19.2.3

95199-CLO

Institute of Marine Science - Seward Improvements EIS

Project Number:	95199-CLO
Restoration Category:	Administration, Public Information and Science Management (closeout)
Proposed By:	ADFG
Cooperating Agencies:	All Trustee Agencies
Cost FY 95:	$46,500
Cost FY 96:	$0
Duration:	1 year
Geographic Area:	Gulf of Alaska
Injured Resource/Service:	Multiple resources

INTRODUCTION

On January 31, 1994 the Trustee Council approved financial support for project 94199, Required Infrastructure Improvements for the Institute of Marine Science - Seward and authorized the Executive Director to:

1. Take necessary steps to secure NEPA compliance;

2. Consult with appropriate entities, including the University of Alaska, the City of Seward, the Seward Association for the Advancement of Marine Science, and appropriate Trustee Agencies to review the assumptions relating to the proposed improvements and capital and operating budgets;

3. Develop an integrated funding approach which assures that the use of trust funds are appropriate and legally permissible under the terms of the Memorandum of Agreement and Consent Decree;

4. Prepare a recommendation of the appropriate level of funding for consideration by the Trustee Council that would be legally permissible under the terms of the Memorandum of Agreement and Consent Decree.

This project will close out the process of preparation of the Environmental Impact Statement and the consultation needed to prepare the revised project description and budget for the proposed expansion and improvements of research facilities affiliated with the Institute of Marine Science in Seward.

NEED FOR THE PROJECT

Federal law requires an Environmental Impact Statement (EIS) for major federal actions significantly affecting the quality of the human environment. The Trustee Council members have agreed that this project would follow an EIS process for NEPA compliance.

Additionally, the project provides for the completion of consultation and analysis needed to develop a recommendation regarding use of settlement funds that would be appropriate and legally permissible to support proposed improvements with an estimated cost of up to $25 million. The Trustee Council is likely to consider this recommendation in late October 1994.

PROJECT DESIGN

A. Objectives

In FY 94, the first objective was to initiate a process to review the assumptions relative to the research functions, improvement needs, and capital and operating budgets for the proposed facility. The second objective was to initiate and formulate a National Environmental Policy Act process to identify and analyze the environmental and social consequences of the proposed facility. The third objective was to review the proposed improvements to ensure that they are legally permissible under the terms of the Memorandum of Agreement and Consent Decree. In FY 95, the objectives will be to complete and publish the EIS Record of Decision and to finalize the Executive Director's recommendation to the Trustee Council concerning the appropriate level of capital funding for the facility. It is anticipated that this project will close out by December 31, 1994.

B. Methods

The first objective was accomplished through the formation of a Scientific Review Group comprised of Trustee Council representatives and the University of Alaska to review the project assumptions and advise the Seward Association for Advancement of Marine Science (SAAMS) and the project architects and consultants on the design and operation of the proposed improvements.

The second objective was accomplished through development and publication of an EIS for the proposed facility.

The third objective was accomplished through regular consultation between the project staff and the Trustee Council legal team and review of a detailed construction cost budget for the progress schematic design of the proposed facility.

In FY 95, objectives will be met through preparing and publishing the Record of Decision for the proposed project and preparation of a revised project description and budget for the Executive Director containing the results of the consultation and EIS process described above.

C. Schedule

The Draft EIS was published on June 17, 1994. The Final EIS is scheduled to be published on or before September 16, 1994. The Record of Decision is scheduled to be published on or before October 28, 1994. The revised project description will be distributed in mid-September. The Executive Director's funding recommendation is scheduled to be acted on in late October.

D. Technical Support

Federal and state agency and University of Alaska personnel will provide technical expertise to the Scientific Work Group, the review of assumptions associated with the project, and the EIS process. Consultants to SAAMS will provide architectural, engineering, project management, and EIS preparation expertise. The Chief Scientist and peer reviewers will review the research assumptions associated with the project.

E. Location

All of the analysis and writing will be conducted in Anchorage, Alaska.

PROJECT IMPLEMENTATION

The ADFG project coordinator will be responsible for consultation with appropriate entities and preparing the revised project description and budget for the Executive Director's funding recommendation. The DOI EIS coordinator will be responsible for ensuring that the EIS process is completed on time.

COORDINATION OF INTEGRATED RESEARCH EFFORT

During FY 94, meetings were held with representatives of other Gulf of Alaska marine research facilities (PWS Science Center, Copper River Delta Institute, Fisheries Industrial and Technical Center, Auke Bay Laboratories) to coordinate and discuss the research functions of the proposed facility. Additionally, regular contacts are kept with the Chief Scientist to keep him apprised of planning for the proposed facility. Meetings were also held with University of Alaska - Fairbanks researchers involved in the SEA program to coordinate the facility, vessel, and anticipated research components of the project.

FY 95 BUDGET ($K)

Personnel	29.3
Travel	10.1
Contractual	1.9
Commodities	0.6
Equipment	0.0
Subtotal	41.9
Gen. Admin.	4.6
Total	46.5

95244

RECEIVED
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EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL

Exxon Valdez **Oil Spill Trustee Council**
FY 95 Detailed Project Description

Project Title: Harbor Seal and Sea Otter Co-op Subsistence Harvest Assistance

Project Number: 95244

Lead Trustee Agency: Alaska Department of Fish and Game

Project Start-up/Completion Dates: 10/1/94 through 9/30/95

Expected Project Duration: 2 years

Cost of Project FY 95: $93,900
FY 96: $22,100

Geographic Area: Prince William Sound and the Lower Kenai Peninsula

Name/Signature of Project Leaders:

Dr. James Fall/Rita Miraglia
P.I.
James A. Fall
Rita A. Miraglia
Subsistence Division
Alaska Department of Fish and Game
333 Raspberry Road
Anchorage, Alaska 99518
phone numbers: 267-2359/267-2358
fax number: 349-4712

Name/Signature of lead agency Project Manager:

Dr. Joseph R. Sullivan
Joseph R. Sullivan
Habitat & Restoration Division
Alaska Department of Fish & Game
333 Raspberry Road
Anchorage, Alaska 99518
phone numbers: 267-2213
fax number: 522-3148

Restoration Project 95244

A. INTRODUCTION

The goal of this project is to work cooperatively with subsistence hunters to assess the impacts of subsistence harvest of harbor seals and sea otters, and other factors, on the recovery of these species, and to identify ways to reduce these impacts. This project began in 1994 (Project Number 94244). The work plan for the year called for a summary of subsistence harvest data, collection of traditional knowledge about these populations, and the compilation of biological data.

The populations of harbor seals and sea otters in Prince William Sound and adjacent waters were injured as a result of the *Exxon Valdez* Oil Spill. The U.S. Fish and Wildlife Service estimates that between 3,500 and 5,500 sea otters were killed by oil in the first months after the spill, and that sea otters were still being injured by oil in the environment 3 years later. The case for a population level oil spill injury to harbor seals is less clear. Harbor seal populations throughout the Gulf of Alaska are known to have been in decline before the oil spill. This decline has continued, but it is difficult to determine how much of the decline, if any, is due to the effects of oil in the environment. However, it is known that harbor seals were exposed to *Exxon Valdez* crude oil in Prince William Sound. They suffered some direct mortality, although the number of harbor seals killed is unknown. Harbor seals also suffered sub-lethal effects, including corneal damage, nerve damage, and brain lesions.

Many subsistence hunters within the spill area, concerned about the decline that they have observed in the numbers of harbor seals and sea otters, have voluntarily reduced their take of these species in an effort to help their recovery. However, at present, there is no mechanism in place to evaluate the effectiveness of these efforts.

Some data available on marine mammal harvests in the spill area have been summarized as part of the first year of the project. This summary will need to be updated with information from surveys conducted on the 1994 harvests. The Division of Subsistence, Alaska Department of Fish and Game has collected information on the numbers of harbor seals and sea otters harvested by subsistence users living in several communities in the spill region for both pre-and post-spill years. In 1993, the Division of Subsistence, in cooperation with the National Marine Fisheries Service and RurAL Cap, also undertook a project to collect more detailed information on the timing and composition of subsistence harvests of harbor seals and sea lions (but not sea otters), including figures on animals struck and lost. This project continues into 1995. The U.S. Fish and Wildlife Service conducts a sea otter tagging program, which gathers information on sea otter harvests, including the location where animals are taken.

There is also some information available on harbor seal and sea otter populations in the region. The Division of Wildlife Conservation, Alaska Department of Fish and Game, working with the National Marine Fisheries Service has conducted a count of harbor seals in both the oiled and un-oiled areas of Prince William Sound, along with other research aimed at assessing the health of the harbor seals (Restoration Project Number 93046). The U.S. Fish and Wildlife Service has continued to monitor the recovery of sea otters in oiled areas, by determining their abundance, distribution, and mortality (Restoration Project Number 93043). New information available from 1994 research will need to be used to update the summary compiled in year one of this project.

In the first year of the project, the Division of Subsistence entered into a cooperative agreement with the Alaska Sea Otter Commission. As part of this agreement, the Alaska Sea Otter Commission has collected and analyzed the available information on seal and sea otter populations, and harvests. They have produced a report, which is currently under review. A principal finding of the report is that subsistence harvests did not cause the decline of the harbor seal population. However, whether the continued subsistence harvest is retarding the recovery of harbor seals is still open to question.

Staff of the Division of Subsistence interviewed subsistence hunters to collect additional information about the location of seal harvests. Researchers also interviewed elders and other knowledgeable individuals to record their observations regarding changes in seals and sea otters. Keyworded transcripts of these interviews have been made, and were made available to the Alaska Sea Otter Commission for use in putting together their report.

Two workshops have been conducted so far as part of this project. The first brought together scientists, agency staff, and representatives of native organizations. The second workshop included subsistence hunters from the impacted communities of Prince William Sound and the lower Kenai Peninsula. Discussion at these workshops centered around the review of available biological information about sea otters and harbor seals. There was also a wide ranging discussion about the role hunters need to play in research and restoration. There was a consensus among the group that a major goal in the second year of the project should be to figure out ways to involve hunters as full partners in subsistence restoration. There is much that scientists need to learn from subsistence users. The mechanism by which they do that needs to be worked out. The Community Involvement and Use of Traditional

Knowledge project (95052) funded by the Trustee Council in 1995 will assist in this effort.

For the second year of the project, we propose to: 1) compile all available information; 2) gather additional data as needed; 3) analyze and interpret the data, in cooperation with the appropriate agencies and native groups; 4) provide an interpretation of the data regarding harbor seal and sea otter population dynamics, trends, and harvests, and their relationships, to subsistence hunters; and 5) if shown to be appropriate by a review of the data, produce a set of recommendations to subsistence users to guide those who want to voluntarily change their harvesting practices to help these two species recover.

This project constitutes a step towards involving subsistence hunters in the resource management process, and may lead to an on-gong exchange of information and consensus building with regard to the management of harbor seals.

B. PROJECT DESCRIPTION

1. Resources and/or Associated Services:

The goal of the project is to assess the available data about the relationship between population dynamics and trends and subsistence harvests of harbor seals and sea otters, and to work cooperatively with subsistence hunters to assess the relationship between these factors and the recovery of these species.

2. Relation to Other Damage Assessment/Restoration Work:

This project will incorporate information on the numbers, distribution and degree of recovery of the populations of harbor seals and sea otters from restoration projects: 95064 (Monitoring Habitat Use and Trophic Interaction of Harbor Seals in Prince William Sound); 94246 (Sea otter Recovery Monitoring Project); 95001 (Condition and health of Harbor Seals) and 95117-BAA (Harbor Seals and EVOS: Blubber and Lipids as Indices of Food Limitation). It will also provide information on seal and sea otter harvest in Prince William Sound and the Lower Kenai Peninsula to help the marine mammal researchers to evaluate the impacts, if any, of the harvest on the recovery of those populations.

3. Objectives:

Project objectives include: a compilation of available data on harbor seal and sea otter populations and trends; conducting a meeting of marine mammal biologists and subsistence users to evaluate and discuss the data; conducting community meetings as appropriate, production of an informational program, either in a slide format or a video, which can be used as an educational tool about harbor seal and sea otter populations and trends; production of a set of recommendations for subsistence users of harbor seals and sea otters based upon study findings and workshop results; and collection of harvest location data to supplement that collected in 1994.

4. Methods:
The project will involve compiling information from a variety of sources. Sea otter tagging data collected by the U.S. Fish and Wildlife Service will be used to estimate both the number of sea otters taken, and the locations in which they were hunted. The Division of Subsistence is administering a survey (funded by the National Marine Fisheries Service) in the oil spill-impacted communities to gather information on the numbers of harbor seals harvested, including a breakdown by life stage and sex of the animal, and an estimate of the number struck and lost. It is anticipated that this project will continue. A section would be added to the questionnaire on location of harvest for this species. Information collected by the Alaska Department of Fish and Game, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service on the biology and population characteristics of harbor seals and sea otters in the oil spill-impact area will also be used. In 1994, the Division entered into a cooperative agreement with the Alaska Sea Otter Commission to assist in the interpretation of the biological and population data, and the potential effects of the harvest on the health of the populations, as such interpretation is outside our expertise. This cooperative agreement will be extended into 1995. The Alaska Sea Otter Commission will be asked to incorporate new data into their report. The task of designing and producing the informational program which will summarize the findings of the ad hoc group, and will be used as an educational tool, will be contracted out on a competitive basis.

Following the compilation and analysis of the data, the ad hoc committee formed in 1994 will be brought back together to evaluate the accumulated information and make recommendations to subsistence users. The committee is composed of the Alaska Department of Fish and Game, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service, and native organizations, including the Alaska Sea Otter Commission, RurAL CAP, the Chugach Regional Resources Commission, and the village and traditional councils of the area. Recommendations of the ad hoc group will be presented to subsistence users both in an informational newsletter, and in community meetings. Any changes to the harvest will be voluntary, as the ad hoc group has no authority to compel any changes. Following this meeting, additional workshops in communities will occur to summarize and discuss the findings. Ideally, the recommendations of the ad hoc group will become part of the harbor seal recovery plan. Additional data on harvests taking place in late 1994 and 1995 will be collected by researchers from the Division of Subsistence.

5. Location:
The study area will include Prince William Sound and the Lower Kenai Peninsula. Primary marine mammal hunting communities in this area include Cordova, Tatitlek, Chenega Bay, Nanwalek, Seldovia, and Port Graham. Hunters in other communities, such as Valdez, Seward and Homer, will also be included. The ad hoc group convened in 1994 agreed it is important to include representatives from Kodiak Island in future meetings. This will be done in 1995.

6. Technical Support:
The project will not require any technical support as defined in the instructions for this document.

7. Contracts:
The Division of Subsistence will contract out for assistance in the analysis and interpretation of the biological and population data. This kind of work is outside the expertise of the Division's staff and the Division of Wildlife Conservation will not have any personnel available. We would prefer to continue the co-operative agreement established in 1994 with the Alaska Sea Otter Commission for this service. Their ties to the Alaska Native communities and experience with these issues will greatly benefit the project. There is also need for a second contract to produce the informational program.

C. SCHEDULE

Feb/March 1995:	Meeting of ad hoc group
May 1995:	Finish collection of harvest information for '94
July 1995:	Finish update of biological and population data
August 1995:	Convene ad hoc group to evaluate data
September '95:	Make recommendations to subsistence harvesters Produce informational newsletter, slide/video program and hold community meetings

D. EXISTING AGENCY PROGRAM

This project will take advantage of several existing programs, both within Alaska Department of Fish and Game, and other agencies. These other programs are described above.

E. ENVIRONMENTAL COMPLIANCE, PERMITTING AND COORDINATION STATUS

Since there is no biological field work component to this project, it is categorically excluded under NEPA guidelines.

F. PERFORMANCE MONITORING

A database will be compiled for this project. The ad hoc group will develop a set of data interpretations and, if appropriate, recommendations for subsistence users of the two species. An informational newsletter will be produced. A report will be completed at the end of each project year.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will incorporate information on the numbers, distribution and degree of recovery of populations of harbor seals and sea otters from restoration projects: 95064 (Monitoring Habitat Use and Trophic Interaction of Harbor Seals in Prince William Sound, Alaska); 95001 (Condition and Health of Harbor Seals); 95117-BAA (Harbor Seals and EVOS: Blubber and Lipids as Indices of Food Limitation), and 94246 (Sea Otter Recovery Monitoring Project). It will also provide information on seal and sea otter harvest in Prince William Sound and the Lower Kenai Peninsula in order to help the marine mammal researchers evaluate the impacts, if any, on the recovery of those populations.

H. PUBLIC PROCESS

This project will incorporate public input from community meetings. Representatives of the communities of Prince William Sound, the Lower Kenai Peninsula and Kodiak Island will be included as members of the ad hoc body evaluating the data. The findings of the ad hoc body will be disseminated to the communities by means of an informational newsletter, community meetings and by instructional video.

I. PERSONNEL QUALIFICATIONS

James Fall: Dr. Fall is the regional program manager for the Division of Subsistence, Alaska Department of Fish and Game, for southcentral and southwest Alaska. He has held this position since 1981. Since 1989, he has supervised the division's oil spill response and research program. Also, he has served as the department's representative on the Oil Spill Health Task Force. Dr. Fall has written several articles and reports on the effects of the *Exxon Valdez* oil spill on subsistence activities and harvests, based upon division research.

Rita Miraglia: Ms Miraglia has served as the oil spill coordinator for the Division of Subsistence since 1990. As such, she has organized and participated in the subsistence resource collection and testing programs of 1990 and 1991. She has also been the lead communicator of study findings to communities through organizing community meetings and writing newsletters. She has also assisted the Oil Spill Health Task Force's activities.

Craig Mishler: Dr. Mishler has been a Subsistence Resource Specialist with the Division of Subsistence since 1989, with primary responsibility for Kodiak Island. He is project leader for the Division's seal and sea lion harvest monitoring program.

Ron Stanek: Mr. Stanek has been a Subsistence Resource Specialist with the Division of Subsistence since 1980, with substantial research experience in the lower Cook Inlet Region.

Bill Simeone: Dr. Simeone was added to the Division staff in 1995 as a Subsistence Resource Specialist. He has extensive prior research experience in most communities in the oil spill area.

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

Project Description: The goal of this project is to assess the available data about the relationship between population dynamics and trends and subsistence harvests of harbor seals and sea otters, to work cooperatively with subsistence hunters to assess the relationship between these factors and the recovery of these species.

Budget Category:	1994 Project No. 95244 Authorized FFY 94	'94 Report/ '95 Interim* FFY 95	Remaining Cost** FFY 95	Total FFY 95	FFY 96	Comment	
						95 Interim	94 Report
Personnel	$32.0	$32.2	$20.5	$52.7	$18.1	$0.0	$32.0
Travel	$5.0	$14.0	$5.0	$19.0	$0.0	$4.0	$10.0
Contractual	$10.0	$1.0	$11.0	$12.0	$1.0	$0.0	$1.0
Commodities	$0.8	$0.5	$1.0	$1.5	$0.2	$0.0	$0.5
Equipment	$1.2	$0.0	$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
Subtotal	$49.0	$47.7	$37.5	$85.2	$19.3	$4.0	$43.5
General Administration	$5.5	$4.9	$3.8	$8.7	$2.8	$0.0	$4.9
Project Total	$54.5	$52.6	$41.3	$93.9	$22.1	$4.0	$48.4
Full-time Equivalents (FTE)	0.5	5.0	3.0	8.0	2.5		

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 Subsistence Resource Specialist II	1.0	$4.3	2.0	$8.6
Subsistence Resource Specialist III	2.0	$10.9	1.0	$5.9
Subsistence Regional Program Mgr.	1.0	$7.3	0.0	$0.0
Research Analyst III	1.0	$5.5	0.0	$0.0
Program Manager	0.8	$4.2	1.0	$6.0
Personnel Total	5.8	$32.2	4.0	$20.5

FFY 96 request is for report writing cost only.

The interim request is for rollover authority for funds that were approved by the Trustee Council in FFY94 and will be used in the fall of FFY95.

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: 95244
Project Title: Seal & Sea Otter Cooperative Harvest Assistance
Agency: AK Dept. of Fish & Game

FORM 2A
PROJECT
DETAIL

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

Travel:		Repr/Intrm	Remaining
Rept	Ad hoc Review Committee meeting in Anchorage attended by marine mammal biologists and community representatives. 4 RT Homer-Port Graham &Nanwalek @ $100/RT 4 RT Anchorage-Homer @ $100/RT 2 RT Chenega-Anchorage @ $900/RT 3 RT Tatitlek-Anchorage @ $550/RT 3 RT Anchorage-Cordova @ $204/RT 4 RT Anchorage-Fairbanks @ $386/RT + $600 per diem 1 RT Anchorage-Juneau @ $444/RT + $150 per diem 2 RT Anchorage-Seattle @ $970/RT + $300 per diem 1 RT Anchorage-Valdez @ $160/RT	$10.0	$0.0
Intr	2 RT Fairbanks/Anchorage @ $0.4 + per diem $150 2 RT Kodiak/Anchorage @ $0.2 + per diem $150 1 RT Chenega Bay/Anchorage @ $0.9 + per diem $150 1 RT Tatitlek/Anchorage @ $0.5 + per diem $150 1 RT Cordova/Anchorage @ $0.2 + per diem $150 1 RT Port Graham/Anchorage @ $ 0.2 + per diem $150 1 RT Nanwalek/Anchorage @ $0.2 + per diem $150	$4.0	$0.0
Rem	Community meetings to review second year's data and Ad hoc sub-committee meetings 2 RT Homer-Port Graham &Nanwalek @ $100/RT 2 RT Anchorage-Homer @ $100/RT 2 RT Chenega-Anchorage @ $900/RT 2 RT Tatitlek-Anchorage @ $550/RT + $300 per diem 1 RT Anchorage-Cordova @ $204/RT 1 RT Anchorage-Fairbanks @ $386/RT + $600 per diem 1 RT Anchorage-Valdez @ $160/RT	$0.0	$5.0
	Travel Total	$14.0	$5.0

Contractual:			
Rept	Sea Otter Commission Cooperative Agreement (for data compilation and analysis)	$0.0	$5.0
	Newsletter production (3 editions)	$0.0	$5.0
	Report printing	$1.0	$1.0
	Contractual Total	$1.0	$11.0

07/14/93

1995

Project Number: 95244
Project Title: Seal & Sea Otter Cooperative Harvest Assistance
Agency: AK Dept. of Fish & Game

FORM 2A
PROJECT
DETAIL

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

Commodities:		Reprt/Intrm	Remaining
Rept	Misc. office supplies	$0.5	$1.0
	Commodities Total	$0.5	$1.0

Equipment:			
Rept		$0.0	$0.0
Intrm			
	Equipment Total	$0.0	$0.0

07/14/93

1995

Page 3 of 3

Project Number: 95244
Project Title: Seal & Sea Otter Cooperative Harvest Assistance
Agency: AK Dept. of Fish & Game

FORM 2B
PROJECT
DETAIL

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
FY 95 DETAILED PROJECT DESCRIPTION

Project Title:	Kenai River Sockeye Salmon Restoration
Project Number:	95255
Lead Trustee Agency:	Alaska Department of Fish and Game (ADF&G)
Cooperating agencies:	None
Project Start-up/Completion Dates:	1 October 1994 to 30 September 1995
Expected Project Duration:	One year
Cost of Project/FY 95:	$ 502.7
Cost of Project/FY 9[illegible]:	$ To be determined
Cost of Project/FY 97 and beyond:	$ To be determined
Geographic Area:	Upper Cook Inlet

Project Leaders:

Lisa W. Seeb 3-24-95
Lisa W. Seeb — Date

Ken Tarbox for Lisa W. Seeb 3-24-95
Ken Tarbox — Date

James E. Seeb
James E. Seeb — Date

Lead Agency Project Manager:

3/24/95
Joe Sullivan — Date

A. INTRODUCTION

Sockeye salmon (*Oncorhynchus nerka*) that spawn in the Kenai River system were injured by the Exxon Valdez oil spill (EVOS). Greatly reduced fishing time in Upper Cook Inlet (UCI) due to EVOS caused sockeye salmon spawning escapement into the Kenai River to exceed desirable levels by three times. The biological impact of EVOS on Kenai River sockeye salmon stocks may be one of the most serious documented. Data collected by NRDA Fish/Shellfish Study 27, *Sockeye Salmon Overescapement*, indicated greatly reduced survival of juvenile sockeye salmon during the winter-spring rearing period beginning with the 1989 parent year. The extremely high escapement may have initially produced more rearing juvenile sockeye salmon than could be supported by nursery lake productivity.

In general, when rearing salmon abundance greatly exceeds lake carrying capacity, the species and size composition of prey resources are altered, affecting all trophic levels. Because of such changes, juvenile growth is reduced, freshwater mortality is increased, greater proportions of fry remain in the lake for an additional year of rearing, smolt condition is reduced, and marine mortality is increased.

Limiting sockeye salmon fry production by closely regulating the number of spawning adults may be the only way to restore the productivity of these rearing areas. Sockeye salmon smolt out-migrations in the Kenai River were likely reduced in 1991 (1989 parent year) and declined through 1993. The number of adult sockeye salmon returning in 1995 may be low, and a reduction of Kenai River sockeye salmon harvests may be necessary to ensure adequate escapements.

Sockeye salmon harvested from the mixed-stock fishery of Cook Inlet include fish from the Kenai, Kasilof, and Susitna Rivers. In order to effectively manage the harvest of EVOS-damaged stocks, Restoration Science Studies R59/93012/94255 were implemented in 1992, 1993, and 1994. These studies developed a Genetic Stock Identification (GSI- allozyme electrophoresis) baseline to identify Kenai River stocks in mixed stock Cook Inlet fisheries. The statistical methods associated with the fishery estimates were refined, and the accuracy and precision of the estimates were evaluated. Area managers can now use this information to modify fishing areas and openings in order to facilitate the harvest of surplus Kasilof and Susitna River stocks while protecting the EVOS-damaged Kenai River stocks. Project 95255 is the continuation of these projects through fiscal year 1995.

Results from previous years' studies indicate that Cook Inlet sockeye salmon are extremely heterogeneous not only within the Kenai River, but throughout Cook Inlet. Results indicate that this genetic heterogeneity can be used as an accurate stock identification tool. Extensive analyses of known mixtures indicate that Kenai River populations can be estimated with a high degree of accuracy and precision in mixtures typically found in Cook Inlet drift and set net fisheries.

A pilot study of fishery sampling was conducted during 1993, prior to the return of the first EVOS-impacted stocks anticipated in 1994 (age-5 sockeye salmon from the 1989 parent year). Two fishery samplings were completed using the genetic baseline collected during the 1992 field season. The emphasis shifted during 1994, and four in-river collections were analyzed from the Kenai River as a test of the method. Two of these collections were analyzed in-season. In addition, one drift net fishery sample was analyzed post-season in 1994. Completion of the laboratory and statistical analyses within 48 hours was demonstrated both in 1993 and 1994. Beginning in 1995, the technique will be incorporated into fishery management decisions in-season and into post-season evaluations.

B. PROJECT DESCRIPTION

1. Resources and/or Associated Services:

Restoration of Kenai River sockeye stocks will benefit subsistence, sport, and commercial fishermen in coastal communities throughout Cook Inlet, from Homer north through Anchorage to Tyonek. In 1992 nearly 10,000 families obtained subsistence permits to harvest salmon in UCI, most targeting Kenai River sockeye salmon. The most recent statistics indicate that nearly 100,000 sport anglers fished the Kenai River for salmon in 1990, spending $38 million in 1986 dollars. Forty percent of those anglers were from out-of-state. Of the 1,323 permits licensed for commercial fishing in UCI, 80% are fished by state residents with the remaining predominately from Pacific Coast states. Average ex-vessel value (1987-1991) of the UCI commercial salmon harvest was $67.8 million.

2. Relation to Other Damage Assessment/Restoration Work:

Results from Restoration project 95258 (Sockeye Overescapement) will be incorporated with results from this investigation to formulate an over-all restoration plan for Kenai River sockeye salmon.

3. Objectives:

The goal of this project is to restore Kenai River sockeye salmon injured by the oil spill. This will be accomplished through improved stock assessment capabilities, more accurate regulation of spawning levels, and modifications to human use. The specific objectives are to:

1. Obtain baseline genetic data (during 1992-1995) from all significant spawning stocks contributing to mixed-stock harvests of sockeye salmon in Cook Inlet.

2. Use Genetic Stock Identification (GSI) algorithms to estimate the proportion of Kenai River stocks in mixed stock fisheries so that managers may modify area and time of harvest in order to protect these damaged stocks while targeting surplus Kasilof River and Susitna River stocks. Genetic data will be obtained from samplings of the various mixed-stock fisheries occurring in 1995. Stocks composition estimates will be provided within 48 hours post-fishery.

3. Investigate the added utility of DNA-level markers to discriminate among Cook Inlet populations.

4. Provide more accurate estimates of abundance of Kenai River sockeye salmon within Cook Inlet through hydroacoustic assessment techniques.

Objective 1 is nearing completion with only limited baseline sampling proposed for FY95. The majority of the effort in 1995 will focus on Objective 2, refinement of the fishery models and estimation of the contribution of Kenai River stocks in the 1995 fishery samples. We will continue refinement of Objective 3 and 4, but with only limited effort and funding. Requests for funding of fishery sampling in 1996 and beyond will depend on the escapement returns in 1995.

4. Methods:

a. Stock Identification:

(1) Allozyme Analyses

We will continue to refine the comprehensive genetic database of sockeye salmon stocks in Cook Inlet. In 1992 we collected baseline genetic data using allozyme analyses from 28 subpopulations from Cook Inlet including the Kenai, Kasilof, and Susitna Rivers. Additional sockeye salmon were collected from approximately 34 baseline subpopulations in 1993 and 12 in 1994. Analyses of 1992 and 1993 collections are complete; analyses of 1994 collection are currently underway. An additional five sites will be chosen in 1995 to refine the database for the Kenai River and monitor temporal stability. Final selection of sample sites will depend on results from the previous year. Target sample sizes for allozyme baseline collections will be 100 individuals to adequately characterize spawning populations (Allendorf and Phelps 1981; Waples 1990).

Mixed-stock fishery samples will be collected from at least four drift fishery openings occurring during July (up to six openings may be sampled). In addition, two Upper subdistrict set net samples will be collected during July. Set net samples will not be collected concurrent with drift samples because of budget and personnel limitations. Mixed-stock sample sizes will be set at 400 individuals to minimize the confidence intervals surrounding the estimates (Pella and Milner 1987). Laboratory and statistical analyses will be completed within 48 hours on at least two of the drift gill net samples.

Muscle, liver, eye, and heart will be dissected from freshly killed individuals. Tissues will be placed in labeled cryovials and transferred into liquid nitrogen (Appendix A, B). Tissues from baseline collections will be stored on liquid nitrogen until transferred to -80°C storage in Soldotna or Anchorage. Soldotna samples will be transferred to the Anchorage laboratory on dry ice or liquid nitrogen and again placed in -80°C storage where they will remain until laboratory analysis.

Allozyme electrophoretic data (Utter et al. 1987; Seeb et al. 1987) will be collected for the loci identified in years earlier years of the study. Allozyme techniques follow those of

Harris and Hopkinson (1976), May et al. (1979), and Aebersold et al. (1987); nomenclature will follow the American Fisheries Society standard (Shaklee et al. 1990). A photographic record of each gel will be made. An extensive allozyme screening was undertaken to maximize the potential number of available gene markers. A total of 77 allozyme loci were resolved and will be collected from the baseline spawning populations. Of the 77 loci, 24 polymorphic loci will be used in the fishery estimation procedure (*mAAT-1; mAAT-2; mAH-1,2; mAH-4; sAH; ALAT; GAPDH-2; GPI-A; GPI-B1,2; sIDHP-1; LDH-B2; sMDH-A1,2; sMDH-B1,2; mMEP-1; PEPA; PEPB-1; PEPC; PEPLT; PGM-1; PGM-2)*.

(1) Analytical Process

We have made considerable progress in developing the analytical and computational techniques to rapidly provide fishery estimates for in-season management. Development of a comprehensive package of genetic analysis programs in Windows 3.1 (Microsoft 1991) includes the following components: (1) an on-line gel scoring program providing extensive documentation of results and error checking capability; (2) a set of genetic analysis functions to estimate allele frequencies, heterogeneity, and fit to expected genetic models; and (3) revised input into the maximum likelihood estimation procedure to allow rapid fishery estimates and a flexible method to conduct multiple simulation studies. The object oriented genetics applications work synchronously within the Windows environment to provide a user-friendly interface for data input and complicated analyses to allow a fast turn-around from field samples to fishery estimates. Fishery composition estimates will be available within 48 hours following the fishery so that management decisions can be based on the actual composition of the fisheries.

