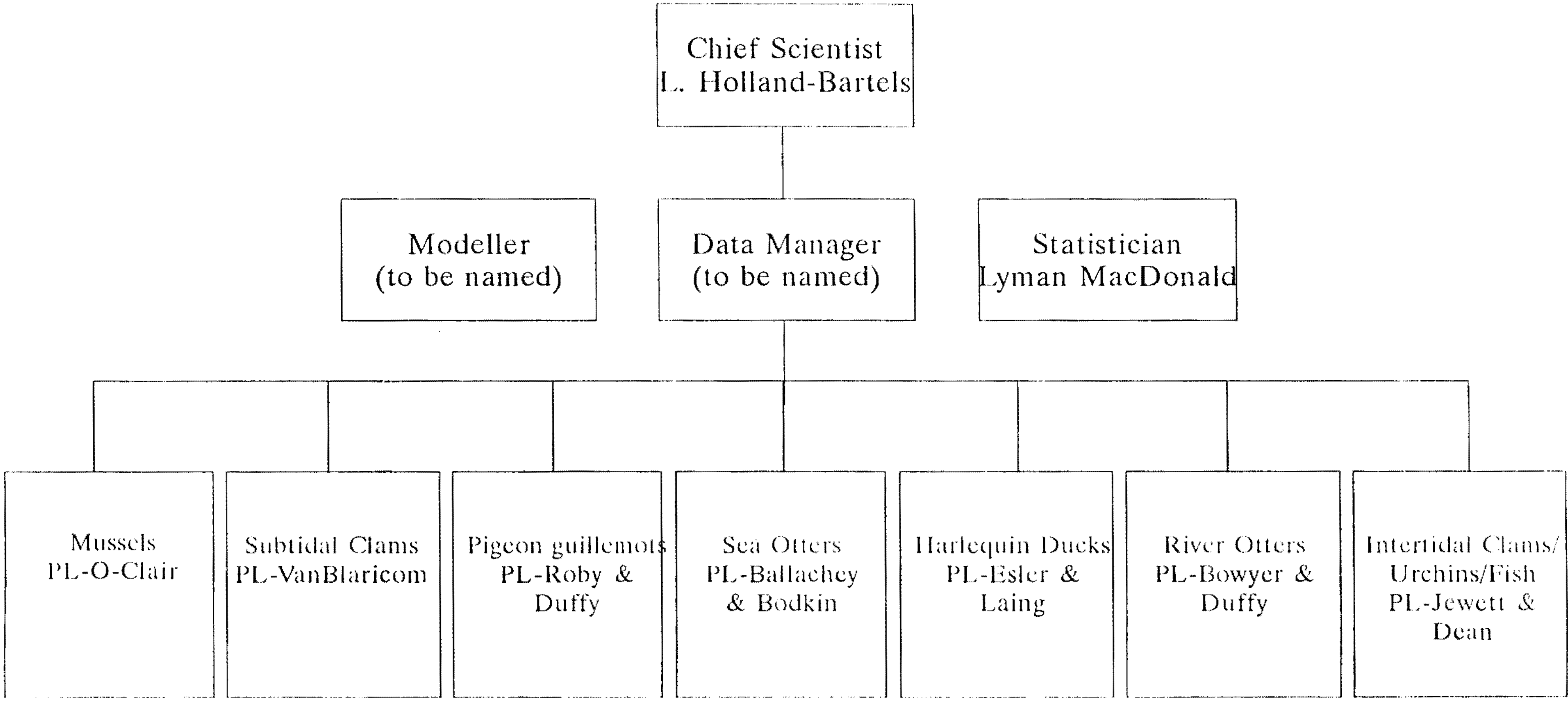

Table 2. Flow diagram showing the file types and the flow of data.