The population-level analyses previously completed will be enlarged to include all 1995 baseline. Genotypic and allelic frequency estimates will be calculated for all loci Nei's genetic distance measures (Nei 1978), which summarize multi-locus data into a single number, will be calculated between all pairs of spawning locations. These values will be used to construct branching diagrams using numerical taxonomic techniques (UPGMA) which provide a representation of overall phenetic similarity. A neighbor-joining tree (Saitou and Nei 1987) will be constructed to provide a phylogenetic tree relating the populations. Cavalli-Sforza and Edwards (1967) chord distance will be calculated and used to perform a multidimensional scaling analysis (MDS, Krzanowski and Marriott 1994). This procedure uses distances to group populations in multidimensional space, so that the expected distance between populations closely match the observed distance in multidimensional space. Additionally, chi-square goodness-of-fit to Hardy-Weinberg equilibrium will be performed to test for random mating within each population. Homogeneity of allelic frequencies among the various collections will be tested using a log-likelihood ratio analysis (G-statistic; Smouse and Ward 1978; $\alpha = 0.01$; Cooper 1968). Rejection of the null hypothesis of homogeneity is indicative of discrete spawning populations. The total gene frequency dispersion at each locus will be subdivided into within-and among-river system components in a hierarchical fashion. Hierarchical levels will be organized to test for homogeneity of (1) within drainages of the systems; (2) among drainages within river systems; and (3) among river systems. The likelihood analysis will use the computational formula of Sokal and Rohlf (1981). This statistic is distributed approximately as the chi-square statistic with (no. of alleles - 1) X (no. of region - 1) = (degrees of freedom). The likelihood values (G) can be summed over all loci to obtain a total value at each level of analysis. All computations will be performed using functions written for *S-Plus* analytical software (Mathsoft, Inc., Seattle, WA.).

Stock contribution to mixed fishery samples will be estimated using a conditional maximum likelihood program (Statistical Package for the Analysis of Mixtures, SPAM), a program developed by ADF&G. This program incorporates routines of (GIRLSEM) and conjugates gradient (CONJA-S) algorithms developed by National Marine Fisheries Service (NMFS; Pella and Milner 1987; Masuda et al. 1991; Pella et al. 1994). The precision of the stock composition estimates will be determined by a parametric bootstrap, where the mixture frequencies and baseline frequencies are assumed to be distributed multinomial (Efron and Tibshirani 1986). This same type of analysis can be used to evaluate the effect of mixture sample size on the accuracy and precision of the stock composition estimates and to adjjust mixture sample size.

(3) DNA Analyses

In 1994, pilot studies using DNA techniques were conducted on a subset of the baseline samples. Techniques investigated included restriction fragment polymorphism (RFLP) analysis of mtDNA, microsatellite analysis, sequencing of *GH1* and *GH1* introns, and random amplified length polymorphism (RFLP) analysis. All of these approaches except *GH* sequencing show promise for discrimination of Cook Inlet stocks of sockeye salmon. Although none of the techniques currently appear promising for the in-season analyses required as a primary component of Trustee Council Project 95255, we will continue to develop these markers for potential utility in post-season analyses. Particular care will be taken to test for an abbreviated DNA screen which may further refine allozyme-based SPAM estimates.

In our own laboratory, at the recommendation of peer reviewers, we will continue to focus upon RFLP analysis of the **NADH5/6** region of mtDNA. We have detected polymorphisms with the restriction endonucleases *Apa I, KpnI, Stu I, Hinf I,* and *Taq I.* We are currently completing the survey of mtDNA variability for approximately 19 collections (including all major Cook Inlet populations) with a sample size of 40 individuals/populations. We will continue to evaluate the additional resolving power of mtDNA for mixed fishery analyses through simulation studies. The mtDNA baseline will be included in future year's fishery estimations depending upon the results of the simulation studies.

Development of other DNA markers through contractors Dr. F. W. Allendorf (University of Montana) and Dr. P. Bentzen (University of Washington), as funded in Trustee Council Project 94255, will also continue at the recommendation of peer reviewers. Based upon results to date, the focus of contractors will narrow to microsatellite analysis and possibly RFLP analysis of additional introns (Bentzen and Wright 1993; Devlin 1993)..

Offshore Test Fish Program:

Total sockeye salmon returns to UCI has been estimated early in the season by test fishing between Anchor River and Red River delta. Northward migrating sockeye salmon are captured with a drift gill net at a series of stations. Salmon are identified to species and sex, and length measurements are recorded. Estimates of total sockeye salmon return are made several times during the season by estimating expected total test fishery catch per unit of effort for the season and catchability of sockeye salmon in the test fishery. Analysis of historical data has indicated that existing sampling effort and catch has not been proportional to abundance. To assess run size more accurately, additional sampling effort will be added to the existing program.

In 1992, 1993, and 1994 hydroacoustic equipment and techniques were tested in UCI offshore waters (Thorne and Salomone 1993; Thorne 1994). Results of this work indicated that hydroacoustic techniques could detect salmon and provide a population estimate for "in season" management use. However, the primary constraint identified in the study was limitations (signal/noise ratio) of the hydroacoustic gear due to rough sea conditions or shallow water in the northern portion of UCI.

In 1995 a single abundance estimate will be made using the techniques developed in 1992, 1993, and 1994. Examination of the data set indicated that a minimum of 12 orthogonal transects sampled over 48 hours within Cook Inlet would be needed to provide a useable estimate of adult salmon abundance. Therefore, a minimum of 12 transects will be completed during the survey. Exact timing of the survey will be determined during the commercial fishing season to meet commercial fishery management objectives.

5. Location:

Upper Cook Inlet, north of a line from Anchor Point to the Red River Delta - Field work will be inlet wide and based out of Soldotna; laboratory analyses and a portion of the data analyses will be conducted in Anchorage.

6. Technical Support:

Administrative support is provided by the Administration, Habitat and Restoration, and Commercial Fisheries Development and Management Divisions' staff of the Alaska Department of Fish and Game. The project leaders and their assistants are not fully funded by this project and are supported with general funds from the State of Alaska. These studies are integrated with ongoing studies by the Commercial Fisheries Management and Development Division. Consequently, the EVOS investigations have been integrated into the normal operations of these Divisions for efficiency in completing the objectives of these studies.

7. Contracts:

We propose to continue to develop DNA-level stock identification techniques with the support of contractors. The approaches currently ripening under the stewardship of University of Montana and Univesity of Washington researchers include analysis of both microsatellite (Bentzen and Wright 1993) and intron (Devlin 1993) polymorphisms. Contract amendments will be assigned for FY1995 research based upon results reported from FY1994.

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C. SCHEDULES

Laboratory analyses of 1994 baseline & fishery samples	July 1994 - Apr 1995
Award contracts for 1995 DNA analysis	Jan - May 1995
Lab analyses of mixtures; refinement of fishery model	May - Sept 1995
Fishery sample collection and in-season estimation	July 1995
Hydroacoustic assessment	July 1995
Baseline sample collection	June - Sept 1995
Draft status report for FY 94	June 1995
Final status report for FY 94	August 1995
Baseline analyses, in-season analyses, annual report FY95	Oct 1995-Sept 1996

D. EXISTING AGENCY PROGRAM

For FY 95 the Division of Commercial Fisheries Management and Development (excluding programs in Sport Fish and Subsistence Divisions of ADF&G) will have the following programs: Area management ($238 K), Research to include catch sampling, escapement monitoring, and offshore test fishing ($480 K), Biometric, technical, and regional support ($250 K), and the statewide genetics laboratory in Anchorage ($500 K).

E. ENVIRONMENTAL COMPLIANCE/PERMITTING/COORDINATION STATUS

The studies proposed provide for data collection and field sampling programs. No environmental effect of these programs occurs beyond that of traditional fisheries management data collection activities. These activities are within existing collecting permits or Federal special use permits issued to the Department of Fish and Game for scientific data collection. This project received a categorical exclusion under the National Environmental Policies Act (NEPA).

F. PERFORMANCE MONITORING

The performance monitoring of this project is conducted through the checks and balances of the State of Alaska Accounting System within the Commercial Fisheries Management and Development, Habitat and Restoration, and Administration Divisions of the Department of Fish and Game and the Department of Administration. Contractual compliance, personnel hiring, EEO compliance, and other administrative provisions are within the State of Alaska hiring and administrative chains of command and covered in standard operating procedures and administrative regulations. Replacement personnel are readily available by reassignment from permanent and seasonal staff within the Commercial Fisheries Management and Development Division of the ADF&G in Soldotna and Anchorage, when temporary problems are encountered. Filling new positions follows state hiring guidelines when permanent vacancies occur. Project time frames for reports and analysis are maintained through proper planning and integration of these activities within the existing administrative structure of the Commercial Fisheries Management and Development Division.

The scientific and technical aspects of the study are subject to internal review within the Commercial Fisheries Management and Development Division. Publications are submitted through an internal peer review process with the major findings submitted to peer review journals. Reports, work plans, and study design are subject to the peer review process established by the EVOS Board of Trustees and Chief Scientist office. In October of 1994, all portions of the study were reviewed by an independent panel of experts chosen by the Chief Scientist. In 1993, technical aspects of the overescapement studies' findings to date and future plans were reviewed by a panel of international sockeye salmon researchers in a special half day session of the Kokanee and Sockeye Salmon workshop sponsored by the Northern Pacific International Chapter of the American Fisheries Society at Vancouver, B.C. These studies provided the basis for the management programs being developed under this restoration project. Interim annual status reports will be generated with publications being provided in peer review journals and scientific symposia, as significant findings are obtained. The final report will be issued upon completion of the final year of field data collection.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

The investigations of Kenai River sockeye salmon have been integrated with long term research efforts by the Alaska Department of Fish and Game. These efforts are adult salmon enumeration by hydroacoustic techniques in various river systems, catch and escapement sampling of salmon for age, length, and weight, test fishing at the Central District southern boundary, and juvenile salmon rearing studies. Development of restoration strategies on the Kenai Peninsula are through a review process with the Regional Planning Team and with ADF&G review teams composed of personnel from all ADF&G divisions.

H. PUBLIC PROCESS

The investigations have been and will continue to be part of the public process. Reports have been prepared to the Alaska Board of Fisheries, the Upper Cook Inlet Regional Planning Team, various fisherman's organizations and civic organizations, in addition to the Trustee Council Public Advisory Group process. Scientific and technical review have included the peer review system established by the Trustee Council. In addition, technical aspects of the studies findings to date and future plans have been reviewed by ADF&G personnel.

I. PERSONNEL QUALIFICATIONS

Lisa W. Seeb (L. Wishard), Statewide Geneticist
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EDUCATION:

A.B. Zoology, 1973, University of California, Berkeley
M.A. Zoology, 1977, University of Montana
Ph.D. Fisheries, 1986, University of Washington

PROFESSIONAL EXPERIENCE:

1991- Statewide Geneticist, ADF&G, Anchorage
1991- Affiliate Associate Professor, University of Alaska Fairbanks
1988-1990 Assistant Professor, Southern Illinois University
1984-1988 Research Assist. Prof., University of Idaho
1978-1981 Fish Geneticist, Pacific Fish. Research, Olympia WA
1977-1979 Geneticist, National Marine Fisheries Service, Seattle

SELECTED PUBLICATIONS:

Wishard, L. N., J. E. Seeb, F. M. Utter, and D. Stefan. 1984. A genetic investigation of suspected redband trout populations. Copeia 1984(1):120-132.

Seeb, J. E., L. W. Seeb, and F. M. Utter, 1986. Use of genetic marks to assess stock dynamics and management programs for chum salmon. Trans. Amer. Fish. Soc. 115:448-454

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EMPLOYMENT:

May, 1980 to Present. Upper Cook Inlet Research Project Leader, Alaska Department of Fish and Game, Soldotna, Alaska. Responsibilities include planning, implementing, supervision, and reporting on various salmon related research and management projects. These involve hydroacoustic enumeration of salmon in glacial systems, defining salmon migratory behavior in both salt and fresh water, evaluation of potential impacts of resource development on habitat and populations, management of the UCI commercial salmon fisheries, stock identification studies using scale or genetic markers, and life history studies of sockeye salmon.

March, 1972 to May, 1980. Project manager and Senior Biologist, Woodward Clyde Consultants, Anchorage, Alaska. Responsibilities included supervision and research for a number of projects. These included an evaluation of existing methodologies for determining instream flow requirements for Alaskan fishes, determining the biological impact of a dredging projects located in lower New York Harbor and Lake Michigan, fishery investigations in the Zayandeh River, Iran, impact assessment of various oil related projects in Virginia, North Carolina, Texas, and Prudhoe Bay, Alaska, and studies and evaluation of impacts associated with nuclear power plants in New Jersey, Louisiana, Indiana, and Pennsylvania.

July, 1970 to March, 1972. Research Assistant, Louisiana Co-operative Fishery Unit, Louisiana State University, Baton Rouge, La. Responsibilities included the design and conduct of a one year investigation of juvenile fish behavior in an estuarine environment.

EDUCATION:

M.S. in Fisheries, 1974. Louisiana State University, Baton Rouge, La.
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CERTIFICATIONS:

Fisheries Scientist, Certificate 1165, American Fisheries Society, 1976.

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EDUCATION: B.S., Biology, 1974, University of Puget Sound
M.S., Fisheries, 1982, University of Washington
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PROFESSIONAL EXPERIENCE:

1990- Principal Geneticist, CFMD Division, ADF&G
1991- Affiliate Associate Professor, University of Alaska Fairbanks
1988-1990 Assistant Professor, Southern Illinois University
1987-1988 Research Assistant Professor, University of Idaho
1982-1986 Graduate Research Assistant, University of Washington
1980-1982 Fish Biologist, Pacific Fisheries Research, Olympia,WA
1978-1980 Fish Biologist, Washington Department of Fisheries

SELECTED PUBLICATIONS:

Seeb, J.E., L.W. Seeb, and F.M. Utter. 1986. Use of genetic marks to assess stock dynamics and management programs for chum salmon. Trans. Amer. Fish. Soc. 115:448-454.

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J. BUDGET

Budget Category '94	Report/'95Interim	Remaining Cost	Total FFY95
Personnel	$260.0	$51.9	$311.9
Travel	$8.8	$7.5	$16.3
Contractual	$16.0	$42.1	$58.1
Commodities	$33.5	$16.1	$49.6
Equipment	$14.0	$2.0	$16.0
Capital Outlay	$0.0	$0.0	$0.0
Subtotal	$332.3	$119.6	$451.9
General Administration	$40.1	$10.7	$50.8
Project Total	$372.4	$130.3	$502.7

EXXON VALDEZ TRUSTEE COUNCIL

FY 95 DETAILED PROJECT DESCRIPTION

Project Title: .... Sockeye Salmon Overescapement

Project Number: 95258

Lead Trustee Agency: .... ADF&G

Cooperating Agencies: .... USFWS and NBS

Project Start-up/Completion Dates: .... October 1, 1994-Sept. 30, 1995

Expected Project Duration: .... 2 years after recovery

Cost of Project: .... $793 K

Geographic Area: .... Kenai Peninsula and Kodiak Island

Name/Signature of Project Leader(s):

Dana Schmidt

D.S.

Ken Tarbox

Ken Tarbox

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EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL

Name/Signature of lead agency Project Manager:

Joe Sullivan

Joseph R. Sullivan

A. INTRODUCTION

This study is a continuation of the oil spill damage assessment program initiated in 1990 (Schmidt and Tarbox, 1993; 1994 (in review). The continuing program reflects modifications based on the FY93 and FY94 study results. Recommendations provided by an international review team of sockeye salmon experts at a March 15, 1993 meeting at Vancouver, B.C. have been incorporated. In addition, the October, 1994 review resulted in curtailment of the smolt program and we delayed implementation of more detailed studies of potential restoration activities. These modifications were warranted because of the uncertainty of the smolt estimates from the Kenai River.

Commercial fishing for sockeye salmon in 1989 was curtailed in UCI, the outer Chignik districts, and the Kodiak areas due to presence of oil in the fishing areas from the EVOS. As a result, the number of sockeye salmon entering four important sockeye producing systems (Kenai/Skilak, Chignik/Black, Red, and Frazer Lakes) and two less important lake systems (Akalura and Afognak or Litnik lakes) greatly exceeded levels that are thought to be most productive. Sockeye salmon spawn in lake associated river systems. Adult salmon serve an extremely important role in the ecosystem, providing food for marine mammals, terrestrial mammals, and birds. Additionally, carcass decomposition serves to charge fresh water lake systems with important nutrients. Juvenile salmon which rear in lakes for one or two years serve as a food source for a variety of fish and mammals. Sockeye salmon are also an important subsistence, sport, and commercial species. The ex-vessel value of the commercial catch of sockeye from these lake systems has averaged about $42 million per year since 1979, with the 1988 catch worth $115 million. Sockeye salmon returns to the Kenai River system support some of the largest recreational fisheries in the State.

Overly large spawning escapements may result in poor returns by producing more rearing juvenile sockeye than can be supported by the nursery lake's productivity (Kyle et al. 1988). In general, when rearing fish abundance greatly exceeds the lake's carrying capacity, prey resources are altered by changes in species and size composition (Mills and Schiavone 1982, Koenings and Burkett 1987, Kyle et al. 1988) with concomitant effects on all trophic levels (Carpenter et al. 1985). Because of such changes, juvenile sockeye growth is reduced, mortality increases, larger percentages holdover for another year of rearing; and the poor quality of smolts increases marine mortality. Where escapements are two to three times normal levels, the resulting high juvenile densities crop the prey resources to the extent that more than one year is required to return to normal productivity. Rearing juveniles from subsequent brood-years suffer from both the poor quality of forage and from the increased competition for food by holdover juveniles (Townsend 1989; Koenings and Kyle 1991). This is the brood-year interaction underlying cyclic variation in the year class strength of anadromous fish.

This project continues examining the effects of large 1989 spawning escapements on the resulting progeny and associated foraging habitat for a select subset of the above mentioned sockeye nursery lakes. Three impacted lake systems where the 1989 escapements were more than twice the desired levels (Kenai/Skilak in UCI; Red and Akalura lakes on Kodiak Island) were selected. Beginning in 1994, Frazer Lake has been used for future comparisons of a system receiving normal escapement. Because this lake has undergone detailed study in the past (Kyle et al. 1988) and has continued funding from other sources, minimal funding is necessary to provide for data collection to insure comparisons with Akalura and Red lakes. Similarly, Tustumena Lake on the Kenai Peninsula received normal escapements and is used as a reference for the Kenai River systems. This lake differs primarily in the increased natural turbidity levels and a history of modest stocking of sockeye salmon fry.

Schmidt and Tarbox (1993;1994 In review) report the results through 1993 on these ongoing investigations. In addition, the study proposal reflects results of data collected in the spring of 1994. These studies suggest a rebound in smolt production from the Kenai River although size and condition of fall fry were poor and significant overwinter mortality occurred. The 1992 and 1993 data indicate Red Lake zooplankton communities and nutrient levels have recovered to the level measured in 1986, prior to the oil spill (Schmidt and Tarbox, 1993). The 1994 zooplankton data indicated a depression in cladoceran abundance. This was associated with increased numbers of fry observed in a beach seine fry indexing program. We will need the 1995 smolt data in order to determine if increased smolt production follows these trends. Smolt numbers from 1994 continue to be lagging but adult forecasts for returns in 1995 suggest escapement goals will be met; therefore management actions will be used as the primary method for restoration. Smolt numbers or spring fry abundance will be used to forecast future returns and provide assistance to managers in future harvest management decisions. Akalura Lake demonstrated poor zooplankton densities with low smolt numbers. The 1994 adult run did not meet escapement requirements. An evaluation report was prepared in 1994 and provided to the Kodiak management staff in consideration of future management practices.

The 1993 smolt information from the Kenai system suggested near normal numbers of smolt outmigrating. In addition, the 1994 adult return to the Kenai was significantly above forecast indicating probable biases of underestimating smolt from the 1989 brood year. This has caused much uncertainty about the numbers of adults expected to return to the Kenai in 1995. Forecasts of the adult return range from failure to meet escapement goals up to near normal commercial and sport fish harvests. Because the smolt program provided inconsistent results when compared with the previous years performance, we decided to curtail the program in 1995 and rely upon a survey of the lake using sonar and tow nets, immediately after ice out in the spring of 1995. A 1994 survey conducted indicated fry densities of similar numbers to the smolt observed in 1994. Changes in abundance, weight, and length were reflective of expected overwintering mortality.

B. PROJECT DESCRIPTION

1. Resources and/or Associated Services:

The studies are located on Kodiak Island and the Kenai Peninsula. Recent findings (Schmidt and Tarbox, 1993; 1994 -In review) have suggested major economic damage to commercial, subsistence, and sport fisheries may result because of the over-escapement event associated with the fisheries closures on the Kenai River sockeye salmon stocks caused by the 1989 oil spill. Smolt numbers emigrating from the Kenai River in the spring of 1992 and 1993 were less than one-fiftieth the numbers estimated in 1989. This suggests a likely possibility of future returns below existing escapement goals, although the 1994 adult return suggests that the smolt numbers may be underestimated by the current abundance estimation program. Red River smolt numbers from the 1989 escapement on Kodiak Island provided evidence that the smolt programs accurately reflect adult returns and consequently, we can expect continued poor returns to Kodiak Island over the next several years.

In addition to monitoring the damage extent, the mechanism that lead to the collapse requires definition. These studies essentially follow the pattern established in the original 1990 study plan but with significant modifications to accommodate recent findings.

2. Relation to Other Damage Assessment/Restoration Work:

Project 95258 provides much of the analysis and forecasting ability of adult runs returning to the Kenai River. Restoration project 95255 which addresses stock separation and run strength assessment in UCI are supported by the assessment of reduction in juvenile production from the Kenai River Lakes.

3. Objectives:

The following objectives are altered based on input from peer reviewers of the 1992 progress report and proposed revisions to the 1994 study program.

a. Estimate critical biological attributes (number, age, size) of both resident and migrant juvenile sockeye in overescaped and normal escaped sockeye salmon nursery lakes of the Kenai Peninsula and Kodiak Island.

b. Determine effects on smolt production and subsequent adult returns caused by large escapements resulting from fishery closures after the EVOS. These effects will be inferred by studying the changes in the rearing capacity of selected nursery lakes which were either affected or unaffected by the oil spill. Data used for these inferences include:

(1). age and growth of juveniles and smolts
(2). nursery area nutrient budgets and plankton populations.
(3). seasonal, diel, and vertical distribution of zooplankton species which are the known prey of sockeye salmon in Skilak, Kenai, and Tustumena Lake; and

(4). seasonally available zooplankton biomass in these lakes and the relationship of this biomass to ambient temperature, light, and other climatic variables.

c. Develop a pilot research project to determine experimentally the cause of the decline and potential restorative actions.

ADF&G in cooperation with the National Biological Service and the Refuge staff of the Kenai National Wildlife Refuge has developed a pilot research project to further define the mechanism of sockeye salmon decline and determine the feasibility of alternative restoration opportunities. This program has been deferred for one year, and depends on the magnitude of the returning runs to the Kenai River in 1995.

4. Methods:

From the inception, these investigations have used an ecosystem approach to determine factors limiting the recovery of the affected sockeye salmon population. The recent book "The Trophic Cascade in Lakes" (Carpenter and Kitchell, 1993) defines the basic approaches used by our team of investigators.

Numbers of adult sockeye salmon that entered selected spawning systems outside PWS prior to and during 1989 have been estimated at weir stations or by sonar. This information was collected during projects routinely conducted by the ADF&G as part of their resource management program. Optimal escapement levels, which on the average should produce maximum sustained yield, have been based on either past relationships between spawners and returning progeny or the extent of available spawning and rearing habitat. The baseline program will continue at each site including but not limited to estimates of adult sockeye escapement and collection of scales for age analysis.

For each of the lake systems identified, the response (abundance, growth, and freshwater age) of rearing juveniles will be studied. Because of the significance and magnitude of the findings on Red Lake, and on Skilak/Kenai lakes, these studies will continue until observed effects on growth and the limnetic community of the lake ecosystems recovers to pre-spill conditions.

The total number of juvenile sockeye in the Kenai Peninsula lakes will be estimated through hydroacoustic surveys conducted during all years up until recovery of the system is observed. Age and size information will be obtained from samples of juvenile sockeye collected from concurrent mid-water trawl netting surveys. Survey transect designs for hydroacoustic sampling and tow-netting have been established for Kenai and Skilak lakes (Tarbox and King 1989) and Tustumena Lake (Kyle 1992). Depending on densities of rearing juvenile sockeye salmon, estimates of fish densities will be made for each transect either by echo integration or by echo counting. Total fish population estimates will be computed, by summing transect populations, along with 95% confidence intervals (Kyle 1989). The number of smolt produced from Skilak lake will be inferred by conducting a spring hydroacoustic survey coupled with tow netting in 1995. This will be used to estimate overwintering mortality and will provide and index of smolt production from the lake when combined with the September, 1995 fall hydroacoustic survey.

Freshwater growth and age of sockeye salmon rearing juveniles from all study systems will be determined from scale and possibly otolith measurements made either by direct visual analysis of scales or using an Optical Pattern Recognition system. In cases where data are available (e.g., Kenai and Skilak Lakes and Tustumena Lake), growth of progeny from the 1989 spawning escapements will be compared with growth or size of progeny during prior years.

The total number of smolt migrating from each system, excluding the Kenai River, will be estimated with a mark-recapture study using inclined plane traps after Kyle (1983). Smolt will be captured in traps, sampled for age and size information, marked with Bismark Brown Y (a biological dye), and transported upstream of the traps and released for subsequent recapture (Rawson 1984). Periodic retesting will determine the capture efficiency of the traps under changing river conditions during the spring. Total population estimates (with 95% confidence intervals) will be made using catch efficiencies, and weekly number weighted smolt size and age information will be calculated using a computer spreadsheet developed by Rawson (personal communication, 1985). Smolt programs consistent with those for the study lakes are continuing for Tustumena Lake (Kyle 1992).

On the Kenai River, the smolt operation will include the Russian River. This lake system may now be the dominant producer of sockeye salmon smolt. Estimates of smolt production from the Russian River lake system must be completed to separate normal Russian River production from the smolt production of sockeye salmon rearing in Skilak and Kenai lakes.

Because the smolt data for 1993 indicated that the Russian River lake systems may be experiencing similar declines in production as the mainstem Kenai River. The 1989 escapement into this system was 138,000 adults, which is far in excess of the minimum 30,000 goal. Therefore, to evaluate the current production potential and impacts of large escapements, limnological and fry hydroacoustic/tow net surveys of the Russian lakes will be conducted for a second year. Techniques duplicate those used on other systems.

In the two Kenai Peninsula lakes, early spring and late fall sampling of fry will be conducted. The reason for the additional sampling period is that approximately 50% of the weight change observed from emergent fry to smolt in the Kenai River system occurs outside of the current sampling regime. If poor survival is occurring because of limitations in rearing habitat quality during this period, these data are crucial for determining the validity of fry density causing decreased over-wintering survival. Based on peer review comments, hydro-acoustic studies of fry abundance was conducted into the fall, 1994 to track and sample the juvenile fish until cold weather prevents further studies. This will be continued in 1995. This is based on the assumption that most of the density dependent mortality occurs in early winter (peer review comments, Hyatt and Hilborn). 1994 spring results indicated likely density dependent mortality over winter but not the large decreases in abundance expected from earlier years investigations using in river smolt traps as indicators of overwintering mortality.

Studies on Kodiak Island will be reduced because of recent findings. We will rely on mark/recapture studies with smolt traps will be used to estimate smolt abundance in 1995 for smolt population estimates from Akalura and Red lakes. In 1992 the hydro-acoustic surveys were eliminated on these lakes because of interference of stickleback with the population estimates. Samples of fall fry for age, weight, and length will continue to be collected. Frazer lake will be used as a control in the future. Monitoring of this system is primarily conducted by general fund expenditures of the Alaska Department of Fish and Game. A minor modification initiated in 1994 will continue in the program to insure compatibility with the monitoring continuing on Akalura and Red lakes. Funding from these studies will be used to augment the regular smolt monitoring program. A second inclined plane trap will be used to ensure that adequate samples are obtained for more accurately describing smolt population numbers and AWL characteristics to insure similar precision with the Red and Akalura lakes studies. The continued poor smolt production in the spring of 1994 suggest continued monitoring of these systems is warranted.

Limnological data will be collected to monitor the response of the lakes to high juvenile rearing densities and their recovery once escapement levels decline. Table 1 provides a time-line of these studies with and reflects the integration with the fisheries investigations previously discussed. These data will be used to estimate carrying capacity parameters of euphotic volume, nutrient budgets (carcass enrichment), and zooplankton biomass, body-sizes, and composition shifts. Approximately six limnology surveys will be conducted at two or more stations, to determine zooplankton species abundance and body-sizes, nutrient chemistry, and phytoplankton abundance for Kenai/Skilak, Tustumena, Akalura, Red, and Frazer lakes. The 1994 decreases in zooplankton abundance which correlates with increased fry abundance in Red Lake suggests an additional year of monitoring the zooplankton community is warranted. This program was initially planned on being eliminated. Methods for limnological studies are detailed in Koenings et al. (1987). In addition we will be further evaluating marine based nutrients as a historical surrogate for escapement by examining stable isotope ratios from fish and sediment. Early work conducted by Dr. Bruce Finney of University of Alaska, Fairbanks, suggests that we may be able to reconstruct historical escapement levels through the analysis of sediment cores collected from these lakes. We will provide some support for evaluations of this technique and collections of samples from Akalura and Red lakes. Preliminary results obtained from Karluk and Frazer lakes appeared promising.

In cases where seasonal data are available (i.e. Kenai and Skilak lakes), limnological parameters taken during residence of the juveniles from the 1989 spawning escapements will be compared to parameters within these systems during prior years.

The holistic approach proposed here involves several evaluation procedures to assess the effects of sockeye salmon overescapement. First, fresh-water production from the 1989 escapements will be assessed in Kenai/Skilak, Red, and Akalura lakes. This will be accomplished through analysis of growth, freshwater survival (in particular over-winter survival), and freshwater age of sockeye smolt populations. Any anomalies will be determined by analysis of freshwater growth recorded on archived scales, historical freshwater age composition, and modeled freshwater survivals; and from results of previous studies as well as the smolt characteristics from each of the study systems. Also, planktonic food sources will be assessed through estimation of zooplankton prey biomass and diversity of species. Some of these analyses have been completed (Schmidt and Tarbox, 1993).

Although in the Kenai River system smolt enumeration and fall fry estimates during 1991, 1992 and the spring of 1993 produced very low numbers, zooplankton biomass estimates in Skilak Lake, the major sockeye salmon producer, has not undergone similar levels of decline. Limited stomach samples evaluated recently from 1987 indicate a possible major switch in diet, further supporting limited food availability as a likely factor in the decline (Schmidt and Tarbox, 1994-In review). Further investigation into plankton availability and growth rates following the methods of Schmidt and Tarbox (1993) will continue.

Experimental and empirical sockeye life history/production models (Koenings and Burkett 1987, Koenings et al 1989) will be used to compare salmon production by life-stage at escapement levels consistent with management goals to the 1989 escapements. These models will be refined by use of food availability data obtained through the vertical sampling studies initiated in 1992 and to be continued through 1995.

Additionally, in the case of the Kenai system, the 1989 escapement effects will be viewed independently of the effects on previous brood years with high escapement.

Consult Schmidt and Tarbox (1993; 1994-In review) for further discussion of analyses and methods used to date in progress reports on these investigations.

5. Location:

Study locations are on Kodiak Island and the Kenai Peninsula. Specific sampling locations are identified in Schmidt and Tarbox (1993).

6. Technical Support:

Administrative support is provided by the Administrative Division, Habitat Division, and Commercial Fisheries Management and Development Division staff of the Alaska Department of Fish and Game. The project leaders and their assistants are not funded by this project and are supported with general funds from the State of Alaska. Most laboratory analyses are conducted by the limnology laboratory in Soldotna. These studies are integrated with ongoing studies by the Commercial Fisheries Management and Development Division on Kodiak Island and the Kenai Peninsula. These studies have different objectives, i.e. to manage, enhance, and rehabilitate common property salmon fisheries, but use the same techniques and data collection methods. Consequently the EVOS investigations have been integrated into the normal operations of these Divisions for efficiency in completing the objectives of these studies and the general mission of these agencies.

7. Contracts:

Technical support for specialized analyses are conducted by reciprocal service agreements with the Washington State University (lipid analysis) and Fairbanks (Nitrogen 15 analysis). These contracts were issued in 1992 and 1993. Because of the desire for a more timely delivery of fat analysis in 1994-95, we will attempt to contract with Washington State University. Costs are expected to be comparable and this laboratory has provided quality control for the 1994 primary analysis. These laboratories provide specialized analysis not routinely used by the Limnology laboratory. These contracts will be initiated after the project leader compares the cost effectiveness and obtains price quotations for other non-Alaska laboratories with the capability of conducting these analyses.

C. SCHEDULE

The timeline of the 1995 studies is outlined on Table 1. This table depicts the sampling schedule for the integrated limnological studies and fisheries studies on the Kenai Peninsula and Kodiak Island.

D. EXISTING AGENCY PROGRAM

The Alaska Department of Fish and Game has ongoing commercial fisheries research operations on the Kenai and Kasilof River, Frazer Lake, Red River, Akalura Lake, Upper Station Lake, and Afognak Lake. In addition, the Division has ongoing data collection activities from Hidden, Karluk, and Spiridon lakes relating to the limnology of these systems. These data are integrated into statewide or regional data bases that are use to directly assess the impacts of the oil spill or are used as controls to measure the response of the studies proposed in this plan, against. In addition, the area research and management biologists for the Division of Commercial Fisheries management and development, the principal limnologist, the regional limnologist, and numerous administrative and support staff are supported by general funds provided by the Alaska legislature. To date, most of the data analysis and reporting for the Sockeye Salmon Over-escapement project has been provided for from contributions of the State of Alaska from these general funds. Total funding for these programs exceeds $1 million. The following is a synopsis of projects in the areas that are covered by State of Alaska general funds: In addition, additional coordinated research projects with the National Biological Service are planned, to further determine the efficacy of alternative restoration activities.

Kodiak Island			
Kodiak Bio Rehabilitation	$174.1		
Spiridon Lake Assessment-	$42.8		
Frazer Lake /smolt operation	$36.6		
Kodiak Finfish research	$154.4		
Kodiak Frazer/Upper Station			
In-season forecasting	$31.5		
Kodiak Major System Weirs-	$168.2		
Total		$607.6	
Kenai Peninsula			
Statewide Limnology Staff (Part)	$160		
Limnology & Estuarine Studies	$100		
Cook Inlet Aquaculture Association			
Contracts (Hidden Lake-Others)	$18		
Kenai River Sonar	$45.4		
Kasilof River Sonar	$28.7		
Soldotna Research Staff	$203.1		
Stock Identification, UCI	$ 56.9		
Total		$612.1	
Grand Total			$1219.7

E. ENVIRONMENTAL COMPLIANCE, PERMITTING AND COORDINATION STATUS

The studies proposed provide for data collection and field sampling programs. As such no environmental effect of these programs occurs beyond that of traditional fisheries management data collection activities and is within existing collecting permits or Federal special use permits issued to the Department of Fish and Game for scientific data collection activities. New programs on the National Wildlife Refuge are updated through permit amendments as needed. No other permits or other coordination activities are involved.

F. PERFORMANCE MONITORING

Scientific presentations have been made at the Oil Spill symposium and the 1992 Gut Shop. The initial results of the investigations have been through peer review and are to be published in the proceedings of these two symposia. In addition, technical aspects of the studies findings to date and future plans have been reviewed by a panel of international sockeye salmon researchers in a special half day session of the Kokanee and Sockeye Salmon workshop sponsored by the Northern Pacific International Chapter of the American Fisheries Society at Vancouver, B.C. in March, 1993.

The peer review process has also included review of the progress reports by the Trustee Council peer reviewers. These studies have also been included in the discussion of the Trustee sponsored restoration workshop.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

The investigations of Kodiak and Kenai River sockeye salmon have been integrated with long term research efforts by the Alaska Department of Fish and Game on these stocks. In addition, studies by the limnology labo atory and the fisheries development staff on Kodiak Island on these systems are included in data analysis. Study design and methodology builds off of earlier efforts. Planning and permitting of research activities and future rehabilitation efforts are coordinated through the USFWS Refuge staff in Soldotna and on Kodiak Island. Consultation and planning is conducted with the newly formed National Biological Service Fisheries Research Laboratory staff in Anchorage. Development of restoration strategies on the Kenai Peninsula are through a review process with the regional planning teams and with an ADF&G review committee including the Sport Fish Division, when adjustments of management policies, such as escapement goals are involved. In addition, studies results from the Coghill Sockeye Salmon investigations in Prince William Sound are reviewed and integrated into the data analysis process for determining the response of the Kenai Peninsula ecosystem to restoration measures.

H. PUBLIC PROCESS

The proposed investigations have been subject to extensive review through the scientific community as well as the public process. Presentations have been made to the Soldotna Rotary Club, the Cook Inlet Regional Planning Team, UCI Drift Netters Association, and the Alaska Sportfishing Association. The Board of Fisheries has been briefed on the process.

I. PERSONNEL QUALIFICATIONS

Dana Charles Schmidt
Alaska Department of Fish and Game
Commercial Fisheries Management and Development Division
34828 Kalifornsky Beach Rd, Suite B
Soldotna, Alaska 99669
(907)262-9368

EMPLOYMENT:

October, 1991 to Present. Limnologist III, Principal Limnologist, FRED Division, Alaska Department of Fish and Game, Soldotna, AK. Responsibilities include establishing research objectives for the Statewide limnological investigations of the Commercial Fisheries Management and Development Division. This section provides direction for other components of the Division for determination of stocking rates for sockeye salmon in lakes and in the application of fertilization. This section also provides input to the commercial fisheries division for determination of the escapement goals for sockeye salmon. Supervise the limnology laboratory which completes water quality and plankton analysis for water samples taken from several hundred lakes statewide.

April, 1985 to October, 1991: Fishery Biologist IV, Regional Research Biologist, Westward Region, Alaska Department of Fish and Game. Responsible for establishing research objectives and priorities for the Westward Region Commercial Fisheries Division. This Division has management authority over extensive salmon and herring stocks on the Alaska Peninsula and Kodiak Island, in addition to management of the major shellfish stocks in the Gulf of Alaska and the Bering Sea. Annual ex-vessel value of these fisheries is several hundred million dollars, Research highlights included studies of crab larvae settling rates in the Gulf of Alaska and investigations on the effects of oil spill overescapement on the sockeye salmon production of major lakes on Kodiak Island.

May, 1982 to September, 1985 Acting F.B. IV, Susitna River Aquatic Studies Coordinator, Alaska Department of Fish and Game. The entire program under supervision included approximately 25 permanent and 50 seasonal employees. During this interim period, responsible for reorganizing the studies into a more efficient structure to meet the long term monitoring needs for determination of the effects of the Susitna project on the aquatic resources of the Susitna River. Supervised development of operational plans for 18 technical study programs on the Susitna River, assignment of priorities of tasks, and review of the technical merit of the programs proposed. Prior to January 1985. F.B. III, Resident and Juvenile Anadromous Project Leader, Su-Hydro Aquatic Studies Program, Alaska Department of Fish and Game. Supervised research programs on resident and juvenile anadromous fish in the Susitna River that may be impacted by development of the Su-Hydro Project. Technical studies included development of models of sport fishery exploitation on arctic grayling populations, modeling instream flow responses of juvenile salmon habitat, development of baseline population parameters of resident fish and juvenile salmon and development of projections of supersaturated gas dissipation below the proposed dam sites.

January, 1981 to May, 1982: Fishery Biologist, Terrestrial Environmental Services, Anchorage, Alaska. Responsible for field and office review of the aquatic studies programs of the Alaska Power Authority for the Susitna Hydro-Electric Program. This responsibility included assisting the Alaska Department of Fish and Game in study plan development, providing preliminary assessment of impacts of the project on aquatic resources and presenting to the public progress of the aquatic studies programs.

May, 1980 to October 1980: Fishery Biologist, U.S. Fish and Wildlife Service, Soldotna, Alaska. Assisted on a radio-telemetry project and juvenile salmon habitat survey on the Kenai River, 6-mile Creek and the Deshka River in the Cook Inlet area. Activities included tagging and radio tagging chinook and coho salmon, collection of juvenile salmon and measurements of associated habitat, and assisting in the analysis of scale patterns from Kenai River chinook salmon. Other activities included statistical analysis of data, report review and preparation of a publication on the Kenai River chinook for Alaska magazine.

EDUCATION:

Ph.D. in Fisheries 1973
Major Field - Fisheries- Minor Field Pharmacology,
Oregon State University, Corvallis, Oregon
M.S. in Biology, 1970 Major Field - Aquatic Biology Minor Field - Sanitary Biology, University of Utah, Salt Lake City, Utah
B.S. in Wildlife Biology, 1968, University of Montana, Missoula, Montana

Ken Tarbox
Alaska Department of Fish and Game
Commercial Fisheries Management and Development Division
34828 Kalifornsky Beach Rd, Suite B
Soldotna, Alaska 99669

EMPLOYMENT:

May, 1980 to Present. UCI Research Project Leader, Alaska Department of Fish and Game, Soldotna, Alaska. Responsibilities include planning, implementing, supervision, and reporting on various salmon related research and management projects. These involve hydroacoustic enumeration of salmon in glacial systems, defining salmon migratory behavior in both salt and fresh water, evaluation of potential impacts of resource development on habitat and populations, management of the UCI commercial salmon fisheries, stock identification studies using scale or genetic markers, and life history studies of sockeye salmon.

March, 1972 to May, 1980. Project manager and Senior Biologist, Woodward Clyde Consultants, Anchorage, Alaska. Responsibilities included supervision and research for a number of projects. These included an evaluation of existing methodologies for determining instream flow requirements for Alaskan fishes, determining the biological impact of a dredging projects located in lower New York Harbor and Lake Michigan, fishery investigations in the Zayandeh River, Iran, impact assessment of various oil related projects in Virginia, North Carolina, Texas, and Prudhoe Bay, Alaska, and studies and evaluation of impacts associated with nuclear power plants in New Jersey, Louisiana, Indiana, and Pennsylvania.

July, 1970 to March, 1972. Research Assistant, Louisiana Co-operative Fishery Unit, Louisiana State University, Baton Rouge, La. Responsibilities included the design and conduct of a one year investigation of juvenile fish behavior in an estuarine environment.

EDUCATION:

M.S. in Fisheries, 1974. Louisiana State University, Baton Rouge, La.
B.S. in Fisheries Science. 1970. University of Washington, Seattle, Wa.

CERTIFICATIONS:

Fisheries Scientist, Certificate 1165, American Fisheries Society, 1976.

Stan R. Carlson
Alaska Department of Fish and Game
Commercial Fisheries Management and Development Division
34828 Kalifornsky Beach Rd, Suite B
Soldotna, Alaska 99669

EMPLOYMENT:

January 1993 - present: Biometrician for the Alaska Department of Fish and Game, Limnology Section, Commercial Fisheries Management and Develop Division, Soldotna, Alaska. Supervised by Dr. Dana Schmidt. Conduct statistical data analyses to evaluate factors that affect dynamics of the biota in lake ecosystems. Design limnological experiments and determine methods to estimate zooplankton and salmon abundance. Develop and approve methods to estimate hatchery contributions to the fishery. Develop, review, and conduct statistical analyses for projects related to the impact of oil on commercial fishery species. Provide biometrical consulting to area and regional biologists and statewide limnologists.

November 1991 - January 1993: Mathematical Statistician for the National Marine Fisheries Service, Auke Bay Laboratory, Juneau, Alaska. Supervised by Mr. Steven Ignell. Conduct statistical studies on community attributes of pelagic fauna in the north Pacific Ocean. Provide biometrical consulting, technical editing, and collaborative input on projects such as salmon bycatch and climate change studies.

January 1989 - May 1991: Statistics Teacher, Experimental Statistics Department, New Mexico State University, Las Cruces. Supervised by Dr. Michael Ames. Instruct laboratory courses in statistics for undergraduate science majors.

May - August 1990: Research Specialist (statistician), Department of Entomology, Plant Pathology, and Weed Science, New Mexico State University. Dr. Ellis Huddleston, Supervisor. Provide statistical modeling, analysis, and design of experiments related to agricultural field studies and pest management programs.

May - December 1988: Field Biologist, Biology Department, New Mexico State University. Supervised by Mr. Roger Skaggs. Conduct field population surveys and habitat analyses of night birds in Lincoln

National Forest, New Mexico. Collect field data, supervise field personnel, and maintain data records. Develop operational strategies and conduct follow-up statistical estimation procedures.

August 1985 - June 1988: Graduate Assistant, Biology Department, New Mexico State University. Supervised by Dr. Ralph Raitt and Dr. Walt Whitford. Teach undergraduate biology and zoology laboratory courses. Collect data and maintain field ecology experiments for ecological research programs. Develop and conduct original field research on desert insect ecology.

June 1983 - May 1985: Research Specialist, Gordon Environmental Studies Laboratory, University of Montana, Missoula. Supervised by Dr. Philip Tourangeau. Manage data, conduct quality assurance/control procedures, and perform statistical analyses for environmental science projects. Aid in the design and implementation of field research, primarily in the area of pollution biomonitoring.

EDUCATION:

1991 Master of Science, Experimental Statistics, New Mexico State University.
1988 Master of Science, Biology (ecology), New Mexico State University.
1983 Bachelor of Arts, Environmental Biology, University of Montana.

J. BUDGET

	ADF&G
Personnel	**$556.2**
Travel	**$12.5**
Contractual	**$68.8**
Commodities	**$55.7**
Equipment	**$12.0**
Capital Outlay	**$0.0**
Sub-total	**$705.2**

General Administration **$88.2**

Project Total **$793.4**

NEPA Compliance **0** (State contributed)

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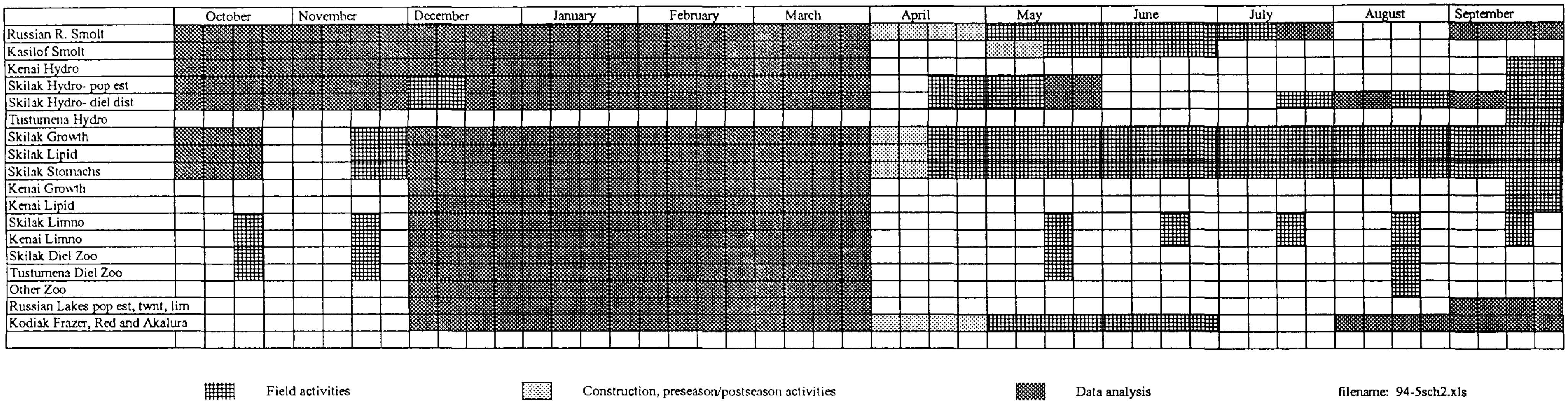
NRDA STUDIES- OCTOBER 1994-SEPTEMBER 1995



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EXXON VALDEZ TRUSTEE COUNCIL
FY 95 DETAILED PROJECT DESCRIPTION

Project Title:	Coghill Lake Sockeye Salmon Restoration
Project Number:	95259
Lead Trustee Agency:	Alaska Department of Fish and Game
Cooperating Agencies:	U.S. Department of Agriculture, Forest Service
Project Start-up/Completion Dates:	October 1, 1994 - September 30, 1995
Expected Project Duration:	Through 1999 (for post-treatment evaluation)
Cost of Project/FY 95:	$273,600
Geographic Area:	Coghill Lake, Prince William Sound
Name/Signature of Project Leader(s):	Gary Kyle (ADF&G)
	Mark Willette (ADF&G)
	Cliff Fox (USFS)
Name/Signature of Project Manager:	W. J. Hauser (for) Joe Sullivan (ADF&G)

INTRODUCTION

The goal of this project is to restore the natural sockeye salmon (*Oncorhynchus nerka*) production of Coghill Lake to historical levels through use of established and proven lake fertilization technology (LeBrassseur et al. 1978; Stockner and Hyatt 1984; Koenings and Burkett 1987; Kyle et al. 1995; Kyle 1994; Kyle 1994). Coghill Lake (61° 4' N, 147° 54' W) is an oligotrophic lake located 130 km northwest of Cordova in Prince William Sound (PWS) at an elevation of 18 m. This lake has a surface area of 12.7 km^2, a mean depth of 46.3 m, and a total volume of 587×10^6 m^3 (Pellisier and Somerville 1984). The lake becomes turbid in late August due to glacier runoff, and is meromictic due to the presence of a permanent layer of saline water (monimolimnion). The outlet of the lake empties into the eastern side of Port Wells in Prince William Sound. This project is conducted cooperatively by the Alaska Department of Fish and Game (ADF&G) and the U.S. Forest Service (USFS).

The Coghill Lake sockeye salmon stock has historically supported an important commercial fishery in western Prince William Sound (PWS), but in recent years returns have declined considerably (Edmundson et al. 1992). In 1982, a record 1.2 million sockeye salmon returned to Coghill Lake. Escapements have been as high as 187,000 (1987), but in recent years less than 10,000 sockeye have escaped into the lake. The restoration of Coghill Lake sockeye salmon will be used to mitigate losses of other fishery resources in Prince William Sound as a result of the oilspill.

During the past year, several review workshops and peer-review comments have addressed the Coghill Lake restoration project. These comments emphasized the need to insure that the lake fertilization project was integrated with management actions and other enhancement techniques conducted by the ADF&G and the Prince William Sound Aquaculture Corporation (PWSAC). Consequently, this project description as been modified from the original and contain more detail pertinent to the comments of the project reviewers.

This project will continue in 1995 because the Coghill Lake sockeye stock continues to be at dangerously low levels. Action must be taken to restore the stock before any further decline occurs. Since sockeye salmon rear in lakes for one to three years before emigrating to sea, sockeye smolt production is closely linked to the productivity of rearing lakes (Koenings and Burkett 1987; Koenings and Kyle 1995; Kyle et al. 1995). Limnological studies indicate that the zooplankton forage base of Coghill Lake cannot support large numbers of fry. Fertilization (for at least 5 yr) is needed to increase lake productivity and boost zooplankton abundance until natural nutrient input from salmon carcasses is restored (Edmundson et al. 1992).

PROJECT DESCRIPTION AND RATIONALE

Coghill Lake has demonstrated a major decline in sockeye production since 1985, as indicated by the very low (<1) return per spawner (Appendix A). This sockeye stock has been used for stocking smolts in PWS from Main Bay Hatchery operated by PWSAC. In addition, harvests of enhanced pink and chum salmon have often compounded the difficulty in meeting escapement goals for Coghill Lake sockeye salmon while concurrently harvesting the return of sockeye salmon to the Main Bay Hatchery (from the smolt releases).

Several mechanisms have been hypothesized as potential causes for the decline of Coghill Lake sockeye salmon including:

1) interception fisheries

2) climatic effects on
   a) marine rearing survival
   b) freshwater rearing survival.

In addition, other restoration activities currently underway outside of the purview of the Trustee Council include:

1) changes in harvest practices
2) stocking of sockeye juveniles directly into Coghill Lake from the Main Bay Hatchery to insure full utilization of improved zooplankton stocks.

Coghill Lake sockeye returns in recent years has declined because of poor returns-per-spawner (Appendix A). Since interception of returning Coghill Lake sockeye lowers escapements (not return-per-spawner), the primary cause of the collapse of sockeye in this system is related to factors other than harvest management. Because return-per-spawner is the problem (low return brood years of 1985-1988 had above normal or exceptionally high escapements), increasing escapements through reduction of interceptions is a major concern of ADF&G managers, and is an integral part of the restoration effort of Coghill Lake sockeye salmon. Although not the cause, inadequate escapements can insure recovery is expedited. The attached section (Appendix A) references the PWS management plans. These plans include harvest rate alterations by time and area to reduce the interception of Coghill Lake sockeye returns.

Climatic effects on marine survival have been speculated as a major cause of the decline of Coghill Lake sockeye salmon. The Sound Ecosystem Assessment (SEA) program has suggested major variations in pink salmon and herring returns in the PWS are most likely driven by broad-scale climatic variables. Consequently, reviewers of this project have commented that this project should also take into account a climatic hypothesis to explain the decline of Coghill Lake sockeye salmon. Although marine survival may be a factor in the variability in return-per-spawner, there is insufficient data to consider this as a major driving variable. However, we are working with the University of Alaska on a sediment coring project for Coghill Lake that may elucidate the indirect effects of climatic changes through the interpretation of silt laminations in the coring analysis.

In contrast to the lack of information of marine survival variables, the smolt outmigration from Coghill Lake in recent years is sufficiently low to account for poor adult returns. This is true whether examined from a numeric perspective or using the smolt-per-spawner data as an index. Hence, the freshwater component of the life cycle is most likely the culprit. If a common marine survival mechanism were hypothesized, we would expect the collapse of sockeye return-per-spawner to parallel that of pink salmon returns-per-spawner, once we account for the protracted freshwater residence of sockeye salmon. This would be true, even if we totally discount the validity of the smolt data. Clearly, the 1985-1988 brood year returns-per-spawner for Coghill Lake sockeye salmon have no correlation to pink salmon brood years of 1986-1989, which if they were correlated would suggest common mechanisms. Thus, we can discount the SEA hypothesis as a major factor for the decline of Coghill Lake sockeye salmon.

Climatic effects on freshwater survival are most certainly a major factor in contributing to the high volatility of in the freshwater production of sockeye salmon smolt in Coghill, including variations in the quality and quantity of the plankton food supply, as well as temperature effects on growth rates, etc. Turbidity changes caused by glacial melt, ice cover on the lake extending into the summer because of snow pack, decreased retention times of water in the lake because of high rainfall and flooding conditions, all contribute to the growth and recruitment of sockeye salmon smolt. These parameters have been monitored and are being examined as covariates affecting production along with the lake fertilization studies, and will be analyzed in subsequent reports.

The underlying philosophy of examining the ecosystem and sockeye salmon production of Coghill Lake centers on restoration, rather than attempting to understand controlling processes. Consequently, inordinate efforts in describing effects of variables that subsequently cannot be influenced through management programs such as fertilization, stocking, harvest regulations, is an inefficient use of our limited financial resources, assuming the primary goal is restoration rather than basic research. Coghill Lake is sampled at least monthly for 25 different physical, chemical, and biological variables; these data are collected to understand the response of nutrient supplements and relate productivity changes to the database we have developed for nearly 200 lakes in Alaska. The benefit of this approach is a clear understanding of the carrying capacity of this system and develop a meaningful evaluation of the benefits derived from the fertilization project.

Changes in harvest practices to reduce interceptions is certainly part of ADF&G's mandate to effectively manage sustainable fisheries. However, allocative effects and economic trade-offs require decisions from the Alaska Board of Fisheries. Management actions and plans have been altered by ADF&G with the Board of fisheries concurrence to insure harvest rates on returning adults to Coghill Lake be reduced to meet the escapement goal (Appendix B).

To insure that restoration efforts designed to increase forage for rearing sockeyes juveniles are fully utilized, fall fingerlings (Coghill brood stock) were stocked into Coghill Lake in the fall of 1994. This action is an effort to restore this system with modest supplementation without putting exceptional stress on the zooplankton community. This program was conducted outside of the Trustee Council funding mechanism and may be continued in the future to provide adequate number of rearing juveniles relative to the standing stock of zooplankton. Future stocking levels will take into account natural recruitment through escapements and issues such as brood stock selection and stocking levels will follow the normal ADF&G regulatory procedures, including fish and egg transport permits and the basic and annual hatchery management plans. These activities are integrated with the lake fertilization project to insure stocking levels are in balance with escapements and available forage.

Lake fertilization coupled with escapement management and fry stocking are the primary restorative techniques for any sockeye lake system. The question has been raised by reviewers as to the role that decreases in lake fertility have had in the decline of Coghill Lake sockeye salmon. Lake fertility may be reduced by carcass reduction or by nutrient loss to the non-mixing saline layer. The history of the saline layer of Coghill is not yet well known; however preliminary analysis of core samples indicates the saline layer is about 200 years old (Bruce Finney, University of Alaska, personal communication). If the saline layer was formed in the 1964 earthquake, we would have expected return-per-spawner rates to drop steadily after its formation. No such trend is apparent. If reduced carcasses have reduced fertility, it most likely would affect nutrient levels in the most recent years and not likely to account for the rapid decline in return-per-spawner from brood years 1985-1988. Therefore, available data does not suggest that the main decline is associated with decreased fertility. Why then fertilize? Coghill Lake is very similar to many oligotrophic sockeye nursery lakes, it is nutrient poor, primarily lacking in the annual loading of phosphorus and sporadically lacking nitrogen during the peak summer period (July) This is also reflected in reduced chlorophyll *a* and the low densities of zooplankton. If the primary goal of restoration is to re-establish the sockeye run to it's former production, regardless of the cause, Coghill Lake will benefit from he addition of nutrients. The trophic-level responses that we have observed so far support this conclusion.
What then is the primary cause of the decline? We have suggested that the very high escapements from 1980-1982 may have initiated changes in the lake plankton community which may have reduced the carrying capacity of the system (overescapement). These high escapements are thought to have reduced the standing crop of zooplankton. Other factors such as in-lake climatic changes which would effect turbidity and temperature in the lake may have compounded the problem. Reviewers have suggested that

the modest rate of return-per-spawners observed following the high 1980-1982 escapements suggest that overescapement is not a likely cause. Other lakes in Alaska have experienced lags of a year in the declines in recruitment and suggest that these initial years may have been the initiation of this process (Kyle et al. 1988; Koenings and Kyle 1995). The failure of the system to respond to decreased densities in 1983-1984 would support this contention. Major recruitment failure from high escapements in 1985-1988 are consistent with this hypothesis. These drops in return-per-spawner are consistent with the magnitude of those observed on Frazer Lake on Kodiak Island (0.1-1981, 0.2-1982, 0.3-1985) following major overescapement events (Kyle et al. 1988; Appendix C). Further, multiple lake comparisons of sockeye production per unit area does not suggest that the oligotrophic nature of Coghill lake and its low standing stock of zooplankton could sustain escapements ranging at a level of 100,000-200,000 as experienced during 1980-1982 and 1985-1987. Because Coghill Lake is meromictic with a saline layer that acts as a nutrient sink, has a short growing season, and at least recently has had very low zooplankton densities suggests that sockeye production would be lower than in other systems. We do not doubt that other factors may have made a major contribution to the production of sockeye salmon from Coghill. For example, major changes in the length of ice cover, high summer turbidity because of warmer than normal conditions and increased run-off and glacial melt. These factors are being evaluated to assess the benefit and efficiency of the lake fertilization project.

Since Coghill has a saline layer at about 25 m which most likely acts as a nutrient sink, reviewers have raised the question of the relative efficiency of a fertilization program on lakes of this type. Turnover rates of the lake volume exclusive of the saline layer, are used in the present calculation of fertilizer loading. Spring loading will probably be reduced from other lakes because of the lack of nutrient mobilization from the sediment water interface. However, significant shoals and stream runoff will provide continued loading from carcasses as escapements improve. Redoubt Lake, a meromictic lake that has been fertilized since 1984 and is located near Sitka, Alaska, has responded to treatment despite the presence of a saline layer (Kyle et al. 1995; Appendix D). The best measure of success, however, is the response we have observed from Coghill Lake over the past 3 years of lake fertilization. These results will be forthcoming in the next month when the 1993 and 1994 progress reports will be submitted for review.

This specific element of the restoration program for Coghill Lake sockeye salmon addressed by this study plan will increase productivity through the use of lake fertilization. Nutrient loading from adult salmon carcasses is expected to maintain lake productivity after the fertilization program is completed, and the run is restored. Restoration of Coghill Lake sockeye will provide alternate restoration for injured fishery resources that have not been restored within the EVOS area. The USFS is responsible for the purchase of fertilizer and application each summer (through 1997). ADF&G will conduct limnological and fisheries studies needed to monitor and refine the fertilization program. These studies will focus on the effects of fertilization on primary and secondary production and the growth and survival of juvenile sockeye salmon in the lake. The results of the monitoring program will be used to evaluate the effectiveness of the restoration effort and to document changes in the rearing capacity.

Resources and/or Associated Services:

This project is intended to increase the productivity of Coghill Lake and to restore the population of sockeye salmon to historical levels. Restoration of the Coghill Lake sockeye salmon stock will replace other fishery resources injured by the EVOS.

Relation to Other Damage Assessment/Restoration Work:

The Prince William Sound Aquaculture Corporation stocked ~350,000 sockeye fingerlings into Coghill Lake this past fall to accelerate the restoration of this stock and to make use of the enhanced rearing conditions through lake fertilization. These fingerling were stocked following the guidelines of ADF&G limnology group using zooplankton abundance observed in Coghill Lake and following brood stock concerns of the pathology and genetics sections of ADF&G. Future stocking of juvenile sockeye will occur and level of stocking will depend upon status of the forage base (zooplankton).

Objectives:

1. Apply fertilizer to increase the rearing capacity of Coghill Lake.

2. Determine the water residence time of Coghill Lake.

3. Evaluate the effect of fertilization on nutrient levels, algal biomass, and the zooplankton community.

4. Evaluate the effect of fertilization on the feeding, growth, and condition of rearing sockeye fry.

5. Evaluate the effect of fertilization on the overwinter survival of fry, and on the age, size, and condition of smolts.

6. Integrate results of the fertilization project with harvest management and other restoration (stocking) activities outside of the Trustee Council funding.

Methods:

Objective 1

Lake fertilization is recommended for one sockeye life cycle (5 yr) to elevate the productivity of the lake and zooplankton forage base to ultimately increase the rearing capacity for sockeye salmon. The recent loading of phosphorus (P) into Coghill Lake is 325 mg m^{-2} yr^{-1}, and the critical loading rate of P (Vollenweider 1976) needed for full phytoplankton productivity is 650 mg m^{-2} yr^{-1}. Therefore, an additional 260 mg m^{-2} yr^{-1} of P (65,000 kg based on an application area of 5.5 km^2) is needed to achieve full phytoplankton productivity. A pharmaceutical-grade liquid blended fertilizer will be applied to the lake by releasing it from a low-flying aircraft. The fertilizer (20-5-0) contains 20% nitrogen and 5% phosphorus, and will be applied during early June to mid or late August. Application will consist of six to nine passes of five-minute duration over a two to three day period each week. Thus, approximately 6,500 kg of fertilizer will be applied each week. In addition, due to nitrogen deficiency during the peak of summer, 10,000 kg of a nitrogen fertilizer (32-0-0) is necessary to ensure proper N:P ios. The nitrogen fertilizer will be applied on a weekly basis during July.
Public reserving the cabin at Coghill will be notified of the fertilization schedule, which will be posted in the cabin. Fertilizer will be applied no closer than a mile and a half from the cabin and lagoon where most of the recreational activity takes place. The pilot will not dispense fertilizer in a portion of the application area if anyone is within that area.

Objective 2

The water residence time of Coghill Lake will be monitored to assist in determining phosphorus loading rates. Discharge will be measured in the Coghill River twice during low, medium, and high flow periods. Water depth and current speed will be measured at 10-m intervals along a transect drawn perpendicular to the stream length. The cross-sectional area of each segment and the current speed will be used to estimate the discharge within each segment. The discharge estimates for all the segments along the transect will be summed to estimate the total stream discharge. Water level in the lake will be measured at the same time that discharge is estimated. Regression analysis will be used to develop an empirical model relating lake level to stream discharge. An electronic pressure recorder will be installed in the lake to continuously monitor changes in lake level. The empirical model will be used to construct a time series of lake flushing rate (inverse of water residence time) throughout the fertilization period and the year.

Objective 3

The effect of lake fertilization on primary and secondary production will be assessed by comparing limnological data collected pre- and post-fertilization. Five years of limnological data collected monthly at Coghill Lake is available for the comparison. Analysis of variance (ANOVA) and multiple comparisons will be used to test for pre- and post-fertilization differences of several limnological variables (e.g. filterable reactive phosphorus, ammonia, nitrate-nitrite, chlorophyll *a*, copepod biomass, and cladoceran biomass). The independent variables in the model will include sampling period and year (pre- and post-treatment effects will be compared by grouping years).