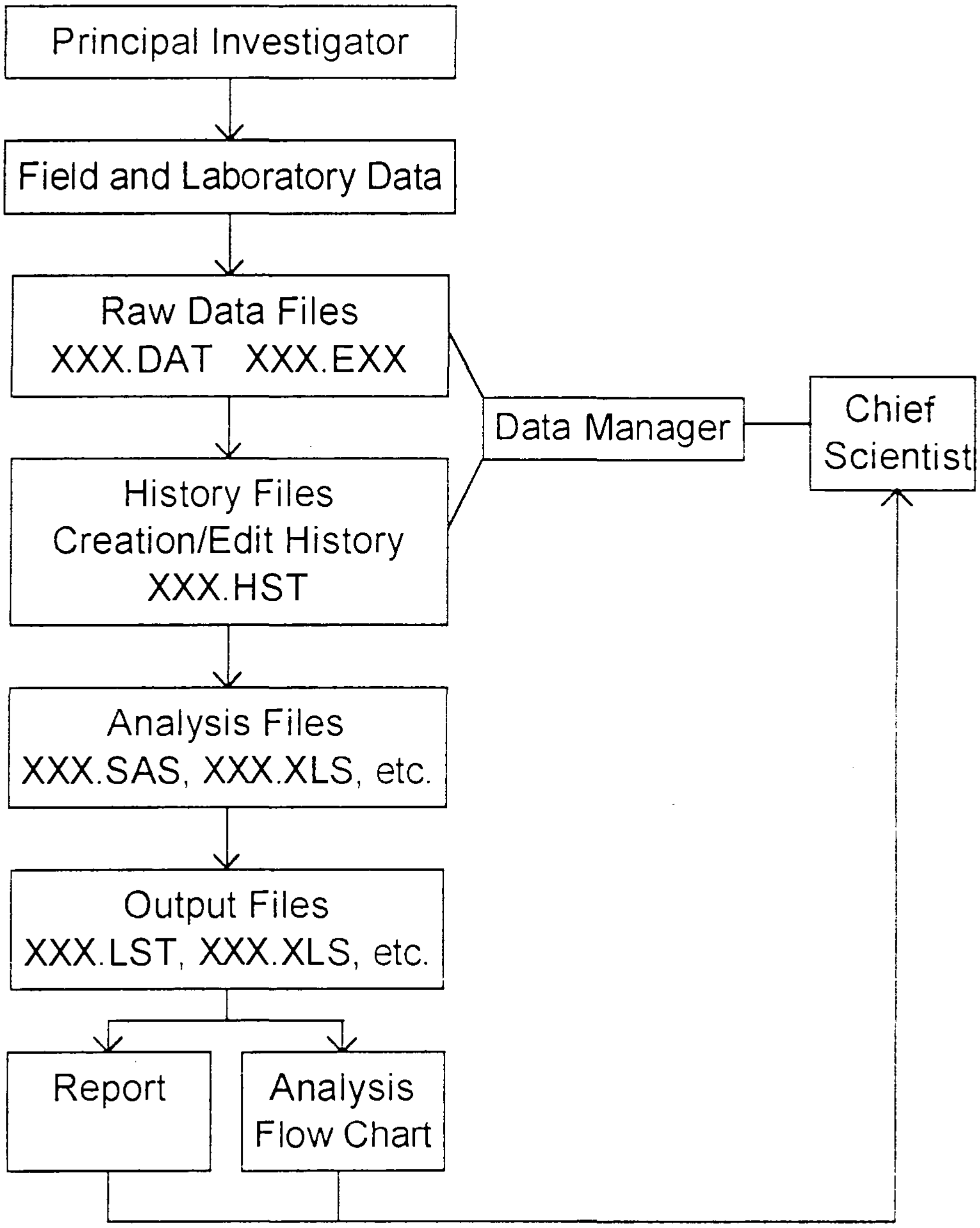

Table 3. Description of file types used in the Nearshore Vertebrate Predator project.

Category	File Name	File Type	Description
Field/Lab Data	None specified	None specified	Field data sheets, notebooks, data tapes, sonar records, etc.
Raw Data	Project code as first 2 digits	.dat (for ASCII) or .exx (for ArcInfo)	Computer file with data from field that has been entered, checked, and edited [1]
History	Same as corresponding Raw file	hst	A text file (ASCII) containing date raw file was created, name of person who created file, date edits were made, who entered data, and a short description of edits
Analysis	None specified	determined by software (e.g. .sas, .xls, .wk1)	Any file which produces analyses, tables, charts, graphs, etc. For example, a SAS or EXCEL file that computes mean abundance from raw data
Output File	None specified	none specified	Output from analysis program (In some cases, output may be imbedded in analysis file)
Report File	AAAXXXXA[2]	WP	First 2 letters are the project code. 3rd letter is the code for type of report- (M = monthly, Q = quarterly, A = annual, F=final). Numbers are the month and year of the initial draft of the report. Last letter indicates draft number - (a = 1, b = 2, etc.).

[1] Note: All raw files should be "sparsed". That is, all zero values should be included. For example, if no harlequin ducks were observed on a particular bird transect, then a "0" value (not a blank or missing value) should be entered. A " • " should appear in raw files for data that are truly missing.

[2] Format conventions: A = Alpha code, N = Numeric code.

Appendix A.

DATA DICTIONARY FOR RAW DATA FILES (Sea Otter Abundance)

Variable	Variable Code	Format	Example	Range	Description
Date	DATE	DDMMMYY	01JUL95	NA	
Observer	OBSRVR	AAAAAAAA	JBodkin	NA	First initial and up to 7 letters of last name
Start Time	STIME	HHMM	1430	0000 - 2400	Military format
Aircraft	AIRCRFT	AAAAA	Scout	NA	Aircraft model
Pilot	PILOT	AAAAAAAA	Pkearney	NA	First initial and up to 7 letters of last name
Area	AREA	AAA	NAK	see list attached	Area being surveyed in Prince William Sound
ınsect Number	TNUM	XXXX	44	1 - 9999	Unique transect number
Strip Count	SCOUNT	XXXX	12	0 - 9999	Number of independent/dependent sea otters in each group
Adults	ADULT	XXXX	4	0 - 9999	Number of independent sea otters
Pups	PUP	XXXX	2	0 - 9999	Number of dependent sea otters
Chop	CHOP	X	2	0 - 4	Quartile of transect with chop
Glare	GLARE	X	1	0 - 4	Quartile of transect with glare
ISU Number	ISUNUM	XXXX	22	1 - 9999	Intensive Search Unit number

Table 4. Example of an analysis flow chart.

Report: SUQ0995A.WP
Author: Dean et al.
Date: 15Sep95
Output: Table 4.2

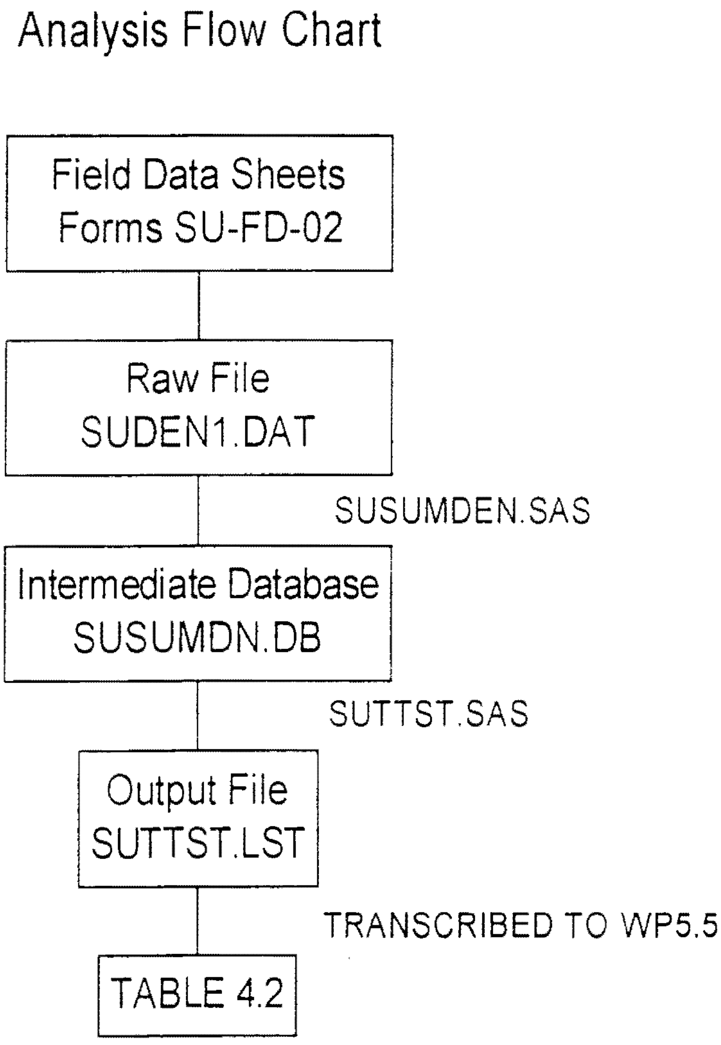

Table 5. Example of a field data sheet.