Limnological sampling will be conducted as in past years to insure valid pre- and post-fertilization comparisons. Sampling will be conducted twice each month from June through October at 3 stations that have been sampled in past years. The samples collected within each month will be used as replicates in the pre- and post-fertilization comparison. Temperature and dissolved oxygen concentrations will be measured from the surface to a depth of 30 m using a YSI model-57 meter. Measurements of light penetration (foot-candles) will be measured at 1 m increments from the surface to a depth equivalent to 1% of the subsurface light using a Protomatic submarine photometer. The euphotic zone depth defined as the depth at which 1% of the subsurface light (photosynthetically available radiation [400-700 nm]) penetrates (Schindler 1971), will be calculated from the relationship of light transmission through water (Wetzel and Likens 1979). Secchi disk transparency will be determined as the averaged reading (depth) taken by lowering a standard 20 cm disk until it disappears, and then raising the disk until it reappears. Most of the water samples will be collected from 1 m and 20 m using a non-metallic, opaque Van Dorn sampler. The exception is that water samples for chlorophyll *a* will be collected from 1 m and 2 m. Eight liters of water will be collected from each depth, stored (<24 hr) in pre-cleaned polyethylene carboys, transported to Cordova for processing, and then shipped to the Limnology Laboratory in Soldotna for analysis.

General water-quality samples will be analyzed for the following parameters as detailed by Koenings et al. (1987). Conductivity (μmhos cm^{-1}) will be measured with a YSI model-32 conductance meter. Alkalinity levels (mg L^{-1}) will be determined by acid titration (0.02 N H_2SO_4) to pH 4.5, using a Corning model-399A specific ion meter. Calcium and magnesium (mg L^{-1}) will be determined from separate EDTA (0.01 N) titrations after Golterman (1969), turbidity (NTU) will be measured with a HF model-DRT100 turbidimeter, and color (Pt units) will be determined with a spectrophotometer. Total iron (mg L^{-1}) will be analyzed by reduction of ferric iron with hydroxylamine during hydrochloric acid digestion after Strickland and Parsons (1972).

Nutrient samples will be analyzed by methods detailed by Koenings et al. (1987). Filterable reactive phosphorus (FRP) will be analyzed by the molybdate-blue/ascorbic-acid method of Murphy and Riley (1962), as modified by Eisenreich et al. (1975). Total phosphorus will be determined using the FRP procedure, after persulfate digestion. Nitrate and nitrite (NO_3 + NO_2) will be determined as nitrite, following Stainton et al. (1977) after cadmium reduction of nitrate. Total Kjeldahl nitrogen (TKN) will be determined as total ammonia following sulfuric acid block digestion (Crowther et al. 1980). Total nitrogen will be calculated as the sum of TKN and NO_3 + NO_2. Reactive silicon will be determined using the method of ascorbic acid reduction to molybdenum-blue (Stainton et al. 1977). Estimation of the yearly phosphorus loading in Coghill Lake will be calculated after Vollenweider (1976).

Algal standing crop will be estimated by chlorophyll *a* analysis, after the fluorometric procedure of Strickland and Parsons (1972). The low-strength acid addition recommended by Riemann (1978) will be used to estimate phaeophytin. Water samples (1-2 L) will be filtered through 4.25-cm GF/F filters to which 1-2 mls of a saturated $MgCO_3$ solution is added just prior to the completion of filtration. The filters will be stored frozen in individual plexislides for later analysis. Samples of unfiltered lake water will be preserved with Lugol's acetate solution for later identification of phytoplankton species.

Vertical zooplankton tows will be taken using a 0.2-m diameter, 153-μm mesh conical net from a depth of 30 m at 5 stations (3 of the stations are the same as those used to collect water samples and the 2 other stations are located adjacent to the outer 2 limnological stations). The net will be pulled at a constant 0.5 m s^{-1}, and all organisms will be preserved in a 10% neutralized formalin solution. Cladocerans and copepods will be identified using keys developed by Brooks (1957), Pennak (1978), Wilson (1959), and Yeatman (1959). Enumeration will consist of counting animals in triplicate 1 ml subsamples taken with a Hansen-Stempel pipette in a 1 ml Sedgewick-Rafter cell. Cladoceran body length will be measured to the nearest 0.01 mm for at least 10 individuals along a transect in each 1 ml subsample (Koenings et al. 1987). Cladoceran weight will be estimated from an empirical regression between body length and dry weight. Zooplankton biomass will be estimated for each species by the product of average body weight and abundance (Koenings et al. 1987).

Objective 4

The effect of fertilization on juvenile sockeye salmon will be assessed by collecting fry samples throughout the summer and early fall for stomach content, food electivity indices, food consumption, growth rates, and condition factor. Any such prior data e.g., fry size will also be compared with same data collected during lake fertilization. Hydroacoustic surveys will be done in August, September, and October to estimate abundance and distribution (both vertical and horizontal) of juvenile sockeye rearing in Coghill Lake. A 420-Khz dual-beam echo sounder will be used to estimate fry abundance and distribution. The survey will be done at night when the fry are uniformly dispersed, and data will be collected along at least 12 randomly selected transects (4-5 per stratum) oriented perpendicular to the longitudinal axis of the lake. The data will be analyzed (under a contract) using echo integration or echo counting techniques depending on fish density (Nunnallee 1983; Thorne 1983, 1988; Kyle 1990).

A 7.5-m long mid-water trawl with a 2 x 2 m opening will be used in conjunction with the hydroacoustic surveys to collect juvenile sockeye for size and growth data, stomach content, and to determine species composition of fish targets. All juvenile sockeye caught will be preserved in 10% formalin for 6 weeks to allow for complete shrinkage, and then will be measured to the nearest millimeter and weighed (nearest 0.1 g). A scale smear will be taken from each fish, affixed to a glass slide, and aged using a microfiche projector.

Stomach contents will be analyzed to test for differences in prey consumption (biomass) and composition between months. Stomach samples will be collected from the fish caught by townetting in August, September, and October. Fry stomachs will be removed and preserved in 10% buffered formaldehyde. Prey items in the stomach will be identified later in the laboratory to the lowest possible taxonomic level. Prey length will be measured to the nearest 0.01 mm. Prey body weight will be estimated from an empirical regression between zooplankter body length and dry weight (Koenings et al. 1987). Stomach content biomass will be estimated by the product of abundance and mean body weight for each taxonomic group. ANOVA will be performed to test for differences in stomach contents weight and prey composition between months. Separate analyses will be conducted on total stomach content weight as a proportion of fish body weight and on prey biomass in each taxonomic group as a proportion of total stomach content weight. As more data are obtained over the five year study, the analysis will be restructured to test for differences between years.

The electivity index (Ivlev 1961) will be calculated to determine the active selection of prey items by rearing sockeye fry. This index has a range of -1 to +1; negative values indicate either avoidance or inaccessibility of a prey item, zero indicates random selection, and positive values indicate preference. There are variations of the electivity index that compensate for bias introduced when either the abundance of prey in the environment differs substantially from the prey found in the fish or when predator-prey habitats differ (Paloheimo 1979; Strauss 1979). However, regardless of the version used, the selectivity of prey preference based on the electivity index is a relative measure until other phenomena such as the probability of prey capture, and distribution of prey are better understood. The electivity index will be estimated by:

$$E_i = \frac{r_i - p_i}{r_i + p_i} \tag{1}$$

where E_i is the electivity measure for prey species *i* in the stomach of the predator expressed as a proportion or percentage of the total stomach contents, and p_i represents the relative abundance of the same prey item in the environment expressed as a proportion or percentage of the total density.

Food consumption rate will be estimated from studies of diel feeding periodicity and stomach content analysis. The diel feeding periodicity study will estimate the food consumption rate of fish throughout the day at a single site. The stomach content analysis will estimate the variability of stomach content weight and prey composition among 3 sites, and differences in these variables between months will be statistically tested.

The diel feeding periodicity study will estimate food consumption utilizing gastric evacuation rates obtained from published laboratory studies and stomach content weight data obtained in the field. Brett and Higgs (1970) estimated the gastric evacuation rate of juvenile sockeye (30-40 g) between 3 and 23° C. Gastric evacuation is described by a negative exponential function:

$$V_t = V_o \, e^{-bt} \tag{2}$$

where V_t is mean stomach content weight (g) at time t, V_o is the mean stomach content weight (g) at time 0, and b is the temperature-specific gastric evacuation rate (Fange and Grove 1979). Samples of ten sockeye salmon fry will be collected at 4-hr intervals throughout a 24-hr period using a townet. The lengths and weights of the fish will be measured fresh. Fry stomachs will be removed and preserved in 10% buffered formaldehyde. Prey items in the stomach will be identified later in the laboratory to the lowest possible taxonomic level. Prey length will be measured to the nearest 0.01 mm. Prey body weight will be estimated from an empirical regression between zooplankter body-length and dry weight (Koenings et al. 1987). Stomach content weight will be estimated by the product of abundance and mean body weight for each taxonomic group. Daily food consumption (I) will be estimated by:

$$I=\sum_{i=0} V_i(1-e^{-bt})$$

(3)

where V_i is the mean stomach content weight at the beginning of each 4-hr interval, and b is the temperature-specific gastric evacuation rate (Brett and Higgs 1970). The vertical distribution of fry and water temperature profiles will be used to estimate the temperature of the habitat occupied during each time period. The food consumption estimates during each of the 4-hr intervals will be summed to estimate the daily ration. This study will be conducted in August, September, and October. If the pattern of diel migration and feeding does not change significantly over time (based on 1993 and 1994 data results), this study will be discontinued. Food consumption rate will then be estimated from stomach samples collected in the morning.

Growth rate (G) will be evaluated by comparing within season charges in mean body weight. The mean growth rate of the cohort during the previous month will be estimated from the following equation:

$$G=\frac{\overline{w_2}-\overline{w_1}}{t_2-t_1} \tag{4}$$

where $\overline{w_2}$ is the mean body weight in the current sample, and $\overline{w_1}$ is the mean body weight in the previous sample. ANOVA and pairwise comparisons will be used to test for differences in mean weight between months. As more data are obtained over the five year study, the analysis will be restructured to test for differences between years. An identical analysis will be conducted using length data.

In addition, the effect of the fertilization program on fry growth will be evaluated by testing for changes in temperature-specific growth between years. The vertical distribution of the fish, water temperature profiles, and continuous temperature measurements (obtained from electronic recorders) will be used to estimate the mean temperature of the habitat occupied by the fish during each month. Monthly mean growth will be regressed against monthly mean water temperature. Analysis of covariance (ANCOVA) will be used to test for differences ($P = 0.05$) in the intercept and slope of the regression between years.

The effect of the fertilization program on the condition of sockeye salmon fry will be evaluated by testing for changes in condition between months and years. The relationship between body weight (W) and length (L) is described by the power model:

$$W=aL^b e^\epsilon \tag{5}$$

which can be written in linear form as : $\ln(w) = \ln(a) + b\ln(L) + \epsilon$, where ln(a) is the intercept and b is the slope of the model. Regression analysis will be used to estimate the relationship between ln(w) and ln(L). The condition factor (K) of individual fish will be estimated by:

$$K=\frac{w}{\hat{w}} \tag{6}$$

where w is the observed weight of the fish and $\hat{w}$ is the predicted weight of the fish from the regression equation (LeCren 1951; Murphy et al. 1991). Analysis of variance and multiple comparison tests will be used to compare the condition factor between months within years. A second approach, using length-adjusted weight from a separate slopes ANCOVA model will also be applied and compared to the results using the condition factor (K).

Objective 5

The effect of the fertilization program on smolts will be evaluated by testing for pre- and post-fertilization differences in smolt age composition, condition, and size at age. Sockeye salmon smolts emigrating from Coghill Lake will be enumerated using inclined-plane traps (Kyle 1983; Todd 1994). The traps will be operated continuously from early May to early June. The catch efficiencies of the traps will be determined by mark and recapture trials (Rawson 1984). A review of this method is provided in Appendix E which addresses reviewer comments on the smolt enumeration method. At least 300 individuals will be marked and released at the lake outlet for each mark-recapture trial. The number marked will depend upon trap efficiency and relative error. Overwinter survival will be estimated by dividing the number of outmigrating smolts by the fry population size estimated the previous fall. A sample of 40 smolts will be collected each day to estimate age composition. The fish will be anaesthetized with MS-222. Several scales will be taken from each fish, affixed to a glass slide, and aged in the laboratory using a microfiche projector. Each fish will be measured to the nearest millimeter and weighed to the nearest 0.01 g. Pre- and post-fertilization differences in the proportion of total smolt population for each age group will be evaluated. Sampling period and year will be independent variables in the model. ANCOVA will be used to test for pre- and post-fertilization differences in smolt condition. The independent variables in the model will be sampling period and year with ln(L) as a covariate. Overwinter survival will be estimated by the ratio of fall fry and spring smolt population estimates.

Objective 6

The data generated from objectives 1-5 will be integrated with management and other restoration activities associated with the Coghill Lake sockeye salmon by the ADF&G and PWSAC. Specifically, smolt outmigrations will be used in the forecast of adult returns. These adult return forecasts will be used to develop annual harvest management plans and proposals to the Alaska Board of Fisheries where appropriate. The information developed on egg-to-fry survival and the carrying capacity of Coghill Lake will be used to examine the escapement goal for this system and to recommend appropriate revisions when necessary. Measurements of the growth rate and survival of fry and the subsequent response of the zooplankton community to fry abundance from escapements and hatchery stocking will be incorporated in recommending future stocking levels. Brood stock selection for stocking will go through normal ADF&G review and approval procedures including disease screening and genetic review. These data will be provided to the regional planning team in their consideration of the annual hatchery management plans and to ADF&G reviewers of fish and egg transport permits. If continued monitoring of smolt abundance and adult returns suggest marine survival is a problem, results from the SEA program will be used in an attempt to interpret alternative hypothesis for poor return rates.

Location

This project will be conducted at Coghill Lake which is located in northwestern Prince William Sound.

Technical Support

Biometric support is provided by Stan Carlson of ADF&G and is funded under this project. However, the ADF&G project leaders and their assistants are not funded by this project; support is through State of Alaska general funds.

Contracts

Contracts will be needed for aerial application of the fertilizer, phytoplankton analysis, lake sediment core sample analysis, and hydroacoustic data processing. Contractual services for air charter will also be used to provide logistical support for field sampling operations. Contracts will be awarded through competitive bid when necessary.

SCHEDULE

Table 1. Schedule of activities for the Coghill Lake sockeye restoration project.

Date	Activity
May - Jun	Enumerate smolts and collect samples to estimate smolt age and size composition
Jun - Oct	Apply fertilizer each week, conduct limnological sampling twice each month, and collect fish samples for growth and stomach contents analysis
July - Dec	Conduct analyses of limnological and fish samples
Aug, Sep, & Oct	Conduct hydroacoustic survey each month to estimate fry abundance and distribution, and collect fry for size, growth, age, and stomach content data
Dec - Feb	Analyze data and prepare annual report
Apr 1996	Submit annual report for peer review

EXISTING AGENCY PROGRAM

The ADF&G operates a weir on Coghill River to enumerate adult salmon returning to Coghill Lake. Age, weight, and length (AWL) data are collected. Along with AWL data from commercial catches, data from the weir are used to forecast adult salmon returns to the lake system. The salmon run forecast for Coghill Lake is an important element in the ADF&G management program for the Coghill sockeye stock. The annual operating cost of the weir project is $18.5K. ADF&G also will conduct a test fishery project to determine the exploitation rate on Coghill Lake sockeye salmon in the Eshamy District and Esther Subdistrict. Data from the test fishery will be used to continue to refine the present fishery management strategy to reduce the interception of Coghill Lake sockeye salmon in an effort to increase the escapement. ADF&G will continue to review and regulate fry and smolt releases from the Main Bay hatchery to insure these activities are complementary to the Trustee funded restoration program for Coghill Lake.

ENVIRONMENTAL COMPLIANCE, PERMITTING, AND COORDINATION STATUS

The USFS has conducted an environmental assessment to evaluate the various alternatives for rehabilitating Coghill lake and the sockeye salmon population (USFS 1993). The assessment has concluded that the lake fertilization program is the most appropriate method for rehabilitation of the Coghill Lake ecosystem and sockeye salmon stock.

PERFORMANCE MONITORING

An annual report detailing project results will be completed for peer review in April of 1996. At the end of the five year study, a peer-reviewed report will be submitted to a scientific journal.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The Prince William Sound Aquaculture Corporation stocked 350,000 sockeye fingerlings into Coghill Lake last fall (1994) to accelerate the restoration of this stock and to make use of the enhanced rearing area through lake fertilization. In addition, the limnological and juvenile sockeye salmon data obtained at Coghill Lake will be interpreted by the ADF&G Limnology Laboratory and used for modeling other similar sockeye nursery lakes in Alaska.

PUBLIC PROCESS

An Environmental Assessment was conducted by the USFS in which various alternatives for the rehabilitation of Coghill Lake and the resident sockeye population were present for public review. The project was also publicly reviewed by the Prince William Sound/Copper River regional planning team.

PERSONNEL QUALIFICATIONS

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Experience:

> April 1977 - April 1988: Project Biologist and later Area Biologist for the Division of Fisheries Rehabilitation, Enhancement, and Development of the ADF&G in Soldotna Alaska. Conducted and evaluated various fisheries enhancement and evaluation projects in the Cook Inlet watershed including limnological investigations of sockeye salmon producing lakes, and evaluation of hatchery stocking programs. Also, during the period I served as a project limnologist for the Limnology Section which involved the collection, analysis, and interpretation of limnological data from sockeye nursery lakes for assessment of rearing capacity and for modeling purposes.
>
> April 1988 - present: Regional Limnologist for the Limnology Section for ADF&G in Soldotna, Alaska. Supervised by Dr. Dana Schmidt. As the Regional Limnologist for the Southcentral Region comprising of the Interior, PWS, Cook Inlet, and Alaska Peninsula; the primary purpose

of this position is the supervision of staff in the coordination, assignment, prioritization, analysis, and review of subordinates work and interagency contract work related to lake fertilization and stocking projects, water quality monitoring projects, and fisheries and limnological research. In addition, the position is responsible for training subordinates, reporting and review of project results for publications and meetings, and administrating state and non-state (contract) budgets.

Education:

1975 Bachelor of Science, Life Science/Natural Resources, University of Wisconsin.

Publications:

A total of 34 technical reports, 8 journal manuscripts, 24 formal presentations, and 6 magazine articles dealing with adult sockeye production, lake fertilization, lake stocking, and in-lake assessments of juvenile sockeye production.

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Experience:

March 1991 - present: Area Resource Development Biologist with the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division in Cordova, Alaska. Supervised by Dr. Stephen Fried. Conduct various fisheries enhancement and evaluation projects in Prince William Sound (PWS) including limnological investigations of sockeye salmon producing lakes, and quality control of coded-wire tagging at private hatcheries. Conduct fisheries oceanographic studies in PWS in cooperation with private hatcheries and University of Alaska investigators. Principal Investigator on Natural Resource Damage Assessment studies on juvenile salmon in PWS. Chairman of PWS Regional Planning Team.

March 1986 - February 1991: Fisheries Instructor/ Assistant Research Professor, University of Alaska Fairbanks, School of Fisheries & Ocean Sciences, Supervised by Dr. Don Kramer. Conduct research on the effects of oceanographic conditions on the growth and survival of juvenile salmon in PWS, fish bioenergetics in an arctic lagoon ecosystem, age and growth of juvenile fish in the Chukchi and Bering Seas, ocean temperature variability in the North Pacific Ocean and effects on pink salmon production, salmon feeding on the high seas. Design and implement a program of education, research, and public service to promote fisheries development in northwest Alaska. Teach college level course in oceanography. Teach a marine safety and vocational training courses in fisheries.

Education:

1985 Master of Science, Fisheries Oceanography, University of Alaska Fairbanks.

1983 Bachelor of Science, Fisheries Science, University of Alaska Fairbanks.

BUDGET

Table 2. Budget summary for the Coghill Lake sockeye restoration project through FY 99[1].

Line Item	FY 95	FY 96	FY 97	FY 98	FY 99
Personnel	116.1	120.5	122.2	58.0	34.5
Travel	1.6	1.8	1.8	1.6	1.6
Contractual	122.0	119.1	119.1	25.1	7.3
Supplies	8.9	7.5	7.5	5.3	1.3
Equipment	0.0	0.0	0.0	0.0	0.0
Total	248.6	248.9	250.6	90.0	44.7
Indirect Costs	25.0	26.4	26.4	10.0	5.3
Grand Total	273.6	275.3	277.0	100.0	50.0

[1]Includes total for ADF&G and the USFS; project is planned to continue through FY 99 for post-treatment assessment.

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Appendix A. Coghill Lake returm-per-spawner summary 1962-1994.

Brood Year	Escapement	Harvest	Total Run	Return	R/S
1962	26,866	.	.	54,520	2.029
1963	63,984	.	.	63,949	0.999
1964	22,200	.	.	163,130	7.348
1965	62,500	.	.	77,666	1.243
1966	82,500	.	.	86,158	1.044
1967	33,000	.	.	153,332	4.646
1968	11,800	.	.	137,508	11.653
1969	81,000	.	.	91,748	1.133
1970	35,200	.	.	220,866	6.275
1971	15,000	.	.	46,728	3.115
1972	51,000	.	.	218,568	4.286
1973	55,000	.	.	233,688	4.249
1974	22,334	102,404	0	110,825	4.962
1975	34,855	147,849	182,704	191,528	5.495
1976	9,056	60,493	69,549	173,531	19.162
1977	31,562	170,778	202,340	1,251,048	39.638
1978	42,284	203,522	245,806	70,303	1.663
1979	48,281	78,800	127,081	150,407	3.115
1980	142,253	59,116	201,369	473,656	3.330
1981	156,112	103,055	259,167	496,238	3.179
1982	180,314	947,431	1,127,745	612,159	3.395
1983	38,783	38,448	77,231	106,297	2.741
1984	63,622	94,977	158,599	203,086	3.192
1985	163,342	350,053	513,395	16,598	0.102
1986	74,135	400,079	474,214	26,918	0.363
1987	187,263	416,353	603,616	60,053	0.321
1988	72,023	83,917	155,940	50,495	0.701
1989	36,881	108,144	145,025	.	.
1990	8,250	12,274	20,524	.	.
1991	9,701	15,202	24,903	.	.
1992	29,642	.	.	.	.
1993	9,232	.	.	.	.
1994	7,264	.	.	.	.

Appendix B. Management activities related to meeting escapement requirements of Coghill Lake sockeye salmon.

Fish stocks in the state are directed by statute (AS 16.05.730) to be managed consistent with sustained yield of wild fish stocks and may be managed consistent with sustained yield of enhanced fish stocks. In addition giving preference to wild stocks over enhanced stocks, this statute also allows the adoption of fishery management plans to guide the Department in managing enhanced stocks.

Sockeye salmon bound for Coghill Lake are harvested primarily in gillnet fisheries in the Eshamy and Coghill Districts in June and July. These fisheries target enhanced stocks of sockeye and chum salmon returning respectively to Main Bay and Noerenberg hatcheries. Management plans for these two hatcheries recognize that fishing may be restricted when wild stock shortfalls occur in the Coghill District (PWSAC 1995). Decisions by the department to conduct common property fisheries in these districts are based upon wild stock escapements and, the strength and origin of the stocks being harvested. Coghill stock sockeye salmon reared at Main Bay have been released on site at the hatchery, into Coghill Lake as presmolts, and as smolts near the mouth of Coghill River. Returning hatchery and wild Coghill stock sockeye salmon are subsequently harvested together in the two fishing districts. The Department recognized it lacked stock and location specific sockeye salmon catch information. Therefore, in 1992 the Department initiated a two year test fishery project in the Eshamy and Coghill Districts to better understand the migration routes used by Coghill bound sockeye salmon and, to gain some insight into the interception rate during commercial fisheries. Stock compositions were determined using scale pattern analysis. Exploitation rates were determined using both scale pattern analysis and coded wire tag recoveries.

The information gathered during these test fisheries has been used to formulate management strategies to provide for protection of Coghill sockeye salmon. Total returns to Coghill Lake have historically averaged 320,000 fish with the majority entering the river between early June and late July. Beginning in 1990 smolt production at Coghill Lake began to decline. The subsequent poor returns and escapement shortfalls at Coghill Lake have resulted in extremely restricted fisheries in the two gillnet districts. The entire Coghill District was last open to commercial fishing in 1989. Since then, the commercial gillnet fleet has been restricted to fishing in either the Esther Subdistrict, a reduced subdistrict, or in the hatchery terminal harvest area in an effort to reduce the harvest of Coghill Lake sockeye. Similar restrictive measures have been incorporated in the Eshamy District. In 1994, the Crafton Island Subdistrict remained closed the entire season to protect weak Coghill and Northwest District stocks which move through the Eshamy District. Closures of the Crafton Island Subdistrict to protect Coghill sockeye occurred in 1993 as well.

Current management strategies include opening gillnet districts concurrently when possible, including the Copper River District, to disperse effort over the greatest area possible. If escapement to the Coghill District is not being met, the Board of Fisheries in 1994 endorsed the use of a reduced Esther Subdistrict, defined as one nautical mile off the southern portion of Esther Island, to harvest enhanced stocks while affording some protection to Coghill wild stocks. In the 1995 PWS Area Commercial Fisheries Salmon Management Outlook (Wayne Donaldson, ADF&G memo to Jeff Koenings), the department outlines it's intent to employ this reduced Esther subdistrict option based on the weak forecast for Coghill Lake sockeye. However, if the escapement at Coghill Lake is still not being met the department intends to use only the Noerenberg Hatchery Terminal Harvest Area to harvest returning enhanced chum stocks. The Crafton Island Subdistrict in the Eshamy District is not anticipated to open during the Coghill sockeye stock run timing.

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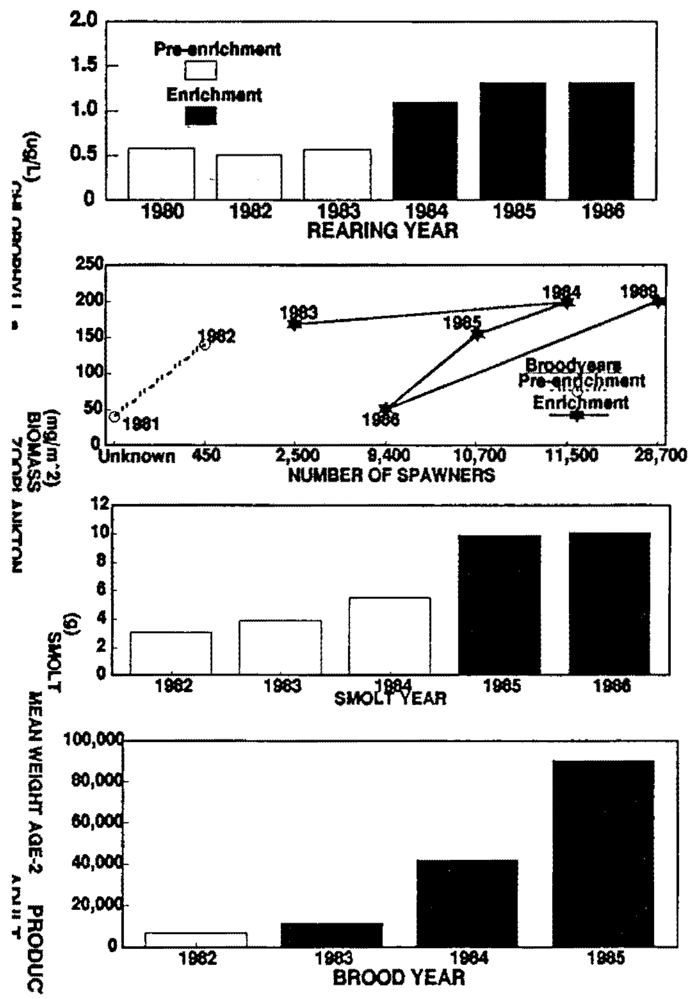
Appendix C. Frazer Lake return-per-spawner summary 1975-1992.

YEAR	ESCAPEMENT	RUN	RETURN	R/S
75	64,199	67,499	299,631	4.7
76	119,321	128,091	709,424	5.9
77	139,548	140,914	425,466	3.0
78	141,981	172,317	235,043	1.7
79	126,742	154,008	59,106	0.5
80	405,535	460,248	761,264	1.9
81	377,716	487,926	29,471	0.1
82	430,423	506,655	80,172	0.2
83	158,340	196,323	1,038,092	6.6
84	53,524	67,377	503,856	9.4
85	485,835	637,871	160,412	0.3
86	126,529	178,377	2,225,638	17.6
87	40,544	58,163	384,663	9.5
88	246,704	457,707	271,566	1.1
89	360,373	1,070,871	357,175	1.0
90	226,707	979,833	1,096	0.0
91	190,358	1,268,145	0	0.0
92	185,825	418,773	0	0.0

Appendix D. Summary of lake fertilization of Redoubt Lake (a meromictic lake located near Sitka, Alaska).

During pre-enrichment of Redoubt Lake, sockeye escapements were relatively low (<1,000) and zooplankton biomass averaged 90 mg m^{-2}. During the years when the lake was treated with nutrients, zooplankton biomass ranged between 160-200 mg m^{-2} (except for 1986), despite much larger recruitment of fry from adult escapements (2,500-28,700). Juvenile biomass is not available for Redoubt Lake; however, the weight of the dominant age-2 sockeye smolts reveal the effect of nutrient enrichment. That is, during pre-enrichment the mean weight ranged from ~2.5-5.0 g (1982-1984), whereas during enrichment (1985 and 1986) age-2 smolts were consistently 10 g. For Redoubt Lake, only one (complete) brood-year production is available before nutrient enrichment; however, adult production has progressively increased and was substantially higher (7-fold increase) than before enrichment.



Appendix E. Response to reviewer comments on smolt estimation methodology.

Two important assumptions in single mark-recapture estimation (both of which apply to the smolt trap method) are (*i*) all animals have an equal probability of capture in the first sample and (*ii*) the second sample is a simple random sample (Seber 1982; Krebs 1989). In general the same sampling device is used for both samples. Seber (1982) discusses effects and possible remedies for departures from these assumptions. If assumption (*i*) is invalid, the more catchable individuals will be caught in the first sample which will lead to a higher catch rate of marked individuals in the second sample. This will ultimately result in an estimator that is biased low. In fisheries, catchability usually varies with the size of the fish (e.g., Ricker 1975). Seber states that little can be done to remedy this problem unless 1) different trapping methods with different selectivity are used for the two samples or 2) subgroups of the population with constant catchability are estimated separately. Relative to smolt enumeration programs in Alaska, these alternatives need to be assessed in terms of feasibility.

The current method used in Coghill River, which was adapted from Cochran (1978) by Rawson (1984), provides an estimate of trap efficiency that is expanded to estimate sockeye smolt abundance. Inclined plane traps (Todd 1994) placed in one location are used to obtain both samples; marked smolt are re-released several hundred meters upstream. A temporally stratified sampling design is used to account for changes in trap efficiency that may be related to fluctuations in stream discharge and variation in catchability. Weekly strata are used and the stratum estimator is unbiased under the usual assumptions of mark-recapture estimation. It is common knowledge that outmigration timing is related to the age thus size of smolt (e.g., Todd and Kyle 1991) . The temporal stratification should therefore satisfy, reasonably well, Seber's remedy #2 since size-based subgroups of the population are estimated separately. Mark-release numbers for Coghill Lake are also projected to obtain a relative error within 25% at the 95% confidence level (a 20.4% relative error was achieved in 1994, for example).

Use of a different trapping method for the first sample (remedy #1) is not currently feasible, primarily because of prohibitive costs and lack of availability of a trap that is either non-selective or has a (known) different selectivity than the inclined plane trap. Installation of a smolt weir is also not possible due to the size of the river and discharge patterns. A method recently described by Schwarz and Dempson (1994), although deserving of further consideration, has practical limitations because it requires operation of two partial weirs separated by several kilometers. In other mark-recapture studies tests of equal catchability have been applied (Chapman 1952; Cormack 1966; Caughley 1977). However, these procedures all require sample collection at three or more different times, which would be difficult if not impossible to perform on a migrating smolt population. The final option is to obtain concurrent weir censuses (N) and trap abundance estimates ($\hat{N}$), in systems where feasible, and test the hypothesis of no difference using a simple one sample test (*t* or *z*, since sample sizes are large). This type of experiment was conducted at Red Lake, Kodiak Island in 1992 (Barrett et al. 1993). The no difference hypothesis was not rejected ($z = -0.672$; $p = 0.251$), indicating no evidence of bias in the abundance estimate for this system. Results are summarized as follows (note that the 95% confidence interval contains the parameter N):

$$N = 1{,}314{,}373$$

$$\hat{N} = 1{,}210{,}554 \quad 95\%\ \text{CI}\ (907{,}945 - 1{,}513{,}163)$$

It is also worth noting that Red Lake produces much larger age-1 smolt – approximately 5-10 g – than Coghill Lake, which typically range from 1-2 g.

The smolt program at Coghill Lake has improved steadily since it was initiated in 1989. Improvements have included weekly stratification (begun in 1991) and placement of traps in a more suitable location downstream (1994). Smolt estimates have been acceptable with respect to escapement numbers and projected survival based on fall fry hydroacoustic estimates. The current program appears to be providing reasonably accurate estimates, suitable for meeting the objectives of the project.