Sea Urchin and Sea Otter Densities on Transects
Form SU-FD-01

Name:______________________________ Date:____________________

Site:________________________________ Depth Stratum:___________

Depth (ft) Actual:____________________ Depth (ft) Adjusted to MLLW:__________

Time In:_____________________________ Time Out:________________

Transect Coordinates (WGS 84)

LAT 1.________ 2.________ 3.________ 4.________ 5.________

(start) (end)

LONG 1.________ 2.________ 3.________ 4.________ 5.________

Transect width (m)_______

Segment #	Taxa	Size Class	#	Vegetation Type	Substrate Type	Notes

Table 6. Example of a raw data file.

Sea Urchin and Sea Star Densities
Form SU-RD-01
File Name - SUDEN1.DAT

Site	Date	Depth	Habitat	Depth	Transect	Transect	Coordinates				Taxa	Size	#	Vegetation	Substrate
		Stratum	Type	(m-MLLW)	Segment #	width (m)	Begin		End			Class		Type	Type
							LAT	LONG	LAT	LONG					
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Sd	J	3	Ac	R
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Sd	HG	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Sd	HG	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Ph	J	8	Ac	R
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Ph	J	4	Zm	S
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Ph	J	0		.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Di	J	2	Ac	R
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Di	J	1	Ac	C
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Di	HG	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.625	147 40.021	60 23.701	147 40.099	Di	J	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Sd	J	3	Ac	R
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Sd	HG	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Sd	HG	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Ph	J	8	Ac	R
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Ph	J	4	Zm	S
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Ph	J	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Di	J	2	Ac	R
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Di	J	1	Ac	C
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Di	HG	0	.	.
BI001	6-Jul-95	S	SR	2.8	1	1.0	60 23.701	147 40.099	60 23.902	147 40.108	Di	J	0	.	.

Table 7. Example of a history file.

File Name - SUDEN.HST

Date	Name	Action	Description
04JAN96	T. Dean	entered data	none
05JAN96	T. Dean	checked data	no errors found
08JAN96	T. Dean	edited data	changed zero to missing value for sea urchin density, J #3
23MAY97	T. Dean	edited data	changed depth from -2.8 to -2.5 for data of 06JUL95. Tide corrections were applied incorrectly.

Table 8. Example of an intermediate database.

Mean Sea Urchin Densities
File name - SUSUMDN.DB

Site	Date	Depth	Depth	Habitat	Transect	#			# on			
		(m-MLLW)	Stratum	Type	Area (m2)	J	HG	A	Rock	Cobble	Gravel	Sand
BI-1	6-Jul-95	2.8	S	SR	192.6	8	1	2	1	10	0	0
BI-2	7-Jul-95	2.1	S	SR	185.6	0	1	0	1	0	0	0
BI-3	7-Jul-95	3.0	S	SR	208.8	0	0	0	0	0	0	0
KI-1	8-Jul-95	1.0	S	SR	219.3	0	6	2	1	7	0	0

Table 9. Example of table output.

Sea Urchin and Sea Star Densities

Table 4.2 Mean densities (no. m^{-2}) of sea urchins at shallow oiled (without sea otters) and nonoiled reference (with sea otters) sites in Prince William Sound in 1995.

	number m^{-2}			
Habitat	Oiled	Reference	n	P
Sheltered rocky	0.01	0.02	4	0.99
Sheltered cobble/gravel	0.05	0.01	4	0.92
Sheltered mud/sand	0.81	0.04	4	0.02
Exposed rocky	0.05	0.00	4	0.99
Exposed cobble/gravel	0.00	0.00	4	----

Table 10. Data dictionary for raw data files specific to sea urchin and fish studies.

DATA DICTIONARY FOR
RAW DATA FILES
(Sea urchin, Fish)

Variable	Variable Code	Format	Example	Range	Notes
Depth Stratum	STRATUM	A	S	S or D	S = shallow(0-3m), MLLW D = deep(3-6m), MLLW
Transect width (m)	TWIDTH	X.X	1.0	0.0-2.0	Adjusted to nearest tenth
Transect segment	TSEG	X	1	1-9	Designates transects broken into several segments
Size class	SIZE	AA	J	J, HG, A	Juvenile - <5cm Half grown - 5-10cm Adult- >10cm (diameter for stars) Juvenile - <2cm Half grown - 2-5cm Adult- >5cm (diameter for sea urchins)
Vegetation type	VEGTYPE	AA	AC	see list attached	Dominant vegetation type
Substrate type	SUBTYPE	AA	R	see list attached	Dominant substrate type

Table 11. Data dictionary for specific variable ranges specific to sea urchin and fish raw data files.