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95266

Prince William Sound Shoreline Restoration (Revised 11/4/94)

Project Number:	95266
Restoration Category:	General Restoration (continuation of 94266)
Proposed By:	Various members of the public
Lead Trustee Agency:	ADEC
Cooperating Agencies:	NOAA, DOI
FY 95 Cost:	$172,900 (includes $97,900 for sample analysis, data analysis and report writing for FY 94 field work)
FY 96 Cost:	Unknown.
Total Cost:	Unknown.
Duration:	1 year. Additional work may be proposed, depending on the results of the project.
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harlequin ducks, black oystercatchers, juvenile otters, subsistence, recreation and tourism, and intertidal and subtidal organisms

INTRODUCTION

In spite of the extensive cleanup efforts that followed the spill and five year's of natural weathering, the 1993 and 1994 shoreline assessments (projects 93038 and 94266) identified beach segments where residual shoreline oil is still obvious, and may still be influencing recovery of resources and services. In addition, Project 94090 identified mussel beds with residual, often unweathered, oil that may also be influencing injured resources and services. These beaches and mussel beds have proven difficult to cost-effectively and safely restore.

This project would fund the Alaska Department of Environmental Conservation, in cooperation with other agencies and the most-affected local community, Chenega Bay, to review available technologies to determine whether any have the potential for cost-effective, safe treatment of these oiled beaches. If techniques are identified, the project may also complete a test on one or more oiled beach segments to determine whether one or more of the techniques will function safely and effectively in the sub-arctic environment of Prince William Sound.

The review and testing is anticipated to cost $75,000 in FY 95. In addition, the project provides $97,900 for sample analysis, data analysis and report writing for FY 94 field work of project 94266. NOAA and DOI are cooperating agencies with respect to the report for 94266. The new part of the project will be undertaken in cooperation with NOAA.

If testing is undertaken in FY 1995, monitoring will be required in FY 96. If testing is not undertaken, the final report will be written in FY 95, and no additional funds will be needed in FY 96. If appropriate, proven or provable technologies are identified, a new project to use the technologies may be submitted in FY 96.

This project is proposed to respond to: 1) requests from the public (especially Chenega Bay) for additional restoration work on the beaches, and 2) proposals from private sector companies that have approached the Trustee Council and ADEC with technologies and cleaning techniques to restore oiled shoreline areas that are not responding well to natural recovery.

The presence of substantial levels of petroleum hydrocarbons persisting under dense mussel beds in Prince William Sound and the Gulf of Alaska provides a continuing source for oil to enter the food chain, potentially impacting higher consumers, especially harlequin ducks, oystercatchers, juvenile otters, and humans. There is a possible link between the presence of oiled mussels and the disruption of reproduction in harlequin ducks and increased mortality in oystercatcher chicks.

The presence and removal of residual shoreline oil is important for subsistence, recreation, sediments, mussels, and intertidal and subtidal organisms. It is also relevant to harlequin ducks, sea otters, and other injured species that feed in the intertidal area. In addition, while oil itself is not an injured resource or service, it is the cause of the injuries.

NEED FOR THE PROJECT

The oil on the beaches in the spill area is disappearing through microbial degradation, photo-oxidation, mechanical abrasion and other means. The oil on most beaches is noticeably disappearing over time. There are about a dozen beaches where natural recovery is proceeding at a very slow rate. These beaches have recently been listed by EPA and ADEC as impaired under the auspices of the Clean Water Act. There are another approximately twelve beaches that are not much better. These same beaches were difficult to deal with during the cleanup. Treatment of these beaches in the past was expensive and would probably be so in the future.

Shoreline Oil. The results of previous shoreline assessments have demonstrated that surface oil in the spill area has become very stable and is showing little sign of degradation. The Trustee Council authorized a project in 1994 to treat some beaches with hard surface asphalt deposits. The asphalt was broken up into very small particles that are much more susceptible to degradation by microbes and photo-oxidation. That method is much less effective on the surface oil deposits that are hard on the outside and still a gooey liquid on the inside. Some of these deposits are up to 20 cm thick.

Between 1991 and 1993, subsurface oil at comparable sites in Prince William Sound decreased on average by about one half. Still, at some sites (approximately 12) there has been little reduction in subsurface oil. These sites are primarily in low energy areas so that recovery is not aided by wave action. Most of the beaches are either heavily rock armored or have large boulders or both. The oil is often between or under large rocks. The beaches were heavily oiled by the spill and the oil is usually in the form of a gooey brown emulsification of oil and water (mousse). The worst sites still sheen. On average, the sites are approximately one quarter to one half mile long by 50 to 75 yards wide. Most of the oil is in the high-intertidal area with small amounts in the mid-intertidal area. Very little oil is in the low-intertidal area.

Contaminated Mussel Beds. Residual subsurface oil presents a harmful set of problems where mussel beds exist in low wave energy areas. Most of the cleanup effort in 1989 through 1991 avoided the protected mussel beds since mussels are an important food source for a variety of organisms including sea otters and birds. The byssal mats and the layer(s) of mussels themselves protect the oil in an anaerobic environment and retard natural weathering and cleaning. Microbial degradation proceeds very slowly in an oxygen free environment. There appears to be slow remobilization of the oil from the sediments to the mussels, which likely provides a continuing source of oil contamination in Prince William Sound. The oiled mussels continue to be a probable route of oil exposure to higher level predators such as sea otters, harlequin ducks, and black oystercatchers — resources that have not yet begun to recover from the spill. This continuing exposure is expected to significantly delay recovery from the spill in some predators, for example in harlequin ducks. Although the oiled mussel beds are relatively few in number, since they occur in protected areas and since animals and birds tend to feed in protected areas, especially during storms, it seems likely that the oiled mussel beds are a more important source of contamination to higher trophic level organisms than would initially be indicated by the number of remaining oiled mussel beds.

Approximately 70 mussel beds were surveyed this summer in Prince William Sound as a part of project 94090. About 15 were cleaned. The primary method for cleaning contaminated mussel beds in project 94090 was a procedure that removed and replaced the oiled sediments from under the beds with little harm to the mussels. This procedure evolved from minimally intrusive site manipulations conducted in 1992 and 1993 by NOAA. However, that method cannot be used with all of the important and contaminated mussel beds in western Prince William Sound. Another method must be found if the remaining approximately 15 known substantially oiled beds are to be cleaned. Most of the remaining mussel beds are characterized by large rocks. Often there is no close source of replacement sediments.

Discussion with residents, especially from Chenega Bay; interviews with recreational users; and comments from the general public indicate that in some locations the remaining oil has important social and economic consequences. Chenega residents have been adamantly unsatisfied with the oiled condition of several clusters of beaches regardless of the technical difficulties involved in further treatment. Some of the Chenega-area sites contain some of the most persistence, heavy and medium oil residual concentrations found in the spill area. While these sites probably will continue to improve over a long time, this does not appear to be acceptable to the people of Chenega Bay, who hunt and fish and beachcomb in the area adjacent to their village on a day-to-day basis. They have expressed continuing interest in accelerating the improvement through treatment of some kind.

PROJECT DESIGN

A. Objectives

1. Review new and currently available technologies to determine the potential for cost-effective, safe restoration of oiled beaches that remain in southwestern Prince William Sound.

2. If appropriate, perform one or more tests on oiled beach segments in southwestern Prince William Sound, to determine whether one or more of the techniques will safely and effectively function in the sub-arctic environment of Prince William Sound.

3. Complete sample and data analysis, and prepare a final report for Project 94266 (the field work for that project was completed in FY 94).

4. Write report (and use other means) to communicate results to Trustee Council, scientists, and community representatives.

B. Methods

METHODS, Objective 1

1. Establish appropriate review group including representatives of ADEC, NOAA, the U.S. Coast Guard, and the community of Chenega Bay.

2. Review information on the conditions of problematic beach segments in southwestern Prince William Sound. Conduct literature and technology search to determine parameters, and effectiveness, and degree of testing of existing and newly available technologies to clean residual oil from the segments.

METHODS, Objective 2:

3. In cooperating with Trustee Agencies and the village of Chenega Bay,
   a) determine if appropriate technologies are available and if testing is appropriate. If testing is appropriate, determine the appropriate beach segment(s); and
   b) undertake test; and
   c) develop and conduct monitoring program before and after beach treatment.

METHODS, Objectives 3:

4. Write final report.

C. Schedule

Schedule Without Test

November-December 1994	Establish Review Group
January - April 1995	Conduct Review. Determine lack of appropriate techniques.
June 1995	Draft Report
September 1995	Final Report

Schedule With Test

November-December 1994	Establish Review Group
January - March 1995	Conduct Review. Determine potential technique(s) for testing.
April- June 1995	Prepare test methodology and logistics
June 1995	Pre-test monitoring
June-August 1995	Conduct test and Initial Post-test monitoring
October 1995	Draft Report
April 1996	Final Report (may be delayed if a second season of monitoring is required.)

D. Technical Support

If a test is undertaken, hydrocarbon sample analysis and mussel monitoring will be conducted by NOAA's Auke Bay Laboratory, as appropriate. Other monitoring components, as necessary, will be carried out by the appropriate entities which will be determined once agreement is reached on the monitoring program.

E. Location

Southwest Prince William Sound

PROJECT IMPLEMENTATION

Implementation will be by the Alaska Department of Environmental Conservation in cooperation with NOAA, the U.S. Coast Guard, and the community of Chenega Bay.

FY 95 BUDGET ($K)

Personnel	$12.9
Travel	3.6
Contractual	50.9
Commodities	2.1
Equipment	0.0
Subtotal	$69.5
Gen. Admin.	5.5
Total	$75.0

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

1. **Project Title:** Chenega Chinook Release Program

2. **Project Number** 95272

3. **Lead Trustee Agency:** AK. Dept. of Fish and Game (ADF&G)

4. **Cooperating Agencies:** None

5. **Project Start-up/Completion Dates:** January, 1995 - September, 1995

6. **Expected Project Duration:** 4 years

7. **Cost of Project:** FY95 $47.2; FY96 $51.9; FY97 $57.1; FY98 $62.8

8. **Geographic Area:** Crab Bay near the Chenega village on Evans Island in PWS

9. **Name/Signature of Project Leader(s):**

Project Leader:

Eric Prestegard

Phone (907) 424-7511
FAX (907) 424-3823
Mailing address PWSAC
P.O. Box 1110
Cordova, AK 99574

10. **Name/Signature of Lead Agency Project Manager**

Joseph Sullivan

Phone (907) 267-2213
FAX (907) 522-3148
Mailing address ADF&G
333 Raspberry Road
Anchorage, AK 99518-1599

A. INTRODUCTION

Oil spilled from the ruptured tanks of the *Exxon Valdez* spread throughout much of the waters of Prince William Sound (PWS). In the wake of this disaster, numerous species and populations of marine resources were impacted. Direct oiling of salmon spawning streams, intertidal beaches, marine mammals, and birds, resulted in injury and in some instances death of affected organisms. In particular, pink salmon were injured and classified as not recovering. As consequence from the injury to the marine resources, associated human activities based in the harvest and utilization of injured resources were curtailed and described as injured services.

Heavy oiling and injury occurred in Southwest PWS in the immediate vicinity of the village of Chenega Bay. Local subsistence harvesting of marine resources was impacted. In 1992 residents of Chenega Bay proposed to the Alaska Department of Fish and Game to begin a release of hatchery incubated chinook salmon *Oncorhynchus tshawyscha* to replace injured marine resources and restore subsistence harvesting services to local residents. Due to the lengthy review and permitting procedures required to implement such a restoration project, the first release of chinook salmon smolt could not be executed until the summer of 1994.

Project 95272 proposes a continuation of the Chenega chinook salmon release project which is anticipated to result in adult salmon returning to waters adjacent to Chenega Village beginning in 1996. The project is recommended for continuation through 1998.

B. PROJECT DESCRIPTION

The project calls for releasing 50,000 chinook salmon smolt at Crab Bay duplicating the number of fish released in 1994. This program is planned to result in a return of adult chinook salmon to Crab Bay reaching a projected 2,000 salmon of different age classes in 1998. Adult chinook salmon will begin returning in 1996. At an average of 20 pounds per fish, 40,000 pounds of salmon are expected to be harvested during years of peak returns.

1. Resources and/or Associated Services:

Marine resources harvested in the vicinity of Crab Bay include salmon, marine invertebrates, birds, marine mammals, and other organisms. There are no local populations of chinook salmon. However, the replacement of injured resources with the highly desirable chinook salmon will provide both an attractive alternative resource for harvest and restore activities associated with the subsistence lifestyle.

2. Relation to Other Damage Assessment/Restoration Work:

Continuation of this project through FY98 will provide a replacement resource to local harvesters into the year 2002. Recovery of many oil injured species may take generations. Chinook salmon returning to Crab Bay will therefore provide an alternative resource. While research is ongoing into species biology, systems relationships, and recovery, the execution of this project will aid localized and near term restoration/replacement subsistence needs.

3. **Objectives:**

A. Rear and release 50,000 Wally Noerenberg Hatchery chinook salmon smolt in Crab Bay near the village of Chenega Bay on Evans Island beginning in Spring, 1995.

B. Develop a return of 2,000 adult chinook beginning in 1998. At an average of 20 pounds per returning chinook, Chenega residents can expect to harvest 40,000 pounds of salmon annually. This projection is based on current fish culture criteria including marine survivals and growth.

4. **Methods:**

Annually, 820,000 chinook salmon eggs are taken at PWSAC's Wally Noerenberg hatchery (WNH) on Esther Island. Brood stock are harvested from among adult chinook salmon returning to the hatchery. Following incubation, hatch and outmigration from incubator trays, chinook fry are reared in raceways at WNH for one year. Prior to release, chinook smolts are transferred to saltwater net pens at the hatchery or to remote release sites for a short period of saltwater rearing.

In the spring of 1995, 50,000 chinook smolt will be taken from WNH and transported via barge and fry/smolt transport tanker to Crab Bay. The smolt will be released into a 350 m^3 (40 ft X 40 ft X 5 ft) net pen anchored in Crab Bay. Smolts will be reared for approximately two to three weeks at the site for imprinting and additional growth prior to release. Technical support for the incubation, hatching and feeding of the smolts will be provided by PWSAC. Residents of Chenega village will be contracted, trained in smolt feeding and rearing, and paid for services.

5. **Location:**

The location for the release is in Crab Bay, located near the village of Chenega Bay on Evans Island in PWS.

6. **Technical support:**

Technical support for the project will be provided by PWSAC. Feeding at the release site will be accomplished by the residents of Chenega.

7. **Contracts:**

A. Cooperative agreement between Alaska Department of Fish and Game and Prince William Sound Aquaculture Corporation to provide, rear, and release 50,000 chinook salmon smolts at Crab Bay. This contract will enable payment by the lead agency to PWSAC for salmon smolt and services (broodstock harvest, egg-take, incubation, coded wire tagging, and transportation). PWSAC operates the only hatchery in PWS which cultures chinook salmon.

B. Contract for services between PWSAC and Chenega Bay (Chenega Corporation) for residents to provide onsite care and feeding for smolts during netpen rearing and imprinting phase at Crab Bay. Residents of

Chenega Bay are locally available throughout the day to monitor the netpen and feed the smolt on a prescribed schedule.

C. SCHEDULE:

Activity	Begin	Complete
Rearing (smolt)	**4/94**	5/95
Outmigration (fry)	3/95	4/95
Install net pen	5/95	5/95
Feed and imprint smolt	5/95	6/95
Release smolts	6/95	6/95
Dismantle/Remove net pen	6/95	6/95
Eggtake	7/95	8/95
Incubation	8/95	**3/96**
Final report submission	9/95	10/95

Personnel needed to carry out project include:
- project leader: oversight, coordination, transportation, reporting;
- hatchery manager: hatchery site management and quality assurance;
- fish culturist: egg-take, incubation and rearing;
- Chenega residents: netpen feeding.

Logistics needs:
- primary logistical demand is barge transportation of smolts in stainless steel oxygenated tanks to site of release.

D. EXISTING AGENCY PROGRAM

N/A

E. ENVIRONMENTAL COMPLIANCE, PERMITTING AND COORDINATION STATUS

Permits are currently in place. Permits and NEPA compliance include:
- NEPA Environmental Assessment (FONSI, 1994);
- hatchery permit alteration (PAR), ADF&G, 1994
- fry transport permit (FTP), ADF&G, 1994
- DOA Army Corp permit to anchor netpen in navigable waters;
- DNR tidelands lease, bond and insurance;
- Coastal Zone Management Consistency determination;
- letter of permit from uplands owner to support tidelands lease;
- US Coast Guard permit, netpen lighting designation, and annual notification of netpen installation and removal.

F. PERFORMANCE MONITORING

Quality assurance begins at brood stock selection and egg-take. Fish culture criteria are stipulated in the operation manual for Wally Noerenberg Hatchery. Quality assurance covers numbers of eggs taken, number of viable eggs, incubation water temperature and oxygen concentration monitoring, egg incubation monitoring and cleaning, fry outmigration and enumeration, coded wire tag placement assessment, food analysis and dietary scheduling, oxygenation of water during transport and ongoing observation for health and disease symptoms. Hatchery monitoring calls for written reports on above fish culture criteria; conferences are arranged to discuss health and disease concerns with ADF&G pathologists.

The project timeline is principally based on the biological cycle of salmon; activities outlined in schedule (above) must occur within date windows to meet conditions of salmon growth, development and readiness for release in marine waters.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

The release of chinook salmon smolts at Crab Bay adjacent to the village of Chenega is conducted to provide replacement salmon resources to users. The program is not integrated with research conducted through funding by the *Exxon Valdez* Oil Spill Trustee Council. However, chinook salmon smolts released at Chenega Bay are coded wire tagged (CWT) and may be recovered in future fisheries to examine imprinting precision, marine survival, migration patterns or other aspects of salmon biology and fishery management required by PWSAC or the ADF&G.

H. PUBLIC PROCESS

Alaska state law requires that PWSAC, as the regional aquaculture corporation in PWS, be comprised of representatives from all interested user groups and possess a board of directors "which includes no less than one representative of each user group that belongs to the association". The concept of a regional association is intended to allow active public participation in the salmon rehabilitation program. The PWSAC board of directors is comprised of: commercial / sport / subsistence / personal use fisherman, native representatives from villages in PWS and the Copper River region, representatives of the fish processing industry and representatives of the communities in PWS. To the extent that PWSAC is directed by a board of all interested users of the salmon resources in PWS, PWSAC will assist with this project and advocate for future funding.

This project has also been reviewed and recommended by the PWSAC Production Planning Committee through its planning process and public notification, and the PWS-Copper River Regional Planning Team (RPT) which has publicly noticed, reviewed and recommended permitting of the project. Further, the project has been publicly noticed by the *EVOS* Trustee Council through its proposal review process, and has been reviewed and recommended by the Public Advisory Group (PAG).

I. PERSONNEL QUALIFICATIONS

Eric Prestegard

Work experience

1989-date: Production manager for PWSAC. Oversees operations of five salmon hatcheries producing five species of Pacific salmon. Works with the PWSAC and regional planning groups to develop fish production goals. Responsible for achievement of hatchery production objectives. Works with ADF&G and other state and federal agencies to assure the PWSAC enhancement program is in compliance with regulations and required permits. Works with hatchery staff, fish culture industry, ADF&G and scientific community to develop research goals for the enhancement program.

1987-1989: AFK hatchery manager, PWSAC. Responsible for all phases of fish culture and production at hatchery.

1985-1987: AFK hatchery fish culturist and assistant manager, PWSAC.

1982-1985: Fish culturist, Oregon Aqua-foods.

1979-1981: Research technician, Domsea Farms

Education

1976-1978: Mt. Hood Community College, A.S. Degree in Fisheries Science.

Exxon Valdez Oil Spill Trustee Council
FY 95 Detailed Project Description

Project Title: Subsistence Restoration Project:
Resource Abnormalities Study

Project Number: 95279

Lead Trustee Agency: Alaska Department of Fish and Game

Project Start-up/Completion Dates: 10/1/94-9/30/95

Expected Project Duration: 2 years

Cost of Project:
Fy 95-$180,600
Fy 96- $51,500

Geographic Area: Prince William Sound, the Kenai Peninsula, and Kodiak Island

P.I. Fall

Name/Signature of Project Leader:

Rita Miraglia
Rita C. Miraglia
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Restoration Project 95279

A. INTRODUCTION

Subsistence uses of fish and other wildlife constitute a vital natural resource service that was injured by the *Exxon Valdez* oil spill. Data collected by the Alaska Department of Fish and Game's Division of Subsistence demonstrated this injury. Annual per capita subsistence harvests declined dramatically (from 4 percent to 77 percent decline compared to pre-spill averages) in 10 of the communities in the path of the spill during the first year after the event. In subsequent years, levels of subsistence harvests, ranges of uses, harvest effort, and the sharing of resources have gradually increased in all of the spill area communities. Some subsistence users reported renewed confidence in traditional foods after receiving information and health advice from the Oil Spill Health Task Force. Others returned to using subsistence foods despite their misgivings because of economic and cultural reasons. Still others have traveled to unoiled areas to harvest resources. A view persists in the communities in the oil spill area, that the natural environment has changed in ways that still pose a potential threat to their health and their way of life. This view is partly fueled by observed abnormalities in resource species, and scarcity of some resources.

We propose to continue a subsistence restoration project involving the following communities; Chenega Bay, Tatitlek, Cordova, Valdez, Nanwalek, Port Graham, Seldovia, Kenai, Seward, Larsen Bay, Karluk, Old Harbor, Akhiok, Port Lions, Ouzinkie, Kodiak City, Chignik Lake, Chignik, Chignik Lagoon, Perryville and Ivanof Bay.

In 1993 and 1994 the *Exxon Valdez* Trustee Council provided funding to restore the subsistence uses of fish and wildlife damaged by the *Exxon Valdez* Oil Spill. Community meetings were held in order to identify and map the specific areas and resources of continued concern to subsistence users. Samples of those subsistence species cited in community meetings as being of continued concern were collected from harvest areas identified during the mapping, with community representatives assisting in site selection, as well as the collection of samples. The samples were analyzed for the presence of hydrocarbon contamination at the National Oceanic and Atmospheric Administration/National Marine Fisheries laboratory in Seattle. Community tests, along with findings from other damage assessment and restoration studies, were interpreted by the Oil Spill Health Task Force, and reported to the communities in an informational newsletter and community visits.

At this point, there is little we can learn about subsistence food safety from additional hydrocarbon testing, and barring unforeseen circumstances, we will not be doing any further testing of this kind. The remaining samples will be analyzed by NOAA this winter; NOAA will provide a report of its hydrocarbon analysis in the spring of 1995. The 1995 project will continue efforts to communicate information on subsistence food safety to the communities, through the Subsistence Restoration Newsletter. The Newsletter will also be used to report information on other restoration projects, putting the information into context for subsistence users. In addition, we will put in place a system for getting samples of abnormal resources from subsistence users to biologists and pathologists for study and will report the findings of the scientists to subsistence users.

This project will assist the Trustee Council in making decisions concerning restoration, enhancement or replacement of lost subsistence resources and uses.

B. PROJECT DESCRIPTION

1. Resources and/or Associated Services:
The goal of the project is to restore the subsistence uses of fish and wildlife damaged by the *Exxon Valdez* oil spill. If the project results in a return to greater use of subsistence foods, this could be beneficial for the physical and emotional health of community residents who have suffered from the increased reliance on store-bought food. This applies especially to the elders, who were the most accustomed to subsistence resources through a lifetime of reliance on locally-harvested wild resources. Younger people will also benefit, as a resumption of subsistence activities will allow them the opportunity to learn the skills necessary to live in these rural communities.

This project answers the need to continue to monitor the risks to human health from the oil spill. This is consistent with the goal of restoring human services of the natural resources damaged in the oil spill. It also addresses the need to restore the natural resources and the services these resources previously provided to subsistence users. Additionally, the project will give biologists and pathologists the opportunity to see examples of abnormalities in resource species that they might not other-wise encounter given their limited time in the field. In this way, this project has the potential of increasing the database these researchers have to work with in trying to understand the effects the *Exxon Valdez* Oil Spill may have had on the ecosystem.

This project also fills, in part, the need to involve residents of the spill area as full partners in restoration activities.

2. Relation to Other Damage Assessment/Restoration Work:
This project pulls together information from damage assessment and restoration projects regarding the oil spill injury to and recovery of various subsistence resources (including salmon, herring, harbor seals, ducks, and shellfish). This information is then put into context with subsistence food safety advice, and presented to

subsistence users in Oil Spill Health Task Force Meetings, community meetings, household visits, and informational newsletters.

The project will assist restoration project researchers working with injured resource populations by providing them access to abnormal specimens harvested by subsistence users. Researchers have expressed an interest in seeing such specimens because due to limited field time and small sample sizes they are less likely to encounter such abnormalities. These specimens may provide clues to on-going problems caused by the spill.

Information gathered as part of a study of oil spill impacts on the communities in the spill area, undertaken jointly by the Division of Subsistence and the U.S. Minerals Management Service, is also used to evaluate the effectiveness of this project and determine where more attention is needed.

3. Objectives:
The goal of the project is to restore the subsistence uses of fish and wildlife damaged by the *Exxon Valdez* Oil Spill. It is expected that by responding to the specific oil spill related concerns of subsistence users, and reporting accurate health information back to the affected communities in clear, understandable language and in one-on-one discussions, subsistence users' confidence in the resource can be restored. Past efforts in this direction have been partially successful.

The following dates refer to the completion of activities for fiscal year 1995. Sampling kits will be in place in the communities by June 15, 1995, and the participating scientists will have been recruited by the same date. Four issues of the Subsistence Restoration Newsletter will be produced. The last round of community meetings will take place in September 1995.

4. Methods:
Community meetings will be held in eleven communities (Chenega Bay, Tatitlek, Nanwalek, Port Graham, Seward, Larsen Bay, Karluk, Old Harbor, Akhiok, Port Lions, and Ouzinkie) to identify any continued oil spill related concerns of subsistence users. Other communities may be added if such concerns are noted by Subsistence Division researchers during community visits. Those communities where no concern is indicated in either the community meetings or by other communication will be dropped from the study.

A system will be put into place whereby subsistence users can send samples of abnormal resources that they encounter to biologists and pathologists to be examined. Scientists willing to examine different types of specimens will be identified by the Division of Subsistence. Community residents will need to be trained to properly preserve, package and ship the different types of samples. Sampling kits and instructions will be placed in each community, with an account set up with an air carrier to transport samples from the communities to Anchorage. The training of subsistence users and the assembling of kits will be contracted out on a competitive basis. Reporting the information from the scientists to the subsistence users will be done by the Division of Subsistence.

Communication of health advice and information on restoration projects to residents of the impacted communities will require the production of a quarterly Subsistence Division newsletter. It is important that the findings of restoration studies be integrated into this communication effort. As this information is released it may cause renewed concern among subsistence harvesters. It is not always possible to anticipate the effect a technical report, or the media accounts derived from it, will have in these communities. The newsletter will serve to put this information in context for subsistence users. It will also be important to follow distribution of the newsletter with community visits. These can involve informal visits to households and/or formal meetings. The purpose will be to further the dialogue between researchers and the communities regarding study findings.

By involving subsistence users in decisions affecting mitigation, and the monitoring, enhancement and replacement of the natural resources, we can accelerate the recovery of the resources subsistence users rely upon. There is a need in these communities to actively participate in restoration of the environment. This project provides for such involvement.

5. Location:
Field work will be conducted on Prince William Sound, the Kenai Peninsula, and Kodiak Island. The communities of Chenega Bay, Tatitlek, Nanwalek, Port Graham, Seward, Larsen Bay, Karluk, Old Harbor, Akhiok, Port Lions, and Ouzinkie will be involved. Other communities may be added if similar concerns are identified.

6. Technical Support:
Technical support will be needed from biologists and pathologists with various state and federal agencies. Some have already indicated their willingness to participate in such a project.

7. Contracts:
The training of subsistence users to collect samples and assembling of collection kits will be contracted out on a competitive basis. Typesetting and printing of four issues of an informational newsletter will also be contracted out. These task involve specific skills, and can be more efficiently completed by a professional.

C. SCHEDULES

February 1995	Informational Newsletter issued.
Feb-June 1995	RFP goes out for kit assembly and training. Work on lining up agency researchers to look at samples. Set up accounts with air carriers to transport samples.
March 1995	Community meetings.
April 1995	Contract awarded for kit assembly and training. Informational Newsletter issued.
June 1995	Training complete, kits in place in communities, scientists lined up. From this point on subsistence users will be able to send in samples.
July 1995	Informational Newsletter issued.
August 1995	Informational Newsletter issued.
April 1996	Final report on fiscal year 1995 activities.

D. EXISTING AGENCY PROGRAM

The Division of Subsistence has been conducting annual household harvest surveys in many of the communities included in this project since 1989. As part of the interviews, we collect information on the relative degrees of confidence in the safety of subsistence resources, and fear of contamination. This is both a result of specific questions on this topic, and of answers to open ended questions regarding changes in the subsistence harvest.

E. ENVIRONMENTAL COMPLIANCE, PERMITTING, AND COORDINATION STATUS

This project is categorically excluded under NEPA guidelines.

All samples will be taken from animals harvested by local hunters or fishers for subsistence use, by the hunters and fishers themselves.

F. PERFORMANCE MONITORING

The progress of the project will be monitored by the Oil Spill Health Task Force. In the past, the member groups in the Oil Spill Health Task Force have included the Indian Health Service, the North Pacific Rim (Chugachmuit), the Kodiak Area Native Association, the Alaska Department of Fish and Game, the United States Coast Guard, and the National Oceanic and Atmospheric Administration.

Restoration Project 95279

Four informational newsletters will be produced, summarizing project findings and test results. A final report and data summary will also be provided at the conclusion of fiscal year 1995 activities.

G. COORDINATION OF INTEGRATED RESEARCH EFFORT

This project pulls together information from damage assessment and restoration projects regarding the oil spill injury to and recovery of various subsistence resources (including salmon, herring, harbor seals, ducks, and shellfish). This information is then put into context with the subsistence food safety advice, and presented to subsistence users in community meetings, household visits, and informational newsletters.

H. PUBLIC PROCESS

The Subsistence Restoration Newsletter will continue to communicate information on subsistence food safety as well as report on other oil spill restoration projects. Community meetings will be held in eleven communities to identify any continued oil spill concerns of subsistence users and discuss new findings.

I. PERSONNEL QUALIFICATIONS

James Fall: Dr. Fall is the regional program manager for the Division of Subsistence, Alaska Department of Fish and Game, for southcentral and southwest Alaska. He has held this position since 1981. Since 1989, he has supervised the division's oil spill response and research program. Also, he has served as the department's representative on the Oil Spill Health Task Force. Dr. Fall has written several articles and reports on the effects of the *Exxon Valdez* oil spill on subsistence activities and harvests, based upon division research.

Rita Miraglia: Ms Miraglia has served as the oil spill coordinator for the Division of Subsistence since 1990. As such, she has organized and participated in the subsistence resource collection and testing programs of 1990 and 1991. She has also been the lead communicator of study findings to communities through organizing community meetings and writing newsletters. She has also assisted the Oil Spill Health Task Force's activities.

Craig Mishler: Dr. Mishler has been a Subsistence Resource Specialist with the Division of Subsistence since 1989, with primary responsibility for Kodiak Island. He organized and conducted the division's subsistence resource collection and testing program in the Kodiak Island area in 1990 and has participated in Oil Spill Health Task Force informational meetings there in 1989 and 1992.

Ron Stanek: Mr. Stanek has been a Subsistence Resource Specialist with the Division of Subsistence since 1980, with substantial research experience in the lower Cook Inlet Region.

Bill Simeone: Dr. Simeone was added to the Division of Subsistence Staff in 1995 as a Subsistence Resource Specialist. He has extensive prior research experience in most communities in the oil spill area.

Subtidal Monitoring: Recovery of Sediments in the Northeastern Gulf of Alaska

Project Number:	95285-CLO
Restoration Category:	Monitoring (closeout)
Proposed By:	NOAA
Cost FY 95:	$121,000
Cost FY 96:	$0
Total Cost:	$121,000
Duration:	1 year
Geographic Area:	Gulf of Alaska
Injured Resource/Service:	Subtidal organisms

P.I Jeep Rice

INTRODUCTION

Subtidal sediments were found to be contaminated by oil at five locations in the Gulf of Alaska (GOA) in 1989. Although hydrocarbon contamination was usually confined to shallow sediments (0-3 m) in GOA, sediment contamination reached a depth of 20 m at at least one location (Chugach Bay). Recovery rates of subtidal marine sediments contaminated by petroleum hydrocarbons at the latitude of GOA are poorly known. Recovery to background levels of hydrocarbons in subtidal sediments at the contaminated sites in GOA may be nearing completion. The purpose of this project was to determine the amount of oil remaining in the subtidal environment at the locations formerly contaminated by oil in GOA sediments there and to compare the amount of oil remaining in sediments at those locations with that at comparable locations in Prince William Sound.

This study will provide the first assessment since 1990 of the contamination of subtidal sediments by *Exxon Valdez* oil outside Prince William Sound. The study will provide information on environmental hydrocarbon concentrations of use to the study on subsistence food [Project Identification Number (PIN), 94279] and the clam study (PIN 94081).

NEED FOR THE PROJECT

The resource that will be monitored is subtidal sediments in the bathymetric depth range of 0 to 100 m on the Kenai and Alaska Peninsulas. Demersal fish, benthic invertebrates, certain diving birds and mammals prey on organisms associated with subtidal sediments. Investigators attempting to restore or monitor recovery of populations of these organisms following the *Exxon Valdez* oil spill will need to know the concentrations of petroleum hydrocarbons present in these sediments.

PROJECT DESCRIPTION

A. Objectives

1. Determine the composition and concentration of petroleum hydrocarbons from the *Exxon Valdez* oil spill in intertidal and subtidal sediments (0-100 m) in the Gulf of Alaska by GC/MS.

2. Compare concentrations of hydrocarbons in subtidal sediments outside Prince William Sound with concentrations at comparable depths inside the Sound.

3. Compare concentrations of hydrocarbons in subtidal sediments outside Prince William Sound in 1994 with concentrations found at the same stations in 1989 and assess the extent of recovery of those sediments.

4. Complete hydrocarbon analysis of sediments collected in Prince William Sound in July 1993.

B. Methods

The methods will be similar to those employed for sediment sampling under the Natural Resource Damage Assessment Subtidal Study Number 1. They are summarized briefly below. Sediment samples will be collected at one intertidal station and five subtidal stations. Intertidal collections will be made at a single tidal height in the range of +1 to -1 m relative to mean lower low water (MLLW) depending on the distribution of fine sediments. Three samples, each a composite of 8 subsamples, collected randomly along a 30 m transect laid parallel to the shoreline will be taken at each intertidal site. These samples will be collected at low tide or by divers.

Subtidal sediment collections will be made at 3, 6, 20, 40 and 100 m below MLLW. Collections at 3, 6 and 20 m will be made by divers on transects laid along the appropriate isobath and sampled in the same way as described above for the intertidal transects. Samples taken at depths below 20 m will be collected with a Smith-McIntyre grab. Three grabs will be taken at each depth. Four subsamples will be removed at randomly selected points within each grab. The subsamples will be combined to form one sample per grab.

All samples collected by hand (including those removed by hand from the Smith-McIntyre grab) will be taken from the surface (top 0-2 cm) of the sediment column. Samples taken by hand in the intertidal region will be collected using a chrome-plated brass core tube (3.6 cm inside diameter) and chrome plated spatula. Each subsample will be transferred to a sample jar using the spatula. The core tube and the spatula will be washed, dried and rinsed with methylene chloride between samples. Sample jars will be cleaned to EPA specifications for hydrocarbon sampling. The jars will be fitted with teflon lined caps also cleaned to EPA specifications. 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. Chain of custody procedures will be followed after collection of all samples.

C. Schedule

Sediment sampling wasl be conducted in July 1994. Chemical analyses will be completed by November 1994. Data compilation and analysis will be completed by March 1995. A progress report will be submitted in November 1994 and a final report will be completed by April 1995.

D. Technical Support

The project will require technical support in hydrocarbon chemistry (UV spectrophotometry and gas chromatography/mass spectrometry). The chemistry will be performed at the Auke Bay Laboratory.

E. Location

This project sampled 7 sites in the Gulf of Alaska (2 reference sites and 5 contaminated sites) and four sites in Prince William Sound (2 reference sites and 2 contaminated sites). The sites were Black Bay, Tonsina Bay, Windy Bay, Chugach Bay, Hallo Bay, Katmai Bay, Wide Bay Moose Lips Bay, Northwest Bay, Olsen Bay and Sleepy Bay. Except for Wide Bay which was sampled only in 1989 all sites were sampled once in 1989 and in 1990 under the NRDA program .

PROJECT IMPLEMENTATION

Name	Responsibility
Stanley Rice	Overall management
Charles O'Clair	Management of data analysis and report writing.
Jeffrey Short	Management of chemical analyses.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The agency will contribute, partially, the management salaries of Rice, O'Clair and Short (~$34K). The project will pay the salaries required for field work, analytical chemistry and data analysis. During the time period October 1, 1993 to September 30, 1994 the agency will complete hydrocarbon analysis, data compilation and analysis and report writing for the field study conducted in Prince William Sound in July 1993.

FY 95 BUDGET ($K)

Personnel	97.9
Travel	3.0
Contractual	0.0
Commodities	5.4
Equipment	0.0
Subtotal	106.3
Gen. Admin.	14.7
Total	121.0

DETAILED RESTORATION PROJECT DESCRIPTION

Project Title:
Hydrocarbon Data Analysis, Interpretation, and Database Maintenance for Restoration and NRDA Environmental Samples Associated with the *Exxon Valdez* Oil Spill

Project ID#: 95290

Project Leader(s): Sid Korn, Jeff Short, and Stanley Rice
P. I = JEEP RICE

Lead Agency: NOAA, Auke Bay Fisheries Laboratory

DEC 22 1994

Cooperating Agencies: None

Project Cost: 163.4 K **FY96:** 163.4K

Start Date: 10/01/94 **Finish Date:** 09/30/95

Expected Project Duration: 5 years

Geographic Area of Project: Entire Oilspill Area

Project Leader Signature:

Sid Korn
NMFS Auke Bay Laboratory
11305 Glacier Highway
Juneau AK 99801
907 789-6021 907 789-6094 (fax)

____

Project Manager:

Bruce Wright
NMFS Auke Bay Laboratory
11305 Glacier Highway
Juneau AK 99801
907 789-6601 907 789-6608 (fax)

Bruce Wright

INTRODUCTION:

The Auke Bay Laboratory (ABL) has provided data archival and interpretive services for environmental samples that have been collected and analyzed for hydrocarbons in support of the *Exxon Valdez* NRDA and restoration efforts. The samples derive from all projects, investigators, and agencies (including both State of Alaska and Federal agencies) that have collected samples for hydrocarbon analysis. The general purpose of this project is to continue to make a large and complex hydrocarbon database available to principal investigators, resource managers, and the public by providing user friendly services. The hydrocarbon database contains sample collection and chemical analyses information from thousands of samples from 1989 to the present. Briefly the database contains:

1) Sample collection information for >44000 samples including major sample types of sediment, tissue, water, and oil.

2) Hydrocarbon analysis information for >12000 samples, each sample analyzed has results for 63 analytes plus quality assurance data.

3) Bile and HPLC analysis for >2000 samples.

4) Data in support of NRDA and restoration projects over the period 1989-1994.

This project will provide the following:

a) Continued use and access of NRDA and restoration hydrocarbon data

b) Expansion of the hydrocarbon database with new restoration data and reponse subsistence resulting in a consistent database allowing comparison of NRDA and restoration results

c) Interpretation of hydrocarbon results for PI's managers, and the public.

d) Continued quality control of sample storage, and hydrocarbon analyses.

Interpretive services include hydrocarbon data interpretation to identify probable sources of hydrocarbons found, evaluation of new hydrocarbon data for evidence of systematic bias, hydrocarbon data editing according to consistent criteria and hydrocarbon data mapping to facilitate identification of temporal and geographic trends of these data . The results of these efforts provide numerical correlates that are directly related to oil, and that may be used by PI's of other Restoration projects, by other governmental agencies, and by the general public, to assess associations of observed biological effects with concentrations of *Exxon Valdez* oil. These archival and interpretive services have been provided by staff at ABL for hydrocarbon samples generated for the *Exxon Valdez* NRDA effort, who have developed automated computer methods to insure that the various criteria are consistently applied to these data, and which result in computer-generated maps of the final results. The purpose of the presently proposed project is to integrate these additional data with the *Exxon Valdez* NRDA hydrocarbon database, and to continue to provide interpretive services, thereby insuring that hydrocarbon data resulting from Restoration efforts are directly and unequivocally comparable with the existing data.

PROJECT DESCRIPTION

1. Resources and/or Associate Services:

Data associated with hydrocarbon samples will be added to the existing *Exxon Valdez* database. This historically has included damage assessment and restoration data. This year we will add subsistence response data from samples collected and analyzed by the Northwest Fisheries Center. Principal investigators from all projects collecting hydrocarbon samples will be assisted by this project through archival, interpretation, and mapping of their data. Data archival will include maintenance of a Rbase and Oracle database with sample collection information and hydrocarbon results. This database allows inventory of hydrocarbon sample collection, and retrieval of collection and hydrocarbon results for PI and management use. Data interpretation will include examination of the data for evidence of systematic bias, which will provide the basis for an evaluation of data quality, and a probability based determination of sources of hydrocarbons found in samples. Finally, maps of specific hydrocarbon samples will be provided on request by principal investigators, government agencies, or the general public.

2. Relation to Other Damage Assessment/Restoration Work:

This project is a continuation of NRDA database and chemical interpretation work. This year subsistence response data will be incorporated into the database.

3. Objectives:

The objective of this project is to continue to apply and extend hydrocarbon interpretation methods and data archival developed in NRDA assessments to samples analyzed for the Restoration effort, and to insure the comparability of analytical and interpretive results with those of the NRDA effort.

4. Methods:

Procedures developed during the NRDA effort will be followed in this project. Incoming samples are inventoried and collection information is entered into a database located at Auke Bay, AK. Hydrocarbon results returned from analytical laboratories are also added to the database. Hydrocarbon data will be evaluated using methods described in the final reports of *Exxon Valdez* NRDA project Subtidal #8 (in prep.). These methods were developed specifically for Exxon Valdez NRDA hydrocarbon data.

5. Location:

The project will be undertaken at the Auke Bay Laboratory in Juneau,Alaska.

6. Technical Support:

This project will provide it's own technical support including chemical, mapping and database needs.

7. Contracts:

No contracts are anticipated.

SCHEDULES:

This project is an ongoing service task and therefore has few set milestone dates. All of the methods, including computer software written specifically for these tasks, have already been developed, tested, and applied. The requested funds are entirely for continuation of these services for additional data that will be produced by Restoration projects. Interpretations and maps of hydrocarbon data will be provided on request to principal investigators and other interested parties. Sample data entry and interpretation depend on the timeframe of sample receipt, and analysis.

EXISTING AGENCY PROGRAM:
None.

ENVIRONMENTAL COMPLIANCE/PERMIT/COORDINATION STATUS
This is not a field study nor does it have any significant effect on the environment. Consequently, an Environmental Impact Statement or Environmental Assessment need not be provided.

All federal, state, and local laws are followed in the management of chemical analysis.

PERFORMANCE MONITORING
The portion of this project examination of hydrocarbon data for systematic bias is, in itself, a performance monitoring function. The performance of the methods developed for examination and interpretation of these hydrocarbon data have already been verified. Database integrity is assured by signed reviews of data entered by principle investigators. We will continue to follow all quality assurance procedures outlined in NRDA efforts.

COORDINATION OF INTEGRATED RESEARCH EFFORT
We coordinate sample analyses with other projects with our sample analysis schedule. Interpretation of services is coordinated with the needs of principal investigators.

PUBLIC PROCESS

PERSONNEL QUALIFICATIONS

Sid Korn
Education:
BA 1966, Nasson College
Graduate Studies 1967, Institute of Marine Biology, University of Miami
Graduate Studies, 1967-68, Humboldt State University
Numerous additional coursework including, fish physiology, Dbase programming, project management, supervision.
Relevant Experience:
1989-1990 Assisted Jim Price in development of the NRDA database and the management of incoming samples and database management.
1990-present Is the database manager of NRDA and restoration hydrocarbon data after the departure of Jim Price. Responsibilities include: supervision of data entry of sample and analytical data; processing and dissemination of data for principle investigators use; database management and design; setup and maintenance of GIS mapping system.

Jeffrey W. Short

Education:
BS, 1972, University of California, Riverside (Biochemistry & Philosophy)
MS, 1982, University of California, Santa Cruz (Physical Chemistry)

Relevant Experience:
1989 - Present: Established and manage the hydrocarbon analysis facility at ABL to analyze hydrocarbon samples generated by the *Exxon Valdez* NRDA effort (about 20% of these samples were analyzed at ABL).
1989 - 1992: Principal Investigator, *Exxon Valdez* project Air/Water #3; Determination of petroleum hydrocarbons in seawater by direct chemical analysis and through the use of caged mussels deployed along the path of the oil spill.
1991 - 1992: Principal Investigator, *Exxon Valdez* project Subtidal #8; Development of computer-based statistical methods for global examination of sediment and mussel hydrocarbon data produced for the *Exxon Valdez* NRDA effort for systematic bias, and for identification of probable sources of hydrocarbons. In addition, this project produced both hard-copy and computer display maps of all the sediment and mussel hydrocarbon data.

Stanley D. Rice
Principal Investigator, ABL Habitat Program Manager

Education:
Received BA (1966) and MA (1968) in Biology from Chico State University, and PH. D. (1971) in Comparative Physiology from Kent State University.

Relevant Experience:
1971-present: Employed at Auke Bay Fisheries Laboratory as a research physiologist, task leader, and Habitat Program Manager since 1986. Rice has researched oil effects problems since 1971, and has published over 70 papers, including over 50 on oil effects. Studies have ranged from field to lab tests, behavioral to physiological to biochemical studies, from salmonids to invertebrates to larvae to meiofauna. Rice has conducted and managed soft funded projects since 1974, including the Auke Bay Laboratory *Exxon Valdez* damage assessment studies since 1989. Activities since the oil spill have included leadership and management of up to 10 damage assessment projects, field work in PWS, direct research effort in some studies, establishment of state of the art chem labs and analyses in response to the spill, quality assurance procedures in biological-chemical-statistical analyses, establishment of hydrocarbon database management, servicing principal investigators and program managers in NOAA and other agencies with reviews and interpretations, provided direct input into agency decisions, interacted with other agencies in various ways (logistics coordination, critique experimental designs, interpret observations, etc.).

BUDGET ($K)

	NOAA	Total
Personnel	131.2	131.2
Travel	6.0	6.0
Contractual	0.0	0.0
Commodities	6.5	6.5
Equipment	1.0	1.0
Capital Outlay	0.0	0.0
Sub-total	147.7	147.7
General Administration	19.7	19.7
Project Total	163.4	163.4

95320A, E, G, H, I, J,
K, M, N, Q, T, U, Y

95320 A, F, G, H, I, J(2), J, K, M, N, O T U Y

EXXON VALDEZ TRUSTEE COUNCIL
FY95 SUMMARY PROJECT DESCRIPTION

Project Title: Sound Ecosystem Assessment (SEA) – An Integrated Science Plan for the Restoration of Injured Species

Project ID Number: 95320

Lead Organization: Alaska Department of Fish and Game

Cooperating Organizations:

University of Alaska Fairbanks
- R.T. Cooney
- D. Eslinger
- C.P. McRoy
- B. Norcross
- E. Brown
- A.J. Paul

Prince William Sound Science Center
- V. Patrick
- D. Salmon
- D. Scheel
- G. Thomas
- T. Kline

Alaska Dept. of Fish and Game; Cordova
- M. Willette

U.S. Forest Service-Copper River Delta Institute, M.A. Bishop

Prince William Sound Aquaculture Corp.
- E. Prestegard

Cost of Project FY95: $ 4613K

Project Startup/Completion Dates: October 1994 – September 1995

Geographic Area of Project: Prince William Sound, Alaska

Name of Project Leader: R.T. Cooney, University of Alaska Fairbanks

P.I.

Table of Contents

CHAPTER 1
Introduction

EVOS Context for the Study

In September, 1993, the EVOS Trustee Council provided funding to the Prince William Sound Fisheries Ecosystem Research Planning Group (PWSFERPG) in Cordova to develop an "ecosystem approach" for understanding the causes responsible for failing, post-spill pink salmon and Pacific herring production in the region. That plan, titled Sound Ecosystem Assessment, was distributed to the Trustee Council and its agents in late November, and subsequently reviewed by a panel of invited scientists at a public workshop in early December. The SEA plan was endorsed (with modification) by reviewers, and immediately used by the PWSFERPG to prepare a proposal for the implementation of studies in the spring of 1994. A package of proposals titled "Sound Ecosystem Assessment" was submitted to the Trustee Council's Public Advisory Group (PAG) in early January and then forwarded to the Council for a decision on funding during its January 31 meeting. The Trustees approved the multi-component program in concept, made provision for the expenditure of some funds for time-sensitive equipment purchases and vessel charter needs, but withheld the remaining support pending the successful peer review of all component Detailed Project Descriptions (DPD). On April 11, 1994, following a strong recommendation from the Trustee Council Executive Director, SEA and some additional related studies of pink salmon were funded as the "Prince William Sound System Investigation." The Council further stated that any continuation of the program in FY95 would be dependent upon the results of an overall program review immediately following the 1994 season.

In early October 1994, preliminary results from the first summer of SEA studies were critiqued in a public three-day workshop held in Cordova. Among the recommendations made by invited peer reviewers was the need for a single, integrated DPD for SEA95 showing explicitly how data products from each research component would be used to test hypotheses and/or otherwise contribute to a functional understanding of natural and anthropogenic factors limiting the recovery of pink salmon and herring populations. The integrated plan was also instructed to address a series of issues including: 1) placing more emphasis on wild juvenile salmon populations; 2) justifying new equipment purchases on the basis of providing specific information for hypothesis testing; 3) articulating greater detail relative to interpreting hydroacoustic information; 4) defining more linkage between the modelling component of SEA and the field studies; 5) identifying a SEA Executive Committee to assist the lead scientist (R. T. Cooney) in program management: 6) showing coordination between SEA research and other EVOS supported studies in the region, and 7) demonstrating clearer focus for new herring studies.

This document represents the integration of 13 research components for 1995 designed to address these recommendations, and more importantly, serious and continuing uncertainties about the recovery status of pink salmon and herring in Prince William Sound (Appendix I). As its focus, the integrated SEA95 workplan presents a series of testable hypotheses linking the production of herring and pink salmon to a suite of physical and biological processes occurring in the Sound, and describes how data products and methodologies from the individual projects will be used to test these conjectures in 1995 and the years that follow. While preliminary results from the recently completed SEA 1994 field season are encouraging, they are by no means conclusive and clearly demonstrate the need for continued study.

New inquiries into juvenile herring growth and habitat utilization, in somatic and spawning energetics of herring and pollock, and in variations in bird-induced predation rates on hatchery released pink salmon fry represent modest, yet justifiable expansions of the effort in FY95. With guidance from peer reviewers, from the EVOS Trustee Council Chief Scientist and staff, and from the Alaska Department of Fish and Game (ADF&G), the SEA program will continue to contribute substantially to a growing understanding of ecosystem function in Prince William Sound - the crucial first step in the process of establishing appropriate interventions to restore pink salmon and herring to healthy pre-spill levels.

Confirmation of Injured Resources and Justification for SEA95

The EVOS Trustee Council officially lists pink salmon and Pacific herring as injured resources that are not recovering (Figure 1). According to the terms of the 900 million dollar settlement with Exxon Corporation, restoration funds must be used "for the purposes of restoring, replacing, enhancing or acquiring the equivalent of natural resources injured as a result of the oil spill, or the reduced or lost services provided by such resources." Approved restoration strategies include actions taken to increase the rate of recovery, to increase the degree of recovery (enhancement) and to increase protection for injured resources. The Trustee Council has recognized that research and monitoring programs are necessary components of effective restoration efforts for injured resources. In its Record of Decision (October, 1994) the Council affirmed an ecosystem approach:

> "Restoration should contribute to a healthy, productive and diverse ecosystem within the spill area that supports the services necessary for the people who live in the area"; and

> "Restoration will take an ecosystem approach to better understand what factors control the populations of injured resources."

Without information about ecosystem-level relationships influencing the production of these resources, well meaning but uninformed restoration activities may no only be ineffective but may cause additional harm.

In an EVOS sponsored workshop in April, 1994 (Science for the Restoration Process), injured and non-recovering pink salmon and herring populations were given high research priorities for studies of direct toxicity and heritable genetic damage, for negative effects of hatchery production, for food limitation, for increased predation and competition, for climate and oceanographic influences, and for a better understanding of the effects of fish diseases. These and related issues arising around the need to also understand marine bird and mammal failures in the spill impacted area, prompted SEA to request a second year for the multi-agency (ADF&G, Prince William Sound Science Center, Prince William Sound Aquaculture Corporation, U.S. Forest Service and University of Alaska Fairbanks) ecosystem approach begun in 1994. Funding for a second SEA year

INJURED RESOURCES			Lost or Reduced SERVICES
Biological Resources		Other	
Recovering	**Not Recovering**	Archaeological resources	Commercial fishing
Bald eagle	Common murre	Designated wilderness areas	Passive uses
Black oystercatcher	Harbor seal	Sediment	Recreation and Tourism including sport fishing, sport hunting, and other recreation uses
Intertidal organisms (some)	Harlequin duck		Subsistence
Killer whale	Intertidal org. (some)		
Mussels	Marbled murrelet		
Sockeye salmon (Red Lake)	Pacific herring		
Subtidal organisms (some)	Pigeon guillemot		
Recovery Unknown	Pink salmon		
Clams	Sea otter		
Cutthroat trout	Sockeye salmon (Kenai & Akalura systems)		
Dolly Varden	Subtidal organisms (some)		
River otter			
Rockfish			

Figure 1. The listing of injured resources and lost or reduced services associated with the EVOS (from *Exxon Valdez* Oil Spill Restoration Plan; November 1994).

was approved by the EVOS Trustee Council in August (interim) and November (remaining), 1994. Expenditure of these remaining funds is contingent upon the development and approval of a detailed workplan for the FY95 field research (this document) by the Council.

The Ecosystem Approach

The 1993 SEA science plan introduced an effective scientific means to pursue focused studies of factors constraining the recovery of pink salmon and Pacific herring production by describing time/space "pathways" followed by juveniles of both species in Prince William Sound (Figure 2). This early life history emphasis was possible because of previous work describing reproductive and marine rearing habitat dependencies, and studies of oceanographic and meteorological factors thought to influence survival during the critical early life stages (see Appendix I). Most losses to annual cohorts of juvenile pelagic and demersal fishes are believed to occur early in life history; the first few weeks of coastal ocean life for pink salmon, the first 2 juvenile years for longer-lived Pacific herring.

Acceptance of this premise allowed investigators to (initially) limit the temporal and spatial dimensions of the SEA inquiry to those times and places hypothesized as major survival bottlenecks during early marine life history. Spatial "pathway" elements include the freshwater and nearshore natal and rearing habitats for herring and salmon, the migratory corridors taken by fry moving through and exiting the region during the spring and summer, and the shallow water over-wintering habitats for juvenile herring. In coming years, it may be necessary to expand the SEA program beyond the immediate confines of Prince William Sound to more accurately address factors influencing the survival of pink salmon and herring populations. The U.S. GLOBEC program and NOAA/NMFS are both proposing work in the North Pacific. SEA might benefit from cooperative efforts with these and other studies.

In addition to defining the habitat dependencies and most probable predators on the eggs, larvae and juvenile stages of herring and pink salmon, SEA also investigated linkages between trophic levels in Prince William Sound by formulating a preliminary carbon budget for the region (Figure 3). This budget identifies phytoplankton, micro and macrozooplankton, 0-class fishes (including

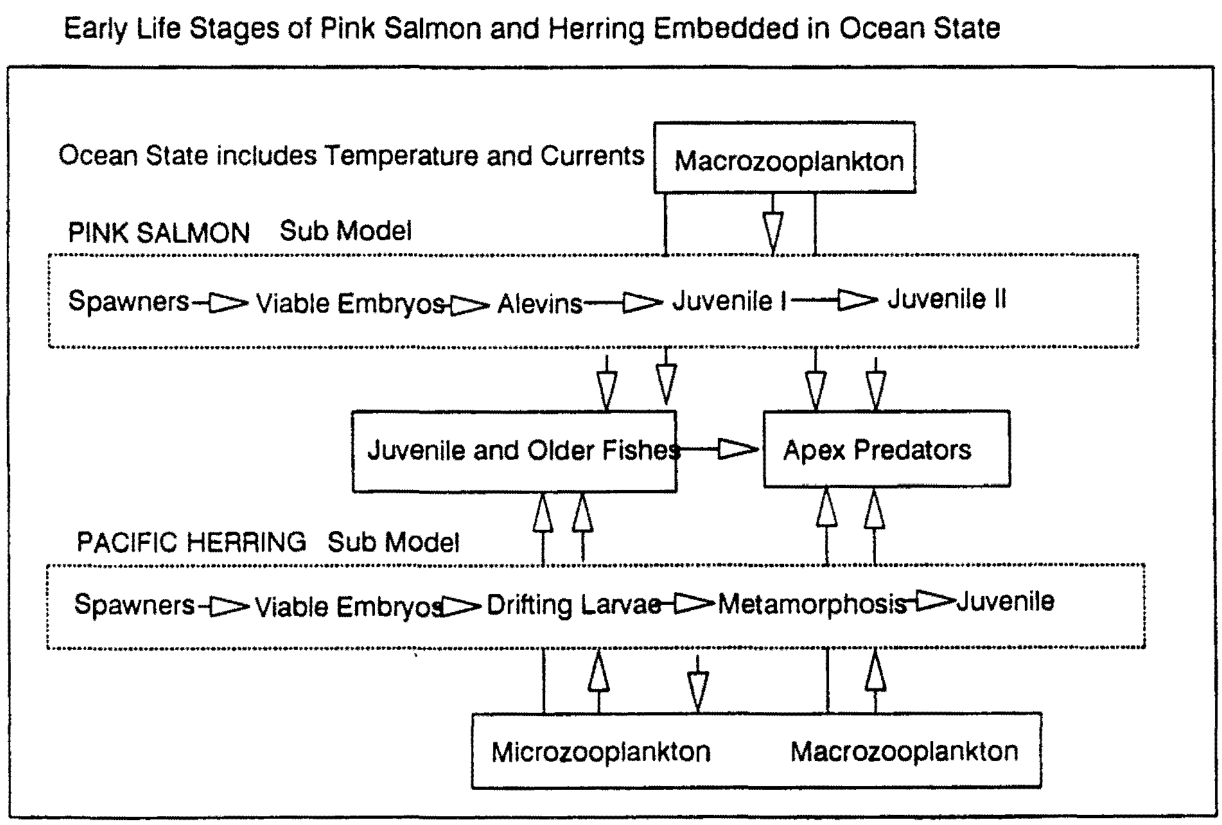

Figure 2. The conceptualization of ecosystem pathways for pink salmon and herring in Prince William Sound, Alaska.

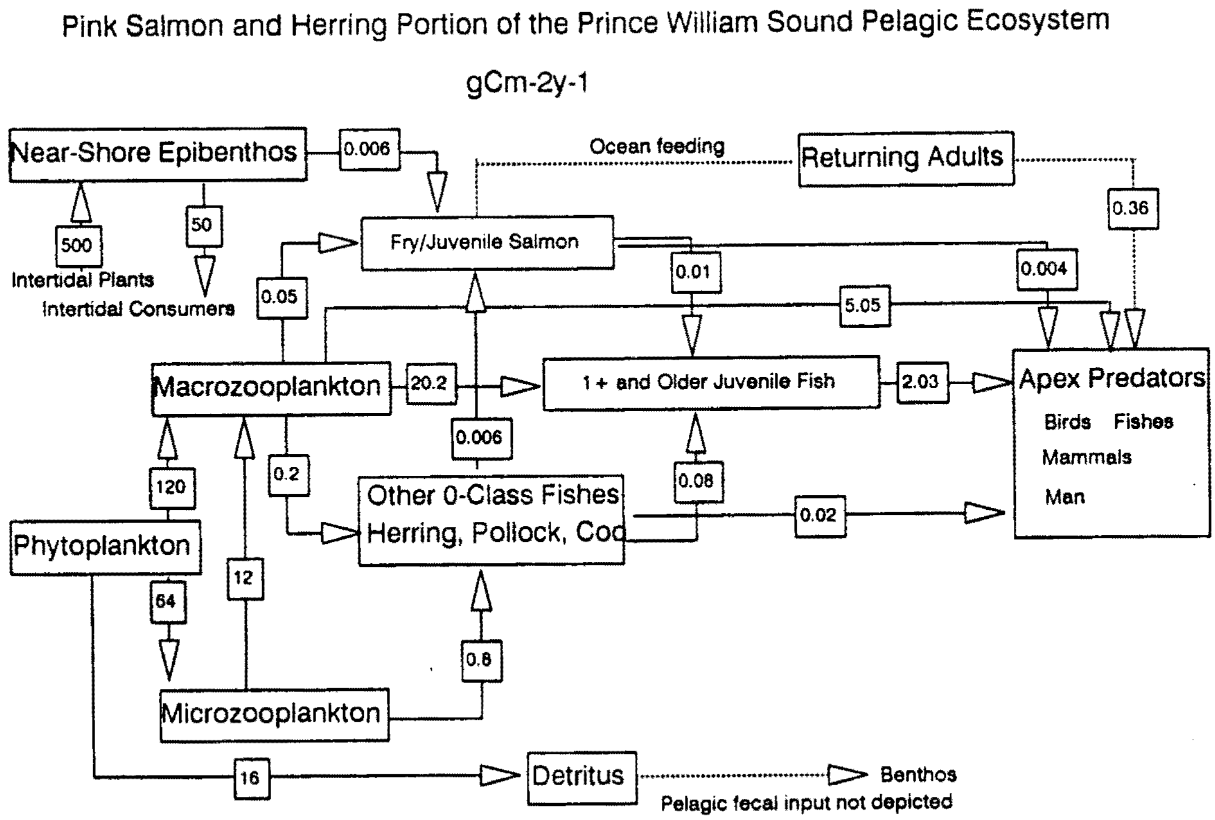

Figure 3. A preliminary annual carbon budget for Prince William Sound, Alaska (Loss of herring spawn to avian predators is not accounted for in the budget).

herring and pink salmon), 1+ and older juvenile fishes, and apex consumers. The model is initialized using 200 gCm-2yr-1 as the annual phytoplankton production and generally accepted percentages for ecological transfers between trophic levels (Appendix I). Energy demands by juvenile salmon on zooplankton stocks were determined from estimates of daily fry growth, mortality, and gross-growth efficiency. The demand on zooplankton forage by other 0-class fishes (including herring) is estimated from the ratio of "other" fish species to juvenile salmon stocks. The modeled annual distribution of carbon assumes that macro-zooplankton (because of their large physical size) are utilized by a wide range of consumers in the Sound.

This carbon budget suggests that all pelagic consumers in the Sound (fishes, birds, and mammals) derive substantial energy from macrozooplankton, and further that interannual differences in amounts of macrozooplankton should modulate trophic exchanges between different levels each year. When zooplankters are abundant (seasonally or annually) the carbon budget indicates consumers will adopt planktivory as a major trophic strategy. Conversely, when zooplankton stocks are weak, the system is expected to exhibit a higher degree of piscivory with losses focused on the smallest fishes (including juvenile pink salmon and herring). Data from the regional aquaculture corporation (PWSAC) demonstrates that zooplankton stocks can vary in some parts of the Sound by a factor of five from year to year. For the southern part of the Sound, good and poor years for macrozooplankton are predicted by the strength of the upwelling index over the shelf south of Hinchinbrook Entrance.

Operationally, SEA uses information from the carbon budget and from prior EVOS-sponsored and other studies to construct a series of testable hypotheses relating ecosystem function to adult pink salmon and herring survival. Since there is little evidence that the early life stages of either species experience high losses from starvation, physical factors influencing survival in the fixed space natal habitats, and predation (by birds, large fishes and mammals) are evoked as the major elements of natural mortality.

Oil-related causes for non-recovery of injured species will be sought at the ecosystem level as statistical anomalies in models and data sets predicting how population variability has been forced naturally by physical and biological influences prior to and after the spill, and historically by local management and enhancement programs for salmon and herring fisheries. SEA will also interact with other EVOS-sponsored projects seeking direct evidence for oil influences on the reproductive potential of pink salmon and herring populations in the Sound and also mortality associated with naturally occurring diseases.

SEA Restoration Goals

SEA has identified three programmatic goals that are being used as tools for the successful restoration of pink salmon and herring populations in Prince William Sound: 1) acquire an ecosystem-level understanding of processes that interact to maintain the production of pink salmon and herring within limits of natural variability; 2) use this information to develop improved predictors of annual levels of pink salmon and herring production; and 3) establish a detailed and comprehensive data base for application to the restoration of these and other injured resources in Prince William Sound. The first restoration goal is being addressed by the multi- component, integrated field research program described in this document. The second goal arises from the ecosystem modelling component of SEA, a detailed integrative activity providing a series of linked numerical and statistical predictors of pink salmon and herring production. The third goal is being addressed by the creation of a SEA data base for use by principal investigators and the EVOS Trustee Council and its member agencies to more effectively restore injured resources in Prince William Sound.