DATA DICTIONARY FOR SPECIFIC VARIABLE RANGES (Sea urchin and fish raw data files)

Invertebrate Taxa

Code	Species
Cx	Cancer crabs (Cancridae)
Di	Dermasterias imbricata
Et	Evasterias troschelli
Mx	Spider crabs (Majidae)
Os	Other sea stars
Ph	Pycnopodia helianthoides
Sd	Strongylocentrotus droebachiensis
Sf	Strongylocentrotus franciscanus
Tc	Telmessus cheiragonus

Vegetation Type

Code	Species
Ac	Agarum cribosum
Ct	Cymathere triplicata
Lg	Laminaria groenlandica
Lp	Laminaria praelonga
Ls	Laminaria saccharina
NA	None
Nl	Nereocystis luetkeana
Ob	Other brown algae
Ra	Red Algae
Zm	Zostera marina

Substrate Type

Code	Description
M	Mud/Silt (<0.0125mm)
S	Sand (≥0.0125mm. <1mm)
G	Gravel (≥1mm, <50mm)
C	Cobble (≥50mm, <300mm)
B	Boulder (≥300mm , <1m)
R	Rock (≥1m diameter or reef)

Table 12. Data dictionary for raw data files specific to all projects.

DATA DICTIONARY FOR
RAW DATA FILES
(All Projects)

Variable	Variable Code	Format	Example	Range	Notes
Date	DATE	DDMMMYY	01JAN95	NA	
Time	TIME	HHMM	1235	0000 - 2400	Pacific Standard or Daylight Time Military Format
Water Depth	DEPTH	XX.X	12.2	0 - 99.9	Record in m, adjusted to MLLW
				degrees minutes	
GPS Coordinates	GPSCOORD	LAT - XX XX.XXX LONG - XX XX.XXX	60 23.625 147 40.099	0 to 90 0 to 60 0 to 180 0 to 60	reference to WGS 84 datum, list as degrees-space-minutes and thousandths of minutes
Map Coordinates	MAPCOORD	LAT - XX XX.XXX LONG - XX XX.XXX	60 23.625 147 40.099	0 to 90 0 to 60 0 to 180 0 to 60	Albers projection
Project	PROJCODE	AA	SU	see attached list	
Site Name	SITE	AAXXX	BI001	NA	First two digits indicate site name (a Bay, Island, Passage), numbers following are sequential at the site
Taxa	TAXA	AA	Sd	see attached list	Code indicating taxa, usually initials of genus and species
Sex	SEX	A	M	M = male, F= female, U = unknown	

Table 13. Data dictionary for project codes.

DATA DICTIONARY FOR PROJECT CODES
(All projects)

Code	Project	Principal Investigator
FS	Fish	Jewett, Dean
IC	Intertidal Clam	Jewett
MY	Mussel	O'Clair
PG	Pigeon Guellemot	Roby, Duffy
RO	River Otter	Bowyer, Duffy
SC	Subtidal Clam	VanBlaricom
SD	Sea Duck	Esler, Laing
SO	Sea Otter	Botkin, Ballachey
SS	Side Scan Sonar	Dean, Jewett
SU	Sea Urchin	Dean, Jewett

Table 14. Example of a site location database.

File name - SITELOC.DAT

Project	Site Name	Area	Tidal Zone	Habitat Type	Oil Category	Type	Buffer (m)	Coordinates A LAT	A LONG	B LAT	B LONG	C LAT	C LONG	D LAT	D LONG	Position Method
SU	BI001	KNT	S	SR	O	SHS	.	60 23.625	147 40.099	60 23.854	147 40.108	. .	. .	. .	. .	GPS
SU	BI002	KNT	S	SR	O	SHS	.	60 23.625	147 40.099	60 23.854	147 40.108	. .	. .	. .	. .	GPS
SU	SH001	MON	S	SS	R	SHS	.	60 23.625	147 40.099	60 23.854	147 40.108	. .	. .	. .	. .	GPS
SO	BISHARM	KNT	S	.	O	SHA	50	60 23.625	147 52.101	60 23.815	147 51.902	. .	. .	. .	. .	GPS
RO	JPB WS	JPB	T	OG	R	PT	.	60 20.025	148 10.020	. .	. .	. .	. .	. .	. .	MAP
SD	MIT001	MON	S	.	R	STA	60	60 23.625	147 52.101	60 20.025	147 52.102	60 20.025	147 53.102	60 21.086	147 53.102	GPS

Table 15. Data dictionary for site location raw data files specific to all projects.

DATA DICTIONARY FOR SITE LOCATION RAW DATA FILES
(All Projects)

Variable	Variable Code	Format	Example	Range	Notes
Project	PROJCODE	AA	SU	see list attached	
Site Name	SITE	AAAAXXXX	BI001	to be determined	
Area	AREA	AAA	NAK	see list of codes	
Tidal Zone	TIDEZONE	A	S	S, I, or T	S = subtidal (on/in water below MLLW), I = intertidal (on/in water between MLLW and HHW), T = terrestrial (above HHW)
Oil Category	OILCAT	A	O	O or R	O = oil, R = reference
Segment Type	SEGTYPE	AAA	SHS	see list of codes	
Buffer	BUFFER	XXX	20	1-999m	A distance from a shoreline segment that defines a polygon extending a given distance offshore from point A to point B
				degrees minutes	
GPS Coordinates	GPSCOORD	LAT - XX XX.XXX LONG - XX XX.XXX	60 23.625 147 40.099	0 to 90 0 to 60 0 to 180 0 to 60	reference to WGS 84 datum, list as degrees-space-minutes and thousandths of minutes
Map Coordinates	MAPCOORD	LAT - XX XX.XXX LONG - XX XX.XXX	60 23.625 147 40.099	0 to 90 0 to 60 0 to 180 0 to 60	Albers projection

Table 15 continued.

Code	Area Name
MON	Montague Island
JPB	Jack Pot Bay
NAK	Naked Island - Knight Island

Code	Habitat Type
T	Terrestrial (above HHW)
SR	Sheltered rocky
SC	Sheltered cobble/gravel
SM	Sheltered mud/sand
ER	Exposed rocky
OG	Old growth spruce forest (?)

others to be added...

Sampling Area

Code	Type	Description
SHS	Shoreline segment	a continuous stretch of shoreline from point A to point B on the shore
STS	Straightline segment	a straight line from point A to point B
PT	Point	
SHA	Shoreline area	a complex polygon extending from point A to point B on the shore, and extending a specific distance from the shore (distance is defined as the buffer)
STA	Straightline area	a rectangular polygon defined by four pairs of coordinates

Appendix A.