CHAPTER 2
SEA Hypotheses and Hypothesis Testing

The SEA program has been planned as an interdisciplinary, multi-year, hypothesis-driven study of factors influencing the production of pink salmon and Pacific herring in Prince William Sound. The program is phased to emphasize studies of processes and mechanisms during the early years, transitioning to numerical modelling and a reduced monitoring effort after the most important predictive relationships have been described (Figure 4). Monitoring during this stage will focus on those variables identified as critical predictors of pink salmon and herring production performance. This latter phase also supports the evaluation of candidate "what if" scenarios providing the Council an objective

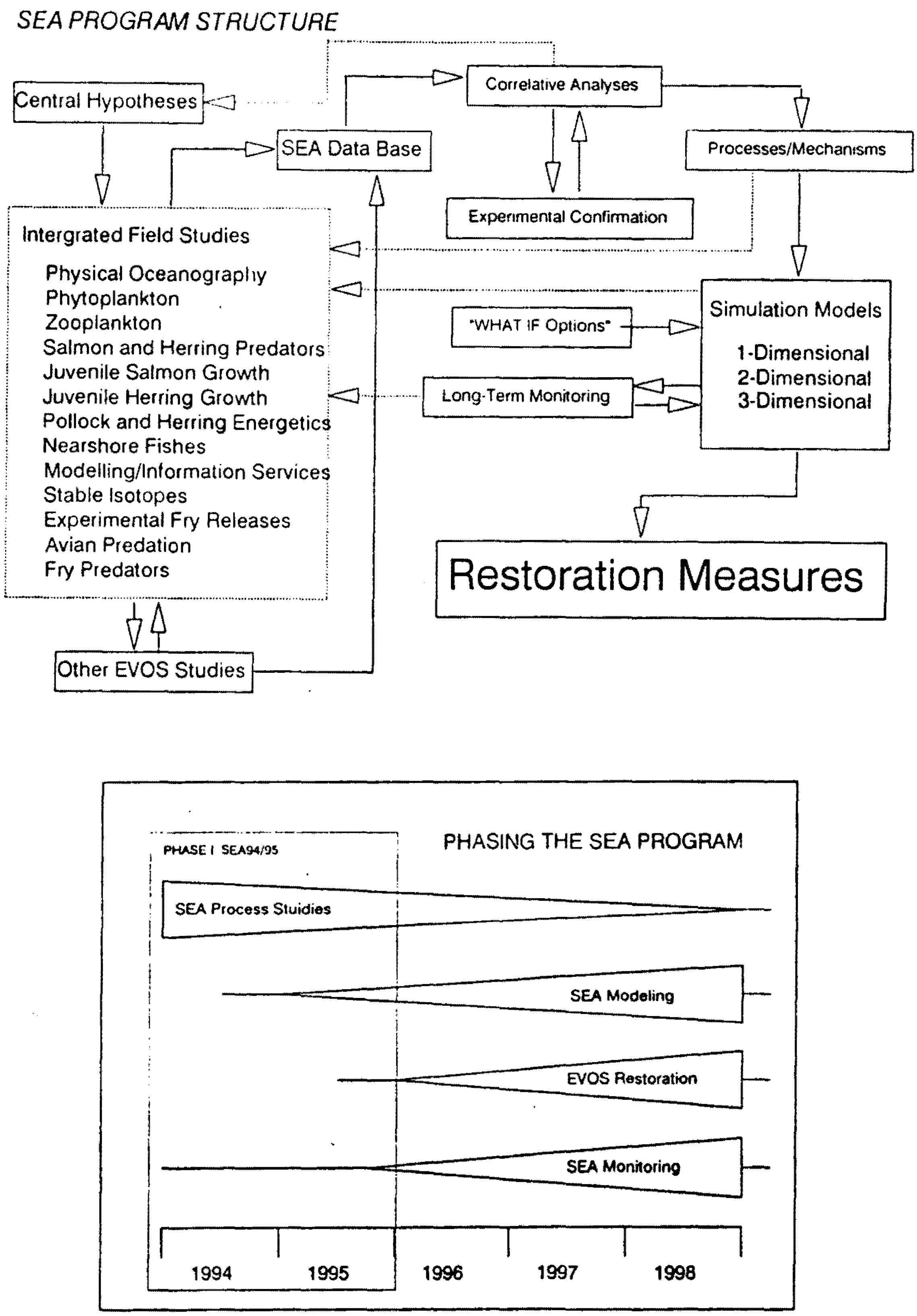

Figure 4. SEA95 program elements (upper) and tentative phasing of the research through FY98 (lower).

means to judge the effectiveness of proposed restoration activities for the target species as well as their influence on other components of the Prince William Sound ecosystem before implementation. Without this level of information, actions taken to restore non-recovering populations could be ineffective or actually produce more damage than they are intended to restore.

Information about Prince William Sound in the published and gray literature, along with many unpublished observations from previous studies (EVOS-sponsored and other), provided the means to articulate several formal notions about the structure and function of the ecosystem relative to survival during the early life stages of pink salmon and herring (density dependent and density independent factors; see Appendix I). These ideas suggest the major sources of mortality:

1. In fixed-space intertidal (also shallow sub-tidal) and freshwater natal habitats, physical factors including scouring, wave erosion, freezing, and drying of embryos are thought to be more important agents of loss than predation.

2. For the free-drifting and swimming post-emergent (larval and post-larval stages, larval herring, salmon smolts), mortality sources may differ from year to year. For most years, losses to predation may be paramount; in other years, abiotic factors assume a greater importance.

3. Losses to predation are modulated by the species composition, standing stock and production of zooplankton in the region and strongly modified by interannual differences in ocean temperature.

4. All biological processes in the region respond to seasonal and interannual variability in coastal ocean state and primary productivity.

These notions have been used to define a series of testable hypotheses that form the backbone of the multi-year SEA research program. In turn, these hypotheses have driven the development of the individual projects comprising the inter-disciplinary effort. Operationally, these studies are grouped into four major interacting sub-programs; 1) Natal studies; 2) Predator/prey studies; 3) Oceanography-Lake/River studies; and 4) Juvenile herring overwintering studies.

SEA research is iterative in as much as the results continually inform the hypotheses and field studies. Within years, this information is used to shift sampling effort and programmatic direction. Between years, study results are used to judge the status of hypothesis evaluation and with that exercise, revision of the kinds and numbers of individual research projects required. The approach advocates a thorough, thoughtful multi-year study.

The sub-program hypotheses stated below represent initial thinking and program direction. They are stated in the context of a long-term study; some testable in 1995 while others form a roadmap for future studies. Results from work conducted in the spring, summer and fall of 1994 are already pointing to priority areas for confirmation and revision. It is expected that new results could (and most certainly will) change the direction of study.

Herring Natal Habitat Hypotheses

Rates of mortality to herring embryos may establish overall recruitment in some years. However, herring recruitment is the result of a complex interaction of many processes, no one of which is truly dominant. Overall survival during a particular life stage may be critical in one year, but not the next. Prince William Sound's Pacific herring spawning populations have declined significantly since 1992 (Figure 5). There may be a critical threshold of spawning biomass (number of eggs) below which embryo survival can significantly effect herring recruitment. Physical removal and avian predation are the main causes of egg mortality. In PWS, decreased numbers of eggs could experience higher rates of predation if the avian predator population (the most important egg predator) remains relatively constant or increases. At the same time, storm induced wave action could result in critically high mortality rates due to egg translocation. The following represent hypotheses guiding the natal studies program in 1995 and beyond:

1. High energy coastal storms, temperature extremes, and predation control density independent mortality and modify some processes causing density dependent mortality of herring embryos. The effect of the physical and

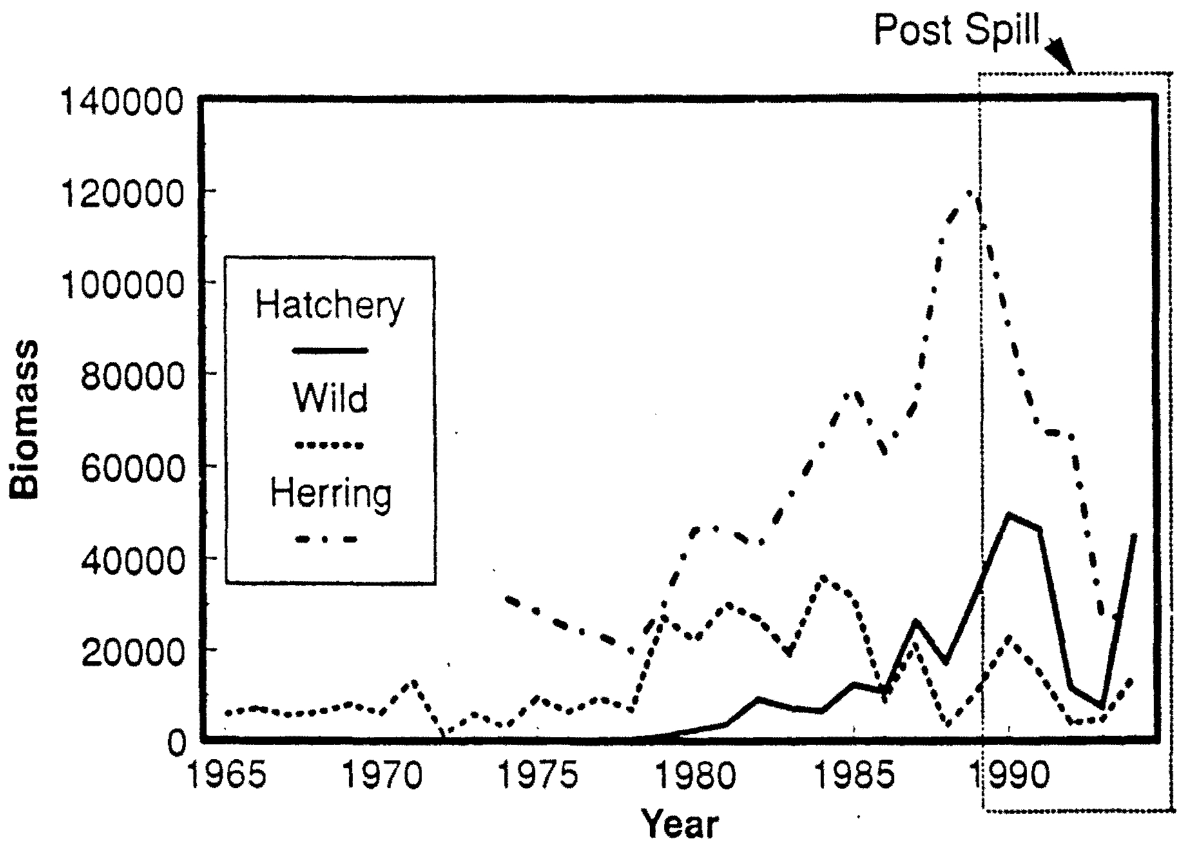

Figure 5. Production histories for pink salmon and herring in Prince William Sound, Alaska.

biological processes on the survival of the embryos varies with spawning habitat.

Corollaries

1.1 *High energy storms generate waves that physically remove eggs from herring spawning grounds. Waves remove eggs directly by dislodging them from vegetation to which they have adhered and indirectly by dislodging vegetation that contains eggs from the substrate.*

1.1.1. *Egg loss is positively correlated with the duration and intensity of wind-generated waves.*

1.1.2 *Egg loss due to wave action is modified by the species of vegetation to which eggs are attached, the water depth in which eggs are deposited, and egg density.*

1.1.3 *Site specific wave action is correlated with regional climatological conditions (geomorphology, fetch, siting).*

1.2 *Temperature extremes cause increased egg mortality. Elevated spring temperatures and increased ultraviolet radiation from increasing spring sunlight cause increased morphologic and cytogenetic abnormalities in herring embryos and reduce the number of viable larvae.*

1.2.1. *Egg mortality in the intertidal zone increases with air temperatures $< 0C$ and $> 13.5C$.*

1.2.2 *Egg mortality increases with continuous exposure to water temperatures $< 4C$.*

1.2.3 *Incidence of cytogenetic and morphologic abnormalities and proportion of nonviable hatched larvae are increased at the upper and lower extremes of the ranges of temperature and* *ultraviolet radiation typically occuring in PWS.*

1.3 *Birds are the single most important predators on herring eggs.*

1.3.1 *The distribution, timing, and abundance of gulls, seaducks, and shorebirds is positively correlated with the dispersion, timing, and abundance of herring spawn. Species composition of avian predators is dependent on spawn location and the timing of spawning.*

1.3.2 *Herring spawn is a major component in the diet of bird species foraging in areas of herring spawn.*

1.3.3 *Viable herring eggs are preferred prey compared to dead and decaying spawn.*

1.3.4 *Avian consumption of spawn is greatest in the intertidal zone and varies with tidal height.*

1.3.5 *Egg loss resulting from avian predation occurs at higher rates in years when eggs are scarce.*

Table 1 lists data products and methodologies used to begin testing these conjectures about herring natal habitats.

Prey/Predator Hypotheses

SEA assumes that much of the variability in annual cohort survival for pink salmon and herring is established during early marine residence (see also "Herring Overwintering Hypotheses" for related hypotheses). The literature suggests this may be happening during the first few weeks for pink salmon, but extended through the second juvenile winter for herring (see Appendix I). The major loss factor is predation rather than starvation, although it is acknowledged that growth rate probably mediates the mortality schedules of both species. Slower growing individuals are suspected of being at risk for a greater period of

Table 1. Summary of natal habitat hypotheses and specific data products and methods needed to conduct formal hypothesis testing.

Hypothesis	Project	Data	Methodology
1.1.1	95166 NOS, 95320M	Wave height and duration	Remote sensing instrumentation
	95166	Egg loss and loose eggs	Diver surveys
1.1.2	95166	Number of eggs deposited and loss rate	Diver surveys
	95166	Vegetation type	Diver surveys
	95166	Substrate type	Diver surveys
	95166	Depth	Diver surveys
	95166	Degree of exposure	Diver surveys
	95166	Beach gradient	Diver surveys
1.1.3	95166 95320M	Wave height and duration	Sonic wave height recorders
	95166 95320M&J	Regional wind speed, direction, and duration	Weather Service data - moorings (e.g. , CFOS Buoy)
1.2.1	95166	Air temperature	Temperature Recorders
	95166	Egg mortality	Diver surveys
1.2.2	95166	Water temp by depth	Temperature Recorders
	95166	Egg mortality	Diver surveys
1.2.3	95166	Viable larvae hatching rates	Laboratory incubation under diff. temp/salinity/UV regimes
	95166	Cytogenetic and morphologic abnorm. rates	Cytogenetic scoring
1.3.1	ADFG	Spawn distribution	Aerial surveys
	95166	Number of eggs	Diver surveys
	95320Q	Gull abundance and distribution	Aerial videography
	95320Q	Shorebird and seaduck abund. and distrib.	Boat surveys
1.3.2	95320Q	Food habits	Stomach content analysis
	95320I	Food web reconstruction	Isotope analysis
	95320Q	Feeding behavior	Visual observation
	95320Q 95166	Egg loss from predation	Diver surveys, bird exclosures, energetic models
1.3.3	95320Q	Feeding behavior	Visual observation; diver surveys
1.3.4	95320Q	Feeding behavior	Visual observation; diver surveys
	95166	Egg loss by depth	Diver surveys
1.3.5	95320Q	Bird abundance	Aerial videography and boat surveys
	95166	Egg loss rate	Diver surveys

time than are faster growing larvae and post-larvae. Thus, while starvation may not be directly implicated, food limitation and its effect on growth mediated survival remains an issue for study.

The initial SEA carbon budget (Figure 3) suggests that 1+ and older juvenile fishes, and adult apex predators (fishes, birds and mammals) are capable of deriving substantial energy from smaller 0-class fishes. The model also indicates that depending on the availability of alternate prey zooplankton for these predators, rates of loss range from nominal to severe (Figure 6).

Two predators known to occur commonly in the region are walleye pollock and older Pacific herring. Spawning populations of both species invest large amounts of energy in egg production, depositing demersal or pelagic spawn in the environment before or during the spring plankton bloom. It is surmised that following this spawning activity, adults feed voraciously to replenish their spent energy reserves. This critical feeding window brackets the time of outmigration for wild pink salmon and also includes the period of hatchery releases. Larval herring begin emerging into nearshore waters in mid-May, and may be subject to increased predation by older herring and pollock at this time as well. Additionally, surface swarms of large calanoid copepods occur in greatest abundance from late April to late May as another important component of the enhanced predation "window" (Figure 7).

April is the month that seasonal warming from winter conditions begins to become evident in Prince William Sound. Because temperature influences the metabolism of fishes, specifically gut evacuation rates, the demand for prey can presumably vary with interannual and seasonal temperatures. During warmer than average spring conditions, the demand for prey is expected to be greatly increased.

These, and other interacting factors each year define the conditions that influence rates at which 0-class fishes (including pink salmon and herring) are consumed by fishes, birds and mammals. SEA proposes the following formal conjectures to guide integrated pink salmon and herring prey/predator studies.

1. Walleye pollock and seabirds are the principal predators on juvenile

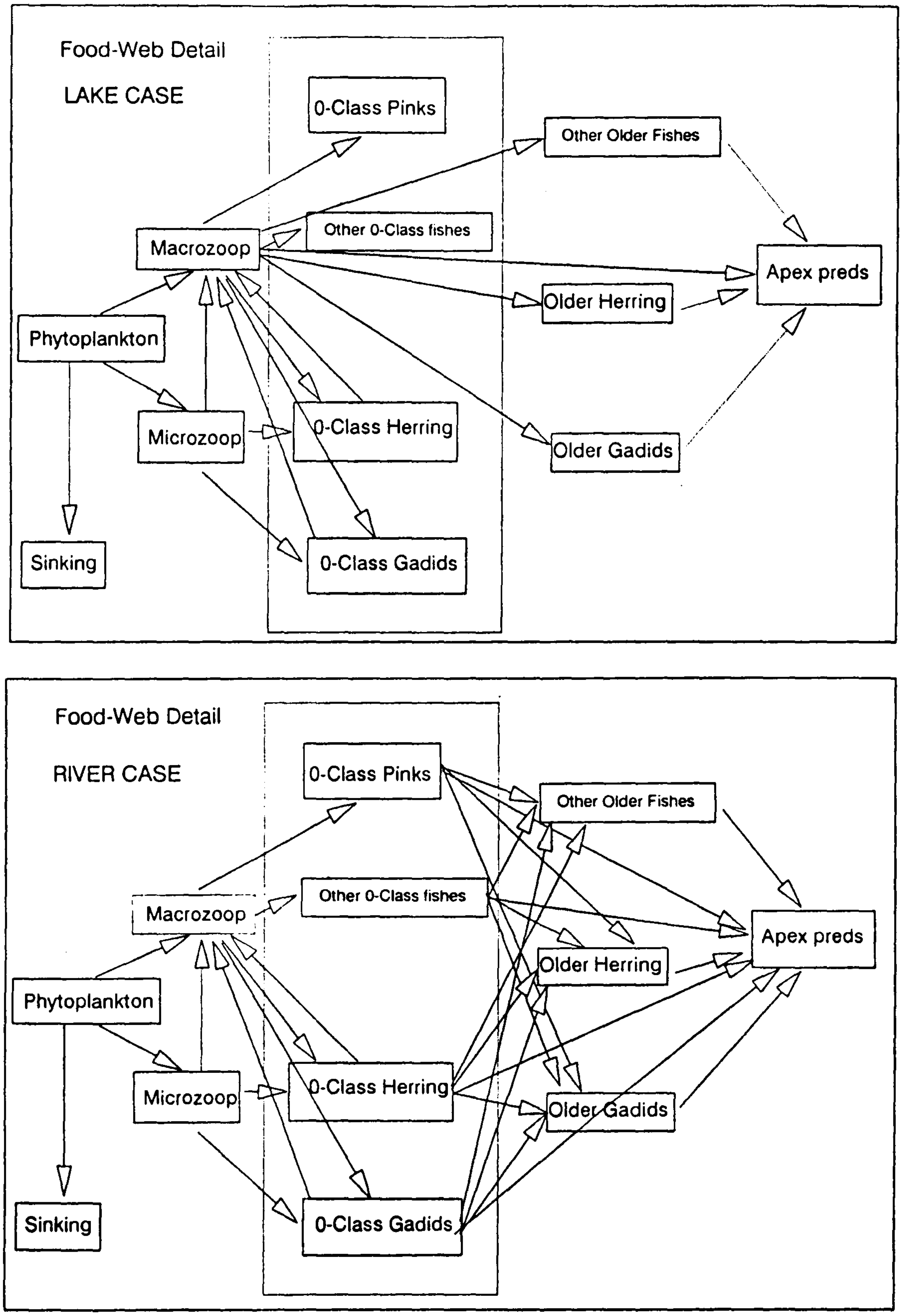

Figure 6. A conceptualization of carbon flow to higher trophic levels under lake conditions (upper) and river conditions (lower) demonstrating prey switching between macrozooplankton and 0-class fishes.

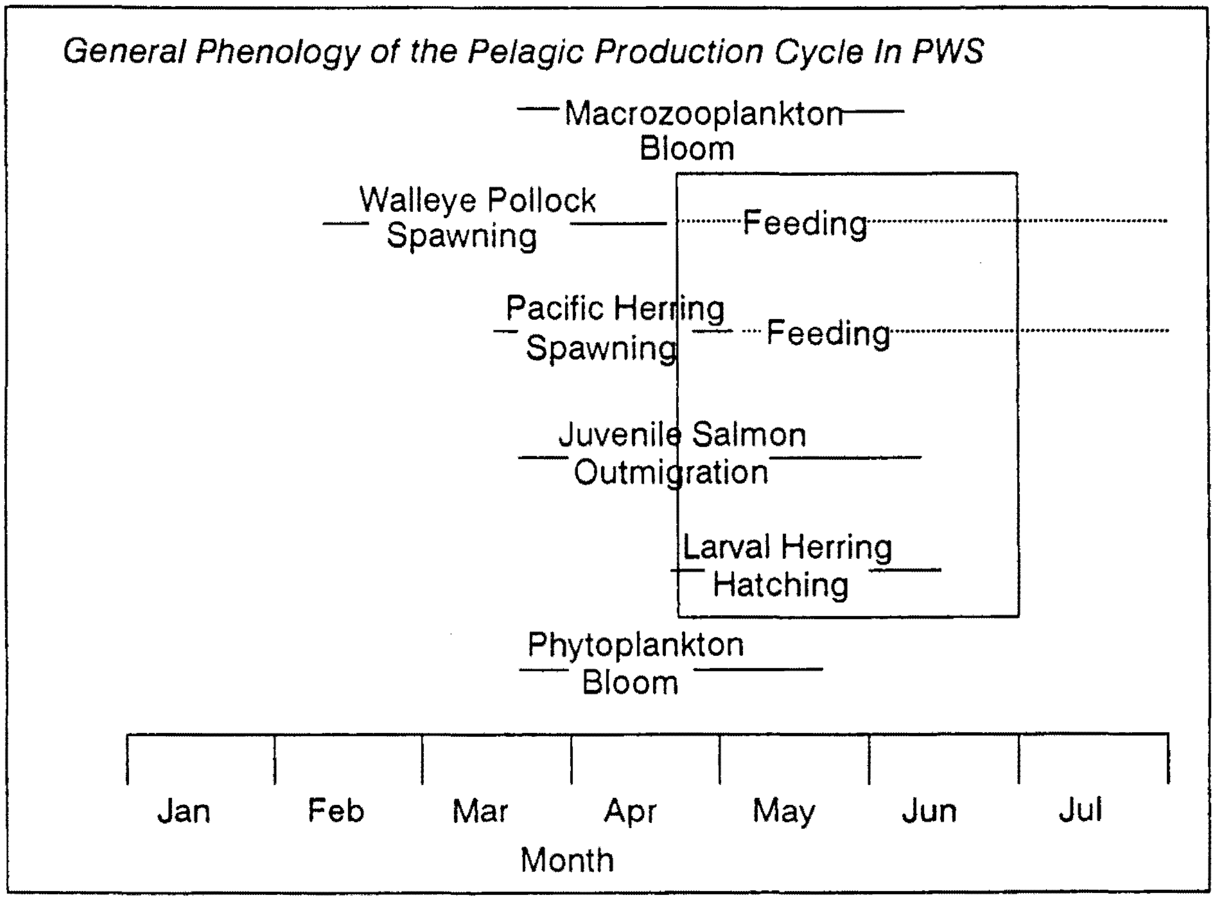

Figure 7. A general phenology of spawning and feeding windows for walleye pollock and Pacific herring relative to the timing of wild and hatchery-released pink salmon, the hatching of herring larvae and the timing of the macrozooplankton bloom.

salmon during the first 30 days of marine residence. After the initial 30 days, walleye pollock, herring, and adult salmon are the principal predators.

Corollaries

1.1. *The juvenile salmon consumption rate by seabirds and age 1+ walleye pollock is greater than for all other predators combined during the initial 30 days of marine residence.*

1.2. *The juvenile salmon consumption rate by age 1+ walleye pollock, herring, and salmon is greater than for all other predators combined after the initial 30 days of marine residence.*

2. The rate of predation on juvenile salmon, herring and other age 0 fish is strongly affected by the timing and duration of the macrozooplankton bloom modulated by ocean temperatures during the early marine period. During the macrozooplankton bloom, predators consume large calanoid copepods and predation on age 0 fish is low. As the abundance of macrozooplankton declines, predators switch to age 0 fish. Predation on age 0 fish is also size dependent; predation risk being substantially less for fish greater than approximately 60 mm FL. The survival of juvenile pink salmon and other age 0 fish therefore depends largely on their growth rate prior to reaching a size of approximately 60 mm FL and the coincident timing of the decline of the macrozooplankton bloom. Ocean temperature during this period is also critical, because the growth of juvenile pink salmon is largely temperature dependent.

Corollaries

2.1. *The biomass of predator diets comprised of juvenile salmon, herring and other age-0 fish is inversely related to the biomass of the diet comprised of large calanoid copepods.*

2.2. *Juvenile salmon consumption rates are greatest when the abundance of large calanoid copepods is low.*

2.3. *More than 75% of the juvenile salmon consumed by fish predators are less than 60 mm FL.*

2.4. *Growth rates of juvenile salmon and herring are positively related to ocean temperature and the proportion of the diet comprised of large calanoid copepods.*

2.5. *The survival of pink salmon to the adult stage is positively related to growth rate before the fish reach 60 mm FL.*

2.6 *The survival of late-released hatchery fry is elevated over historical averages for fry grown to 1.0g or larger.*

3. The carrying capacity of PWS for juvenile salmon is determined by the availability of predation refuges that are both temporally and spatially limited. Temporal limitation of the predation refuge for juvenile salmon results from seasonal inshore movements of predators. Foraging time of juvenile salmon and thus predation risk is inversely related to interannual and seasonal changes in prey density and composition. Increased juvenile salmon density leads to longer juvenile salmon foraging times and increased predation risk.

Corollaries

3.1. *The abundance of fish predators increases substantially from May to June in nearshore nursery habitats occupied by juvenile salmon.*

3.2. *The seasonal increase in fish predator abundance in nearshore nursery habitats is related to ocean temperature structure.*

3.3 *Zooplankton abundance and the abundance of large calanoid copepods is greater offshore (outside of the predation refuge) than nearshore (within the predation refuge).*

3.4. *The daily foraging time of juvenile salmon is inversely related to total* *prey density and the proportion of large calanoid copepods in the diet.*

3.5. *The daily foraging time of juvenile salmon is positively related to juvenile salmon abundance.*

3.6. *The juvenile salmon consumption rate by predators is positively related to the daily foraging time of juvenile salmon.*

4. Predation on wild salmon fry is greater when wild fry are mixed with larger hatchery-reared fry in nearshore nursery habitats. Behavioral responses of predators lead to predator aggregations and greater predation rates in areas of high juvenile salmon abundance. Predators select smaller wild fry in mixed schools of wild and hatchery salmon.

Corollaries

4.1. *Predator abundance is positively related to juvenile salmon abundance.*

4.2. *Wild salmon fry are smaller than hatchery-reared fry in nearshore nursery habitats.*

4.3. *The ratio of wild to hatchery salmon in predator stomachs is greater than the ratio of wild to hatchery salmon in nearby nearshore nursery areas.*

Spatial patterns of adult pink salmon production in Prince William Sound are determined by the distribution of age 1+ walleye pollock and macrozooplankton during the early marine period.

Table 2 lists data products and methodologies that will be used in FY95 and beyond to test formal conjectures addressing prey/predator relationships influencing the production of salmon and herring in Prince William Sound.

Table 2. Summary of prey/predator hypotheses and specific data products and methodologies needed to test hypotheses.

Hypothesis	Project	Data	Methodology
1.1	95320Y	seabird consumption of juvenile salmon	seabird enumeration/bioenergetics
	95320E	daily ration of walleye pollock & other fish species	serial slaughter/bioenergetics
	95320E	proportion of diet comprised of juv. salmon in all fish predators	stomach contents analysis
	95320E	species/size comp. of fish predators	net sampling
	95320N	biomass of all fish predators	hydroacoustics/net sampling
	95320M	ocean temperature profiles	CTD
1.2	95320E	daily ration of walleye pollock & other fish species	serial slaughter/bioenergetics
	95320E	proportion of diet comprised of juv. salmon in all fish predators	stomach contents analysis
	95320E	species/size comp. of fish predators	net sampling
	95320N	biomass of each fish predator species	hydroacoustics
	95320M	ocean temperature profiles	CTD
2.1	95320E	proportion of fish predator diet comprised of salmon & large calanoid copepods	stomach contents analysis

prey density and the proportion of large calanoid copepods in the diet.

3.5. *The daily foraging time of juvenile salmon is positively related to juvenile salmon abundance.*

3.6. *The juvenile salmon consumption rate by predators is positively related to the daily foraging time of juvenile salmon.*

4. Predation on wild salmon fry is greater when wild fry are mixed with larger hatchery-reared fry in nearshore nursery habitats. Behavioral responses of predators lead to predator aggregations and greater predation rates in areas of high juvenile salmon abundance. Predators select smaller wild fry in mixed schools of wild and hatchery salmon.

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Table 2. (Continued)

Hypothesis	Project	Data	Methodology
3.2 (Continued)	95320N	biomass of fish predators	hydroacoustics
	95320M	ocean temperature profiles	CTD
3.3	95320A	zooplankton abundance nearshore and offshore	pump samples
3.4	95320A	daily foraging time	diel net samples/stomach contents analysis
	95320A	prop. large copepods in diet	diel net samples/stomach contents analysis
	95320H	zooplankton biomass/species	net samples/laboratory analysis
3.5	95320A	daily foraging time	diel net samples/stomach contents analysis
	95320A	species composition of age-0 fish in nearshore habitats	diel net sampling
	95320N	population size of age-0 fish in nearshore habitats	hydroacoustics
3.6	95320A	daily foraging time	diel net samples/stomach contents analysis
	95320E	daily ration of walleye pollock & other fish species	serial slaughter/bioenergetics
	95320E	proportion of diet comprised of juv. salmon in all fish predators	stomach contents analysis
	95320E	species/size comp. of fish predators	net sampling
	95320N	biomass of each fish predator species	hydroacoustics
	95320M	ocean temperature profiles	CTD
	95320Y	seabird consumption of juvenile salmon	seabird enumeration/bioenergetics fish in nearshore habitats
4.1	95320A	species composition of age-0	net sampling

Table 2. (Continued)

Hypothesis	Project	Data	Methodology
2.2	95320E	daily ration of walleye pollock & other fish species	serial slaughter/bioenergetics
	95320E	proportion of diet comprised of juv. salmon in all fish predators	stomach contents analysis
	95320E	species/size comp. of fish predators	net sampling
	95320N	biomass of each fish predator species	hydroacoustics
	95320H	zooplankton biomass/species	net samples/laboratory analysis
	95320M	ocean temperature profiles	CTD
	95320Y	seabird consumption of juvenile salmon	seabird enumeration/bioenergetics
2.3	95320E	size frequency of salmon in fish predator stomachs	stomach contents analysis
2.4	95320A	growth rates of juv. salmon	CWT juv. salmon recovery
	95320A	prop. calanoid copepods in diet	stomach contents analysis
	95320M	ocean temperature profiles	CTD
2.5	95320A	growth rates of juv. salmon	CWT juv. salmon recovery
	95320B	salmon survival to adult	CWT recovery of adult salmon
2.6	95320K	Marine survival	CWT recovery of adult salmon
3.1	95320E	species/size comp. of fish predators	net samples
	95320N	biomass of fish predators	hydroacoustics
3.2	95320E	species/size comp. of fish predators	net samples

Oceanography-Lake/River Hypotheses

A multi-year time-series of upper-layer zooplankton biomass in the southwestern corner of Prince William Sound correlates with the wind-forced upwelling index measured over the shelf south of Hinchinbrook Entrance (Figures 8 and 9). Over 70 percent of the interannual variability in spring-time upper-layer (50 m) zooplankton biomass at this location can be accounted for by the strength of the upwelling index averaged over the months of April and May from 1981 to present. During years of strong onshore convergence (more negative index), zooplankton stocks are lower than when the upwelling index is higher (weakened onshore convergence). SEA investigators hypothesize that this correlation describes a relationship between wind-forced flushing rates in southern PWS and the retention or wash-out of upper layer zooplankton stocks. Strong onshore convergence (more negative upwelling index) is believed to accelerate the coastal current and force elevated upper-layer flushing (a river-like condition) in southern Prince William Sound leading to the diminishment of surface zooplankton populations by washout. Conversely, weak onshore convergence is associated with reduced flushing (a lake-like condition) and higher retention of south Sound zooplankton stocks.