SAMPLING PROTOCOL FOR SEA OTTER AERIAL SURVEYS

Overview of survey design
The survey design consists of 2 components: (1) strip transect counts and (2) intensive search units.

1) Strip Transect Counts

Sea otter habitat is sampled in two strata, high density and low density, distinguished by distance from shore and depth contour. The high density stratum extends from shore to 400 m seaward or to the 40 m depth contour, whichever is greater. The low density stratum extends from the high density line to a line 2 km offshore or to the 100 m depth contour, whichever is greater. Bays and inlets less than 6 km wide are sampled entirely, regardless of depth. Transects are spaced systematically within each stratum. Survey effort is allocated proportional to expected otter abundance in the respective strata.

Transects with a 400 meter strip width on one side of a fixed-wing aircraft are surveyed by a single observer. Transects are flown at an airspeed of 65 mph (29 m/s) and an altitude of 300 feet (91 m). The observer searches forward as far as conditions allow and out 400 m, indicated by marks on the aircraft struts, and records otter group size and location on a transect map. A group is defined as 1 or more otters spaced less than 3 otter lengths apart. Any group greater than 20 otters is circled until a complete count is made. A camera should be used to photograph any groups too large and concentrated to count accurately. The number of pups in a group is noted behind a slash (eg. 6/4 = 6 adults and 4 pups). Observation conditions are noted for each transect and the pilot does not assist in sighting sea otters.

Each strip or block of water to be sampled will have two possible flight paths, an A side and a B side (Fig. 1). The observer chooses a side from which to survey depending on direction of glare so the same block of water will be sampled. Because this method involves choosing one of 2 sets of waypoints per block (a start and end coordinate for the A side or a start and end coordinate for the B side), the observer will select either an A card or a B card for each region to load into the GPS.

2) Intensive Search Units

Intensive search units (ISU's) are flown at intervals dependant on sampling intensity*, throughout the survey period. An ISU is initiated by the sighting of a group and is followed by 5 concentric circles flown within the 400 m strip perpendicular to the group which initiated the ISU. The pilot uses a stopwatch to time the minimum 1 minute spacing between consecutive ISU's and guide the circumference of each circle. With a circle circumference of 1,256 m and an airspeed of 65 mph (29 m/s), it takes 43 seconds to complete a circle (eg. 11 seconds/quarter turn). With 5 circles, each ISU takes about 3.6 minutes to complete. ISU circle locations are drawn on the transect map and group size and behavior is recorded on a separate form for each ISU. For each group, record number observed on the strip count and number observed during the circle counts. Otters that swim into an ISU post factum are not included and groups greater than 20 otters cannot initiate an ISU.

Behavior is defined as "whatever the otter was doing before the plane got there" and recorded for each group as either diving (d) or nondiving (n). Diving otters include any individuals that swim below the surface and out of view, whether traveling or foraging. If any individual(s) in a group are diving, the whole group is classified as diving. Nondiving otters are animals seen resting, interacting, swimming (but not diving), or hauled-out on land or ice.

* The targeted number of ISU's per hour should be adjusted according to sea otter density. For example, say we have an area that is estimated to take 25 hours to survey and the goal is to have each observer fly 40 "usable" ISU's; an ISU must have more than one group to be considered usable. Because previous data show that only 40 to 55% of the ISU's end up being usable, surveyors should average at least 4 ISU's per hour. Considering the fact that, one does not always get 4 opportunities per hour - especially at lower sea otter densities, this actually means taking something like the first 6 opportunities per hour. However, two circumstances may justify deviation from the 6 ISU's per hour plan:

1) If the survey is not progressing rapidly enough because flying ISU's is too time intensive, *reduce* the minimum number of ISU's per hour slightly

2) If a running tally begins to show that, on average, less than 4 ISU's per hour are being flown, *increase* the targeted minimum number of ISU's per hour accordingly.

The bottom line is this: each observer needs to obtain a preset number of ISU's for adequate statistical power in calculation of the correction factor. To arrive at this goal in an unbiased manner, observers must pace themselves so ISU's are evenly distributed throughout the survey area.

Preflight

Survey equipment: stopwatches (2)
4 X 12 binoculars (low power, wide angle)
clipboards (2)
transect maps
transect data forms
ISU data forms
list of transects waypoints
Global Positioning System (GPS)

Appendix A.

memory cards with waypoints
35 mm camera with wide angle lens
high-speed film

Airplane windows must be cleaned each day prior to surveying.

Global Positioning System (GPS) coordinates used to locate transect starting and end points, must be entered as waypoints by hand or downloaded from an external source via a memory card.

Electrical tape markings on wing struts indicate the viewing angle and 400 m strip width when the aircraft wings are level at 300 feet (91.5 m) and the inside boundary is in-line with the outside edge of the airplane floats.

The following information is recorded at the top of each transect data form:

Date - Recorded in the DDMMMYY format.
Observer - First initial and up to 7 letters of last name.
Start time - Military format.
Aircraft - Should always be a tandem seater fixed wing which can safely survey at 65-70 mph.
Pilot - First initial and up to 7 letters of last name.
Area - General area being surveyed.

Observation conditions
Factors affecting observation conditions include wind velocity, seas, swell, cloud cover, glare, and precipitation. Wind strong enough to form whitecaps creates unacceptable observation conditions. Occasionally, when there is a short fetch, the water may be calm, but the wind is too strong to allow the pilot to fly concentric circles. Swell is only a problem when it is coupled with choppy seas. Cloud cover is desirable because it inhibits extreme sun-glade. Glare is a problem that can usually be moderated by observing from the side of the aircraft opposite the sun. Precipitation is usually not a problem unless it is extremely heavy.

Chop (C) and glare (G) are probably the most common and important factors effecting observation conditions. Chop is defined as any deviation from flat calm water up to whitecaps. Glare is defined as any amount of reflected light which may interfere with sightability. After each transect is surveyed, presence is noted as C, G, or C/G and modified by a quartile (eg. if 25% of the transect had chop and 100% had glare, observation conditions would be recorded as 1C/4G). Nothing is recorded in the conditions category if seas are flat calm and with no glare.

Observer fatigue
To ensure survey integrity, landing the plane and taking a break after every 1 to 2 hours of

survey time is essential for both observer and pilot. Survey quality will be compromised unless both are given a chance to exercise their legs, eat, go to the bathroom, and give their eyes a break so they can remain alert.

Vessel activity
Areas with fishing or recreational vessel activity should still be surveyed.

Unique habitat features
Local knowledge of unique habitat features may warrant modification of survey protocol:

1. **Extensive shoaling or shallow water (ie. mudflats)** may present the opportunity for extremely high sea otter densities with groups much too large to count with the same precision attainable in other survey areas. Photograph only otters within the strip or conduct complete counts, typically made in groups of five or ten otters at a time. Remember, groups >20 cannot initiate an ISU.

   Example: Orca Inlet, PWS. Bring a camera, a good lens, and plenty of film. Timing is important when surveying Orca Inlet; the survey period should center around a positive high tide - plan on a morning high tide due to the high probability of afternoon winds and heavy glare. Survey the entire area from Hawkin's cutoff to Nelson Bay on the same high tide because sea otter distribution can shift dramatically with tidal ebb and flow in this region.

2. **Cliffs** - How transects near cliffs are flown depends on the pilot's capabilities and prevailing weather conditions. For transects which intersect with cliff areas, including tidewater glaciers, discuss the following options with the pilot prior to surveying.

   In some circumstances, simply increasing airspeed for turning power near cliffs may be acceptable. However, in steep/cliff-walled narrow passages and inlets, it may be deemed too dangerous to fly perpendicular to the shoreline. In this case, as with large groups of sea otters, obtain complete counts of the area when possible.

   In larger steep-walled bays, where it is too difficult or costly to obtain a complete count, first survey the entire bay shoreline 400 m out. Then survey the offshore transect sections, using the 400 m shoreline strip just surveyed as an approach. Because this is a survey design modification, these data will be analyzed separately.

   Example: Herring Bay, PWS. Several cliff areas border this area.
   Example: Barry Glacier, PWS. Winds coming off this and other tidewater glaciers may create a downdraft across the face. The pilot should be aware of such unsafe flying conditions and abort a transect if necessary.

3. **Seabird colonies** - Transects which intersect with seabird colonies should be shortened

accordingly. These areas can be buffered for a certain distance in ARC dependant on factors such as colony size, species composition, and breeding status.

Example: Kodiak Island. Colonies located within 500m of a transect AND Black-legged Kittiwakes > 100 OR total murres > 100 OR total birds > 1,000 were selected from the seabird colony catalog as being important to avoid.

5. **Drifters** - During calm seas, for whatever reason - possibly a combination of ocean current patterns and geography - large numbers of sea otters can be found resting relatively far offshore, over extremely deep water, miles (up to 4 miles is not uncommon) from the nearest possible foraging area.

Example: Port Wells, PWS. Hundreds of sea otters were found scattered throughout this area with flat calm seas on 2 consecutive survey years. As a result, Port Wells was reclassified and as high density stratum.

4. **Glacial moraine** - Similar to the drifter situation, sea otters may be found over deep water on either side of this glacial feature.

Example: Unakwik, PWS. Like Port Wells, Upper Unakwik was reclassified as high density stratum.

Planning an aerial survey
Several key points should be considered when planning an aerial survey:

1) Unless current sea otter distribution is already well known, it is well worth the effort to do some reconnaissance. This will help define the survey area and determine the number of observers needed, spacing of ISU's, etc.

2) Plan on using 1 observer per 5,000 otters.

3) Having an experienced technical pilot is extremely important. Low level flying is, by nature, a hazardous proposition with little room for error; many biologists are killed this way. While safety is the foremost consideration, a pilot must also be skilled at highly technical flying. Survey methodology not only involves low-level flying, but also requires intimate familiarity with a GPS and the ability to fly in a straight line at a fixed heading with a fixed altitude, fixed speed, level wings, from and to fixed points in the sky. Consider the added challenge of flying concentric 400 meter circles, spotting other air traffic, managing fuel, dealing with wind and glare, traveling around fog banks, listening to radio traffic, looking at a survey map, and other distractions as well. Choose the best pilot available.

95025

March 10, 1995

NEARSHORE VERTEBRATE PREDATOR PROJECT
DETAILED BUDGET FFY 1996

SALARIES

River Otters/Pigeon Guillemots (Roby, Bowyer, Duffy)			
Scientist 1 mo.	5,014		
Grad student Ph.D. (12 mo.)	12,500		
Grad student M.S. (12 mo.)	11,440		
Lab Tech.	6,282		
Field Tehnician	12,064		
Account. Tech. 40 hr @ 13.92/hr	1,114		
Benefits (staff leave)	7,896		
Student tuition	9,648		
		Subtotal	65,958
Sea Otters (Ballachey, Bodkin)			
Superv. WB GS-12 (3 mo.)	15,000		
Research WB GS-11 (6 mo.)	24,000		
Biotechnician GS-7 (6 mo.)	18,000		
		Subtotal	57,000
Harlequin Ducks (Esler, Laing)			
Veterinarian (1 mo.)	6,000		
Research WB (12 mo.)	58,000		
Wildlife Biologist (4 mo.)	17,400		
Bio. Technician (12 mo.)	28,800		
Training	2,000		
		Subtotal	112,200
Mussels (O'Clair)			
Fishery Biologist (3 mo.)	20,040		
Fishery Biologist (1 mo.)	4,108		
Fishery Biologist (3 mo.)	13,854		
Lab Technician (12 mo.)	32,864		
Chemist GS-11	14,916		
Project Manager (1 mo.)	5,000		
		Subtotal	90,782

March 10, 1995

Subtidal Clams (VanBlaricom)		
Graduate student	17,145	
Tuition	6,156	
Benefits	1,372	
Hourly diving assistants	3,200	
Benefits	320	
Hourly Lab asst.	2,600	
Benefits	240	
Subtotal		31,033
Invertebrate Predators (VanBlaricom)		
Graduate student	16,990	
Tuition	6,156	
Benefits	1,280	
Hourly diving assistants	6,400	
Benefits	640	
Subtotal		31.466
Intertidal Clams (Jewett & Dean)		
Scientist (10 mo.)	40,837	
Benefits	21,744	
Subtotal		62,581
Urchins/Crabs (Jewett & Dean)		
Scientist	14,948	
Divers	7,225	
Technician	3,005	
Benefits Scientist	8,461	
Benefits staff	5,828	
Subtotal		39,467
Fishes		
Scientist (5 mo.)	23,948	
Technician/Divers	6,613	
Benefits	17,529	
Subtotal		48,095

Harlequin Duck Prey			
Scientist		4,982	
Technician		3,005	
Benefits		4,949	
	Subtotal		12,936
Side Scan Sonar			
Scientist		2,373	
Benefits		1,344	
	Subtotal		3,717
Project Management			
Chief Scientist		17,500	
Program Asst.		14,000	
Secretarial		2,800	
Data Manager		27,500	
Modeller		4,846	
	Subtotal		66,646
TRAVEL			
River Otters/Pigeon Guillemots			
FAI/VDZ/FAI (8 trips @ $380)		3,040	
SITKA/VDZ/SITKA		460	
FAI/ANC/FAI (12 trips @ $200)		2,400	
Per diem in Anchorage		2,100	
	Subtotal		8,000
Sea Otters			
ANC/Cordova/ANC (16 trips @ $250)		4,000	
Per diem Cordova (60 days @ $141)		8,460	
Rail to Whittier, 25' boat - 2 RT		3,000	
	Subtotal		15,460

Harlequin Ducks			
Meetings/Workshops		2,500	
ANC/CDV/ANC (20 trips @ $250)		5,000	
Per diem		4,000	
	Subtotal		11,500
Mussels			
JNU/ANC/JNU (8 trips @ $600)		4,800	
JNU/SEW/JNU (8 @ trips @ $720)		5,760	
	Subtotal		10,560
Subtidal Clams			
Field Work SEA/ANC/SEA (4 trips @ $360)		1,440	
ANC/Whittier/ANC (4 trips @ $150)		600	
Meetings SEA/ANC/SEA (4 trips @ $360)		1,440	
ANC/Whittier/ANC 2 @ $100		200	
Per diem 28 days @ $225		6,300	
Conferences		2,000	
	Subtotal		11,980
Invertebrate Predators			
Field work SEA/ANC/SEA (8 trips @ $382)		3,056	
ANC/Whittier/ANC (8 trips @ $110)		880	
Meetings SEA/ANC/SEA (2 trips @ $382)		764	
Per diem 30 days @ $225		6750	
Conferences		1,600	
	Subtotal		13,050
Intertidal Clams			
Field FAI/CDV/FAI (2 trips @ $500)		1,000	
Per diem (9 days @ $141)		1,269	
FAI/ANC/FAI (1 trip @ $200)		200	
	Subtotal		2,469

Urchins/Crabs			
FAI/CDV/FAI (3 trips @ $500)	1,500		
FAI/SD/FAI (1 trip @ $800)	800		
Per diem (14 days at $141)	1,974		
		Subtotal	4,274
Fishes			
Santa Barbara/CDV/Santa Barbara (2 trips @ $800)	1,600		
FAI/CDV/FAI (1 trip @ $600)	600		
Per diem (6 days @ $141)	846		
		Subtotal	3,046
Harlequin Duck Prey			
FAI/ANC/FAI (1 trip @ $200)	200		
Per diem (2 days @ $211)	422		
		Subtotal	622
Side Scan Sonar			
FAI/ANC/FAI (1 trip @ $200)	200		
Per diem (3 days @ $211)	633		
		Subtotal	833
Project Management			
ANC/FAI/ANC (2@200)	400		
ANC/Cordova/ANC (2@250)	500		
Per diem (14@141)	2,052		
		Subtotal	2,952

CONTRACTUAL

River Otters/Pigeon Guillemots	
Vehicles (lease, FAI/VDZ/FAI)	2,250
Equipment maintenance	1,850
ADF&G - Contract (project assistance)	10,000
Project support services	5,000
Freight	3,000
Publication costs	1,000
Vessel charter (25 days @ $400)	10,000

Duplication/computer fees	600	
ELISA analysis (oil on pelage)	1,600	
IG analysis	2,000	
HP analysis	1,000	
Telephone	400	
Subtotal		38,700
Sea Otters		
Veterinarian (7 days @ $300)	2,100	
Shipping	3,000	
160 hrs. Scout aircraft @ $200/hour	32,000	
Warehouse space at Cordova w/ USFS	2,000	
Blood, immune function and oil exposure assays (costs for all four NVP species)	60,000	
Air taxi (24 hrs. @ $250)	6,000	
Subtotal		105,100
Harlequin Ducks		
Vessel charter (50 days @ $1500)	75,000	
Aircraft (192 hrs. @ $275)	52,800	
Body composition analyses	5,000	
Statistical consulting	2,000	
Radio telemetry	5,800	
Subtotal		140,600
Mussels		
Vessel charter (14 days @ $1600)	22,400	
Subtotal		22,400
Subtidal Clams		
Shipping	900	
Copying/postage	400	
Computer consultant	2,500	
Graphics/Publication costs	500	
Telephone	500	
Subtotal		4,800

Invertebrate Predators			
Shipping		800	
Copying/postage		500	
Telephone		500	
Vessel charter (21 days @ $1600)		33,600	
Computer consultant		2,500	
Graphics/Publication costs		500	
	Subtotal		38,400
Intertidal Clams			
Freight		500	
Telephone/FAX		300	
Sediment analysis		6,000	
Reporting		500	
	Subtotal		7,300
Urchins/Crabs			
Freight		200	
Coastal Resources Associates		51,022	
Telephone/FAX		300	
Vessel Charter (21 days at $2500)		52,500	
	Subtotal		104,022
Fishes			
Coastal Resources Associates		40,136	
Telephone/FAX		300	
Vessel charter (15 days at $2500)		37,500	
Freight		200	
	Subtotal		78,136
Harlequin Duck Prey			
Coastal Resources Associates		7,036	
Telephone/FAX		200	
	Subtotal		7,236

Side Scan Sonar			
Coastal Resources Associates		15,085	
Side Scan Sonar contract		15,000	
	Subtotal		30,085
Project Management			
Statistical Consultation		15,000	
	Subtotal		15,000

COMMODITIES

River Otters/Pigeon Guillemots			
Lab supplies/assay kits			
2 Interleukin kits		1,100	
2 P450 kits		520	
68 blood panel assays		2,380	
Food (14 weeks @ $600)		8,000	
Camp gear (sleeping bags, pads, chairs, cots)		1881	
Camp/sample prep. fold-out table (3 @ $92)		276	
Pesola scales (8 @ $50)		400	
Whirl-pacs		200	
Miscellaneous boat safety supplies		350	
MSR Waterworks filtration system (2 each + replace)		355	
First aid kit (2 @ $132)		264	
Miscellaneous field camp supplies		1000	
Climbing gear		1450	
Day packs (3 @ $50)		150	
Rite-in-rain notebooks, data sheets		325	
Rain gear		1000	
Waders/hip boots (4 @ $119)		476	
Boat fuel (65 gal/day @ $2/gal, 90 days)		11,700	
Propane tank, 100 lbs (4 @ $120)		480	
Propane regulator, lines		250	
Coleman propane stove, 2 burner (2 @ $68)		136	
Camp cooking supplies		300	
Hancock live traps (34 @ $245.25)		8,339	
Bait for live traps		500	
Blood sampling/storage supplies		3,500	
	Subtotal		45,332

Sea Otters		
Fuel (2500 gal @ $3/gal)	7,500	
Food (60 days @ $20/day)	1,200	
Office/field supplies, miscellaneous	1,500	
Subtotal		10,200
Harlequin Ducks		
Fuel (1000 gal @ $3/gal)	3,000	
Surgical supplies	9,000	
Equipment maintenance	2,000	
Subtotal		14,000
Mussels		
Hydrocarbon chemistry supplies	2,500	
Field & lab chemicals	2,300	
Field & lab supplies (pumps, sieves, jars)	1,200	
Weight/measure supplies	600	
Publication/presentation costs	500	
Shipping, freight, containers, equip. maintenance	2,000	
Image analysis	5,000	
Subtotal		14,100
Subtidal Clams		
SCUBA gear	1,500	
Sampling supplies	2,800	
Skiff fuel	160	
Photographic film	225	
Spare parts, outboards	500	
Shipping supplies	200	
Subtotal		5,385

March 10, 1995

Invertebrate Predators			
SCUBA gear		1,500	
Sampling supplies		3,000	
Skiff fuel		320	
Photographic film		225	
Spare parts, outboards		300	
Shipping supplies		200	
	Subtotal		5,545
Intertidal Clams			
Field supplies		500	
Computer software		500	
	Subtotal		1,000
Urchins/Crabs			
Diving supplies		2,500	
	Subtotal		2,500
Fishes			
Sampling equipment		1,000	
	Subtotal		1,000
Harlequin Duck Prey			
Lab supplies		200	
	Subtotal		200
Side Scan Sonar		50	
	Subtotal		50
Project Management		2,248	
	Subtotal		2,248

March 10, 1995

EQUIPMENT

River Otters/Pigeon Guillemots			
Centrifuge, field, DC powered		1,341	
Propane freezers (2 @ $1450)		2,900	
Top-loading balance, battery powered (2 @ $500)		1,000	
	Subtotal		5,241
Sea Otters			
70 HP Outboard engine, OMC		4,000	
Capture gear and supplies		5,000	
Hand held VHF radios (2 @ $500)		1,000	
	Subtotal		10,000
Harlequin Ducks			
Radio transmitters (100 @ $200 ea)		20,000	
Miscellaneous		8,000	
	Subtotal		28,000
Mussel			0
Subtidal Clams			
Dissecting microscope		7,500	
	Subtotal		7,500
Invertebrate Predators			0
Intertidal Clams			0
Urchins/Crabs			0
Fishes			0
Harlequin Duck Prey			0
Side Scan Sonar			0

March 10, 1995

Project Management	0

Note: FFY 96 field equipment needed through available EVOSTC equipment consists of

1. 2 Mark II (14-15') inflatable boats
2. 2 25 HP Outboard motors
3. 2 hand-held marine radios
4. Heater, propane

6. Binoculars, low-light- 3 ea
7. Mustang suits
8. Survival suits
9. Laptop computer-486 minimum
10. Desktop computer-486 minimum, printer

ADMINISTRATION (Overhead)

River Otters/Pigeon Guillemots (10% of total direct)	16,323
Sea Otters (10% of total)	19,776
Harlequin Ducks (10% of total)	30,630
Mussels (15% of salaries)	13,617
Subtidal clams	9,078
Invertebrate predators	12,850
Intertidal clams (20% of total direct)	14,670
Urchins/Crabs (20% of total direct)	30,053
Fishes (20% of total direct)	26,055

Harlequin Duck Prey (20% of total direct)	4,199
Side Scan Sonar (20% of total direct)	6,937
Project Management (10% of total)	8,700
Subtotal	**193,843**

TOTALS by Budget Category

Salaries	640,626
Travel	81,794
Contractual	576,779
Commodities	100,812
Equipment	50,741
Administration	193,843

March 10, 1995

TOTALS by Project Component

River Otters/Pigeon Guillemots	179,554	
Sea Otters	217,536	
Harlequin Ducks	336,930	
Mussels	151,459	
Subtidal Clams	69,776	
Invertebrate Predators	101,311	
Intertidal Clams	88,020	
Urchins/Crabs	180,316	
Fishes	156,332	
Harlequin Duck Prey	25,193	
Side Scan Sonar	41,622	
Project Management	95,546	
NVP PROJECT TOTAL, FFY 1996		**1,644,595**