Alternatively, the observed statistical relationship between the upwelling index and zooplankton may instead describe the influence of east winds on local (within PWS) Ekman transport and its effect on upper-layer zooplankton. Periods of strong coastal convergence over the shelf of the northern Gulf of Alaska are associated with low pressure systems directing predominately easterly winds across the central basin of the Sound. These winds are expected to force a local convergence on the north side of the region with an early spring build up of zooplankton like that consistently seen in the more northerly hatchery plankton records. The result is a local redistribution rather than washout of macrozooplankton including a diminishment of central and southern populations (imitating the river condition). Periods of relaxed winds would allow upper-layer stocks to spread out over broader areas of the Sound, including the central basin and southern sections (imitating the lake-like condition).

In reality, it seems likely that "both" local and broad-scale physical processes contribute to establishing patterns of within-Sound upper-layer zooplankton

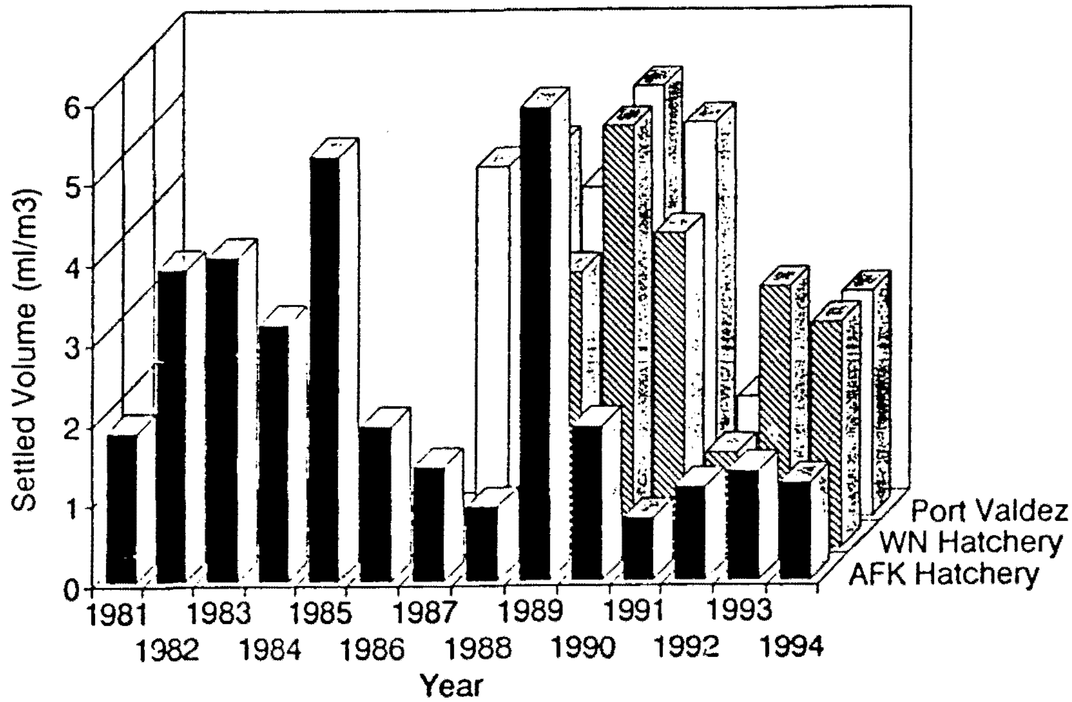
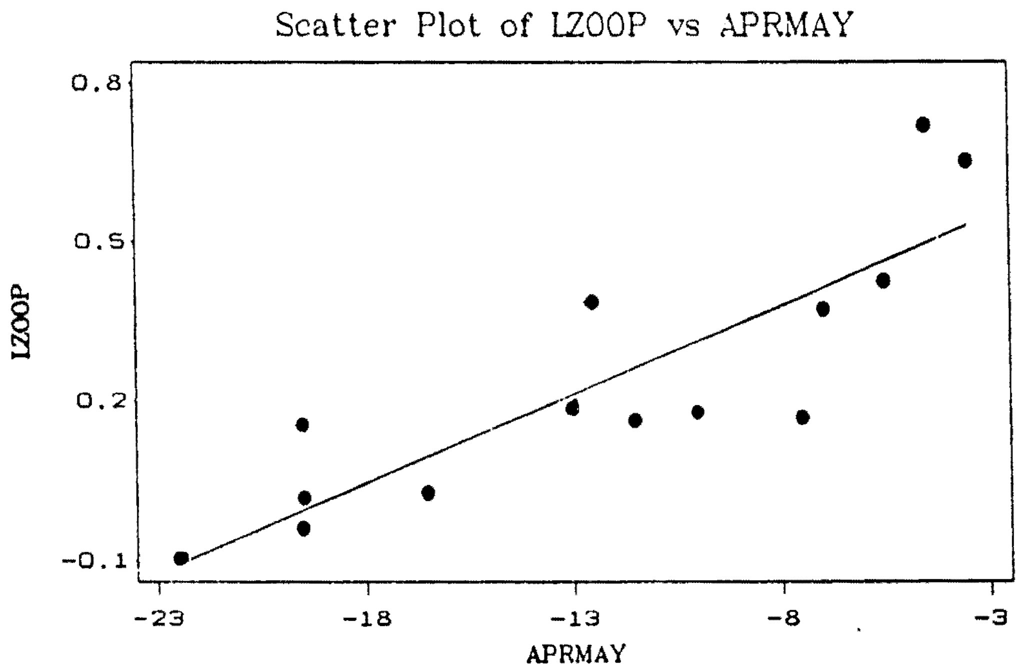


Figure 8. The time series of zooplankton settled volumes recorded at three hatchery locations in Prince William Sound, Alaska.



STATISTIX 4.0 NUPWELL4, 10/01/94, 13:00

UNWEIGHTED LEAST SQUARES LINEAR REGRESSION OF LZOOP

PREDICTOR VARIABLES	COEFFICIENT	STD ERROR	STUDENT'S T	P
CONSTANT	0.64656	0.07866	8.22	0.0000
APRMAY	0.03337	0.00572	5.83	0.0001

R-SQUARED	0.7391	RESID. MEAN SQUARE (MSE)	0.01701
ADJUSTED R-SQUARED	0.7174	STANDARD DEVIATION	0.13042

SOURCE	DF	SS	MS	F	P
REGRESSION	1	0.57833	0.57833	34.00	0.0001
RESIDUAL	12	0.20410	0.01701		
TOTAL	13	0.78243			

CASES INCLUDED 14 MISSING CASES 0

Figure 9. The statistical relationship between annual average springtime zooplankton settled volumes measured at the AFK hatchery and the strength of the upwelling index provided by NOAA for a location just south of Hinchinbrook Entrance.

stocks during the critical months of April and May. Some washout cannot be discounted even under the most quiescent of spring seasons. Regardless of the oceanographic mechanism, the final effect - some level of predation sheltering for 0-class salmon and herring - is still a primary issue of interest for SEA. However, to create reasonable simulations of the ocean state and its effect on zooplankton distributions and abundance, questions about oceanographic processes on several different levels of scale must be resolved.

An additional question involves understanding how local large calanoid stocks are recruited each year. Under lake conditions and minimal washout, a substantial fraction of locally produced stocks descend to overwintering depths to make up a large percentage of the next year's reproductive population. However, under the more common river-like conditions, all stocks are eventually diluted without replenishment from the bordering deep ocean. We hypothesize that a period of replenishment occurs each summer and early fall as the late stages of *Calanus* and *Neocalanus* enter the Sound with the surface and deep flow, migrate down below sill depth and become "trapped" in the region. The clustering of stable isotope values for *Neocalanus* into two distinct groups (observed in 1994) suggests a way to begin evaluating the question of local versus trapped recruitment. The relative importance of seasonal seeding from the adjacent deep ocean is unknown.

Lastly, herring larvae hatching from site-specific natal areas are feeble swimmers and planktonic for many weeks. The distribution of surviving juveniles must in some way reflect the patterns of upper-layer flow and interactions with predator fields. Since most of the spawning occurs in the easterly and northern portions of the region, it is likely that the net flow will distribute surviving juveniles to the west. However, if river-like conditions describe a northward forced local Ekman transport, a more northerly trajectory in drift could also occur. Larval herring begin entering the system during the transition period between coastal downwelling and weak upwelling. During this transition, weak and variable winds might tend to randomize the drift of upper-layer plankton communities. Also, seasonal warming during this time, and precipitation in the form of rain rather than snow, will increase local runoff and promote surface outflow from the Sound. The timing and influences of these seasonal events (winds, warming, runoff) will be taken into account when interpreting patterns of upper layer plankton and the distributions of larval and juvenile herring.

The following hypotheses guide research in 1995 and beyond seeking resolution of the Lake-River contention:

1. Upper layer and deep circulation processes connect PWS to the adjacent Gulf of Alaska and provide physical mechanisms to affect interchange of plankton populations between these regions.

2. Deep water overwintering populations (below 200 m) of macrozooplankton increase their abundance in Prince William Sound from July to October because of seeding (trapping) from the bordering ocean.

3. Surface (inside and outside the region) and deep water populations (in PWS) of large interzonal copepods (*Neocalanus* spp.) exhibit different stable isotope ratios of carbon and nitrogen reflecting different growth/feeding environments.

4. Upper layer (upper 50 m) macrozooplankton stocks in all or portions of the Sound are diminished by wind forced flushing from the region in the months of April and May.

5. Patterns and rates of upper layer advective processes create a measurable north-south gradient in PWS upper layer macrozooplankton stocks during April and May.

   Corollaries

   5.1. There are measurable north-south gradients in physical/chemical near surface property distributions in the western Sound that is reflective of the advective regime.

   5.2. The waters of the ACC constrain property distributions in HE and the southwestern Sound (SWS), while the northwestern Sound (NWS) near surface property distributions are largely determined by local *input from glaciers and streams. The residence time of waters in the NWS is longer than that of the southern Sound, which reflects the decoupling of the NWS surface circulation regime from the flow through system that characterizes the southern Sound.*

6. The rate of growth, timing and size of late stage *Neocalanus* and *Calanus* are dependent on the timing, duration, and species composition of the phytoplankton bloom, and on ocean temperature.

7. Springtime upper layer flushing of PWS also reduces the recruitment of adult herring to PWS by removing larvae from the region. Ocean circulation and the location of the herring embryos and predator fields within PWS determines the ultimate distribution of age-0 herring at the time of metamorphosis.

Table 3 describes the data products and methodologies that will be used to address lake-river hypotheses.

Juvenile Herring Overwintering Hypothesis

Following the free-drifting, planktonic stage, juvenile herring migrate into nearshore nursery habitats. The herring overwintering sub-program will derive information about the distribution and habitat selection of 0-class herring from studies describing the location and extent of spawning, by tracking the planktonic larvae, and finally by identifying and describing overwintering habitat selected by juveniles spending their first two winters in the region. At present, little is known about over-wintering habitat utilized by 0-class and 1+ juvenile herring in Prince William Sound. Some believe that juveniles overwinter at the heads of inlets in relatively shallow water but there is a paucity of information to support this view (see Appendix I). For example, overwintering juveniles actually occur in the boat harbor at Cordova, although this habitat is not considered representative of all overwintering locations.

Our concerns about the overwintering period focus on the bioenergetics of juveniles during a time when upper-layer food stocks are thought to be greatly diminished. Cold winter water temperatures reduce the overall energy demands

Table 3. Summary of lake/river hypotheses and specific data products and methodologies needed to test them.

Hypotheses	Project	Data	Methodology
1.1	95320M 95320G 95320J	Determination of the time and space variability of near surface currents	Satellite tracked drifting buoys, a towed ADCP, a moored ADCP, and property distribution from CTD, oxygen and nutrient measurements as tracers Computed Baroclinic geostrophic velocities, Numerical modeling
	95320J 95320G 95320M 95320M	Determination of the time and space variability of deep currents	Towed ADCP, moored ADCP, property distribution from CTD, oxygen and nutrient measurements as tracers, computed Baroclinic/geostrophic velocities, Numerical modeling CTD
	95320M 95320H	Temperature, Salinity and Density of surface and deep waters Zooplankton, species composition and assemblages	CTD
	95320H 95320G 95320M	Obtain water mass characteristics; nutrient distribution, oxygen concentration, zooplankton and phytoplankton, species composition, temperature and salinity characteristics.	Vertical closing net, 1/2 meter ring net, backscatter from high frequency hydroacoustics (420, 750 and 1000 KHz), and ADCP backscatter (150 KHz)
1.2	95320J 95320H 95320M	Time series of Zooplankton abundance, distribution and species composition	Vertical closing net, 1/2 meter ring net, backscatter from high frequency hydroacoustics (420,750 and1000 KHz), and ADCP backscatter (150 KHz), Optical Plankton Counter

Table 3. (Continued)

Hypotheses	Project	Data	Methodology
1.2 (Continued)	95320J 95320H 95320G 95320M	Determination of the time and space variability of deep currents	Continuous oxygen sensor, Niskin bottles on a rosette, net sampling and laboratory taxonomic analysis, auto analyzer for nutrient analysis.
	95320G 95320M	Physical/chemical environment inhabited by plankton	Towed ADCP, moored ADCP, CTD, nutrient and oxygen analysis and plankton assemblages as tracers, computed baroclinic geostrophic velocities, Numerical modeling
1.3	95320I 95320J	Trophic interactions in the pelagic part of the ecosystem	Stable carbon and nitrogen analysis using a mass spectrometer, statistical model of interactions
	95320E 95320H 95320I	Zooplankton tissue and fish tissue isotopic signatures within PWS	Stable carbon and nitrogen analysis using a mass spectrometer, statistical model of interactions
	95320E 95320H 95320I	Zooplankton tissue and fish tissue isotopic signatures in the Alaska Coastal Current and the adjacent Gulf Of Alaska	Stable carbon and nitrogen analysis using a mass spectrometer, statistical model of interactions
1.4	95320M	Relative flushing rates	Analysis of historical and current upwelling index and direct ocean current measurements with ADCP and indirect with CTD and computed baroclinic currents

Table 3. (Continued)

Hypotheses	Project	Data	Methodology
1.4 (Continued)	95320H 95320J 95320H	Zooplankton abundance, distribution, species composition and assemblages	a. Vertical closing net, 1/2 meter ring net, backscatter from high frequency hydroacoustics (420,750 and 1000 KHz), and ADCP backscatter (150 KHz),possibly Optical Plankton Counter b. AFK and WNH Hatchery plankton watch time series
1.5	95320J 95320H 95320J	Zooplankton abundance, distribution, species composition and assemblages	a. Vertical closing net, 1/2 meter ring net, backscatter from high frequency hydroacoustics (420,750 and 1000 KHz), and ADCP backscatter (150 KHz),possibly Optical Plankton Counter b. AFK and WNH Hatchery plankton watch time series
	95320M	Relative flushing rates	Analysis of historical and current upwelling index and Direct ocean current measurements with ADCP
	95320G 95320M	Determination of the time and space variability of near surface currents	Satellite tracked drifting buoys, a towed ADCP, a moored ADCP, and property distribution from CTD, oxygen and nutrient measurements as tracers Computed Baroclinic geostrophic velocities, Numerical modeling

Table 3. (Continued)

Hypotheses	Project	Data	Methodology
1.5 (Continued)	95320G 95320M	Determination of the time and space variability of deep currents	Towed ADCP, a moored ADCP, and property distribution from CTD, oxygen and nutrient measurements as tracers, Computed Baroclinic geostrophic velocities, Numerical modeling
	95320M	Temperature, Salinity and Density of surface and deep waters	CTD
1.6	95320H 95320J 95320G	Phytoplankton abundance, distribution , species composition and assemblages	CTD, ocean temperature four year time series from the CFOS buoy, Sea surface temperatures from the Scripps Institute of Oceanography, fluorometer on aquashuttle,
	95320J 95320M	Determination of the time and space variability of near surface currents	Satellite tracked drifting buoys, a towed ADCP, a moored ADCP, and property distribution from CTD, oxygen and nutrient measurements as tracers, computed baroclinic currents, Numerical modeling fluorometer mounted on the CFOS buoy and fluorometer on oceanography research boat. Phytoplankton, CTD and nutrient data also collected by hatchery personnel at near shore station

Table 3. (Continued)

Hypotheses	Project	Data	Methodology
1.6 (Continued)	95320G	Timing and duration of phytoplankton bloom	CTD, ocean temperature four year time series from the CFOS buoy, Sea surface temperatures from the Scripps Institute of Oceanography, fluorometer on aquashuttle, fluorometer mounted on the CFOS buoy and fluorometer on oceanography research boat. Phytoplankton, CTD and nutrient data also collected by hatchery personnel at near shore station, Numerical modeling
	95320H	Zooplankton growth and size	Staging and weighing specimens of *Calanus* and *Neocalanus* in the laboratory. Samples from hatcheries and shipboard collection.
1.7	95320T	Location and abundance of herring embryos	Scuba and aerial surveys of egg deposition
	95166	Relative survival of hatching embryos	Egg loss component of 95166 (UAF-RSA)
	95320M 95320J	Ocean circulation data	Historic data (UAF), CTD, ADCP and satellite tracked drifting buoys Numerical model
	95320M 95320T	Larval herring distribution and relative abundance	Net capute with 1 m^2 Tucker trawl
	95320N 35320T	Presence, location and size of juvenile herring	Net sampling and hydroacoustics in NWS and Pt. Fidalgo, NES, W and CS

Table 3. (Continued)

Hypotheses	Project	Data	Methodology
1.7 (Continued)	95320M	Relative ocean flushing rate	Upwelling index combined with ocean data in 1994
	95320N	Relative distribution and abundance of juvenile herring and their prey resources	Hydroacoustics data of fish; high frequency transducers for prey
	95320N 95320H 95320J	Relative abundance and distribution of zooplankton	Net sampling synoptic with other SEA projects
	95320I	Prey selection and trophic level	Isotope ratios in tissue of juvenile herring

of juveniles allowing them to survive the winter on stored body fat acquired during the summer and fall. However, warmer than average winter temperatures could force significant reductions in energy reserves before the spring forage bloom occurs in late April and May. Energy-stressed juveniles may have to spend more time in nearshore habitats where food is available. However, doing so may increase susceptibility to predation. Winter energy dynamics may influence habitat selection into spring and summer. Energy bottlenecks are thus suspected to strongly influence juvenile survival during their first two winters in the Sound.

The following hypotheses will guide SEA research on herring overwintering survivals for 1995 and beyond:

1. Overwintering ocean temperatures and the energy reserves of herring prior to the onset of winter strongly modify recruitment of juvenile herring to age 3 and survival of adults. Depletion of body energy reserves leads to starvation or weakened springtime condition, increasing susceptibility to predation and disease, and a reduction of energy devoted to reproduction.

   Corollaries

   1.1. Age-0 herring condition, food supply in autumn and winter, overwinter ocean temperatures, along with the quality and distribution of spawning (location and abundance of embryos) are the primary factors controlling herring recruitment to age 3.

   1.2. Age-0 and -1 herring food supply is strongly modified by temperature and location. There are regional differences in juvenile growth and energy reserves during the autumn and winter.

   1.3. Herring overwintering in embayments and estuaries are more susceptible to the effects of winter temperature than herring overwintering in passes and straits. These nearshore habitats are characteristic by high predation risk to small fish.

   1.4. Increased winter ocean temperatures result in decreased overwinter *survival of juvenile herring which are at or near critical energy reserve levels.*

1.5. *The distribution of juvenile pollock and herring (the two most abundant fish species in PWS) overlap to the extent that the somatic energies of the two species are correlated.*

1.6. *Condition factor and size at age of adult herring during the winter is correlated to temperature and food availability of the preceding summer and fall.*

1.7. *Gonadal somatic index and gonad weight are negatively correlated with winter sea surface temperature the previous year and positively correlated with sea surface temperature the previous summer and fall.*

1.8. *Depletion of energy reserves in adult herring can cause density-dependent epidemics of disease.*

Table 4 describes the data products and methodologies applied to formal tests of herring overwinter hypotheses.

This is the first year of a multiple-year SEA program on overwintering survival of juvenile herring and affects on adult reproduction. Although we will begin to acquire the data necessary to test the hypothesis, we do not expect a completion of that task in this fiscal year. Two of the projects that will be examining over-wintering processes (95320T & U) are new and have no funding until detailed project descriptions (DPD) have been approved. Therefore, we anticipate limited sampling over the winter of 94/95 and project start-up by February, pending DPD approval. We have archived samples from the summer and fall of 1994 for analysis once funding is approved. Samples were provided by the forage fish project (94163), the fall hydroacoustic survey (a cooperative survey conducted by ADFG, PWSSC, and Cordova District Fisherman United (CDFU), and the pink salmon predator/prey (94320E) project.

Table 4. Summary of overwintering hypotheses and specific data products and methodologies needed to test hypothesis.

Hypothesis	Project	Data	Methodology
1.1	95320H	Zooplankton production	Plankton tows from March-Sept.
	95320M	Ocean temperatures	CTD taken year around
	95320-96	Autumn and winter prey availability	Plankton tows taken in fY96 SEA program
	95166	Location and abundance of embryos	SCUBA surveys on egg deposition
	ADFG-CFMD	Extent and timing of spawning	ADFG regular aerial survey program
	ADFG-CFMD	Recruitment series	Age structured analysis model
1.2	95320H	Relative zooplankton abundance	Plankton tows on SEA cruises
	95320M	Relative ocean conditions	CTD synoptic with zooplankton and fish sampling
	95320T	Relative abundance of juvenile herring	Net sampling and hydroacoustics from 95320 and 9516 platforms
	95320U	Energetics of juvenile herring	Subsampling from 95320T project
1.3	95320-96	Temporal changes in juvenile herring relative abundance, condition and growth rates in herring sampling from bays versus passes	FY-96 SEA program
1.4	95320M	Ocean temperatures	CTD data collected year around
	95320T	Juvenile herring relative abundance	Comparison of 1994 with 1995 survey data
	95320U	Juvenile herring energetics	Comparison of a limited no. of 1994 samples with 1995 samples
	95320-96	Critical condition factor data	FY96 SEA program experiment
	95320-96	Overwinter herring sampling	FY96 SEA program net sampling
1.5	95320U	Somatic energy measures of pollock	Age, sex, weight, length and condition and herring factor and energy content (by bomb calorimetry)
	95320T	Samples of herring and pollock	Net capture from 95320 and 95163 cruises
	95320-96	Continuation of measurements	FY96 SEA plan and forage fish studies

Table 4. (Continued)

Hypothesis	Project	Data	Methodology
1.6	ADFG-CFMD	Age, weight and length of adult herring from overwintering areas;	Net capture of adult herring
	95320M	Ocean temperatures	CTD data
	95320H	Summer and fall prey abundance	Zooplankton tows synoptic with CTD
1.7	95166	Gonad weight and somatic index	Age, weight, and length measurements of individual herring; historic and current
	95320M&J	Indices of seasonal sea-surface temp.	Historic and current data sets from PWS and the Gulf of Alaska
1.8	95320S	Occurrence of disease in herring;	Histopathological and gross examinations for lesions and disease of synoptic measure of fish condition systematically sampled adult herring
	95320U	Measurements of energy reserves	Sea above
	ADFG-CFMD	Historic measures of weight and length; of individual herring; historic herring	Net capture of fish; age structured analysis of historicdata population estimates; size-at-age of dependent processes
	Fish Processors	Historic data base on fat reserves	Net sampling of commercial catch; estimates of percent body fat

Modelling the Pink Salmon and Pacific Herring Subsystems

The ultimate objective of SEA is the capability to understand quantitatively and to simulate the time evolution of processes regulating the populations of pink salmon and Pacific herring in Prince William Sound during their early life stages. The SEA project addresses this objective by means of a sequence of coordinated and adaptive monitoring and modelling efforts.
The modelling effort has five aspects:

1) The development of numerical models.
2) The implementation of prototype models and the delivery of interim models and results.
3) The development of data analysis tools to facilitate system description and model validation.
4) The use of prototype models in sample design and in the development and execution of adaptive sampling strategies.
5) The use of models to support and evaluate restoration activities.

During FY94 the primary issues were a plan for model development, data analysis tools, and establishing the infrastructure to support realtime adaptive strategies. Based upon the progress in those areas the effort in FY95 implements the plan for model development, adds a new effort for the implementation of interim modelling products based on prototype models, and begins the use of the new resources supporting adaptive sampling. In particular, the modelling effort in FY95 is more tightly coupled with the monitoring effort.

Problem Formulation

The SEA objective is a quantitative understanding of the early life stages and the ecosystem that sustains them. This objective requires much more structure in order to serve as the basis for the development of a numerical model. The problem can be formulated as a nowcast/forecast problem. This is not the format commonly used to state questions regarding restoration, so it is important to put these questions into a format better suited to numerical models.

The formulation of a sampling strategy with which to estimate the number of fish entering the ocean or commencing overwintering is far from trivial and seems beyond current measurement methods. The estimation of mortality requires both the number surviving and initial conditions. If, however, answers can be obtained, each of these represents the net effect of all of the system processes. In effect, all of the ecosystem function has been relegated to the role of variability, that is, noise. At best the answers could be part of a statistical model wherein a set of similarly formulated variables is used as covariates.

An alternative approach is to put these questions into a common systems context and to link them wherever possible with prior knowledge and with testable conjectures (about both data and models) such that the measurements become feasible and the resulting answers contain information about the linkages as well. In particular, the SEA hypotheses are such testable conjectures regarding linkages. In so doing we gain in feasibility at the sacrifice of having to address the questions indirectly.

Nowcasting/Forecast Formulation

A question formulated as a nowcast/forecast problem has the following format

- given all available information about the past, up through to the present and

- given a set of models describing the coupling and forcing of components, what is (a best estimate of) the present and future state of the system, including values for the strength of coupling between components?

This formulation reflects implicitly that at least some measurements are necessarily sparse and inadequate for a determination of the present state. The forecast in this formulation is short term.

Questions about overall survival and mortality are formulated by accumulating retrospectively quantities from nowcasts. For example, each nowcast would contain an estimate of the spatial distribution of fry mortality rates. The integration of these rates over space is an estimate of the current instantaneous mortality rate. The integration retrospectively of a time series of these rates is the answer to the question of cumulative mortality.

Questions that cover substantial time intervals into the future require that those components of the system that are forcing be specified independently. These components include all of the environmental variables, such as temperature, current velocity, and mixing events. In the case of nowcasts these variables are (in principle) available from measurements and from physical models. However, these physical models extend no further into the future than the forecasts for the atmospheric forcing functions. Consequently, "what-if" problems are formulated using a stochastic model for these variables, and longer term "what-if" questions are posed using probabilities of outcomes.

From SEA Hypothesis to Numerical Models

A summary of three primary SEA hypotheses for pink salmon is graphically represented in Figure 10. These hypotheses are in fact conjectures about the structure of the coupling mechanisms between the system components along with conjectures regarding the magnitude of the coupling in terms of its effect on the growth and survival of pink salmon.

To convert these hypothesis into simulations it is necessary to restate them as nowcasts/forecasts in terms of time-varying populations that are distributed relative to space and size and that interact only if they are coincident in space and time. *Model thumbnail sketches* are shown in Figures 11 through 15. These are graphical methods to summarize the essential elements of a model with space-time dependent trophic interactions. Each figure is for a single time given at the top. The plane of the figures is a generalized space-size coordinate system. Three dimensional physical space (x) is represented by the horizontal axis and individual size (s) across all trophic levels is represented by the vertical axis. The five principle interacting trophic levels are shown: predators, fry or alevin, macrozooplankton, phytoplankton, and nutrient concentrations. Each of these is represented by boxes, with the position and size of the box indicating a generalized and relative spatial and size distribution for the population. This greatly oversimplifies the trophic levels and suppresses the roles of other juvenile fish and other zooplankton. Things vertically aligned are understood to be coincident

Pink Salmon Growth and Survival

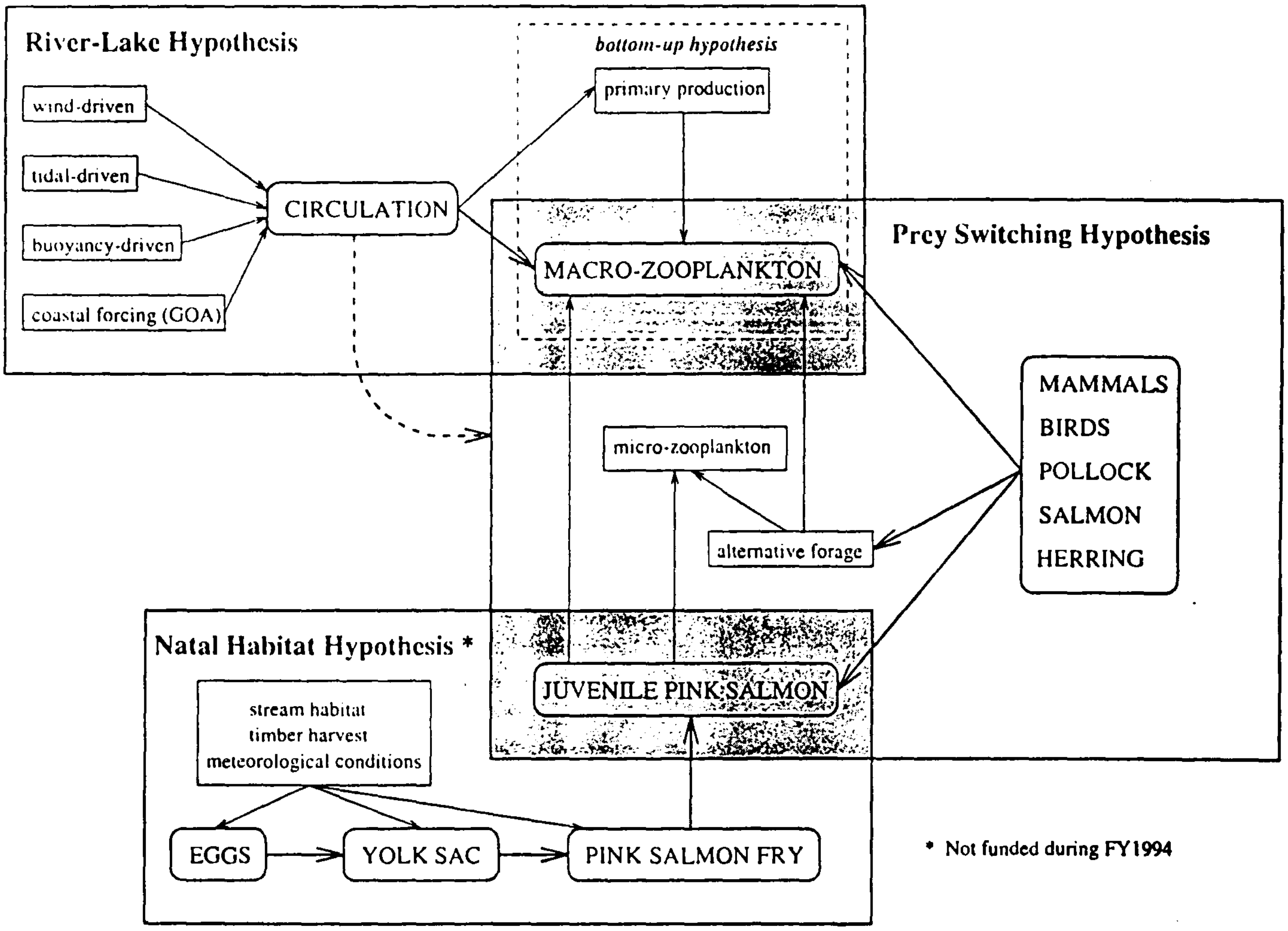


Figure 10. A composite of conceptualizations and conjectures influencing the growth and survival of pink salmon in Prince William Sound, Alaska.

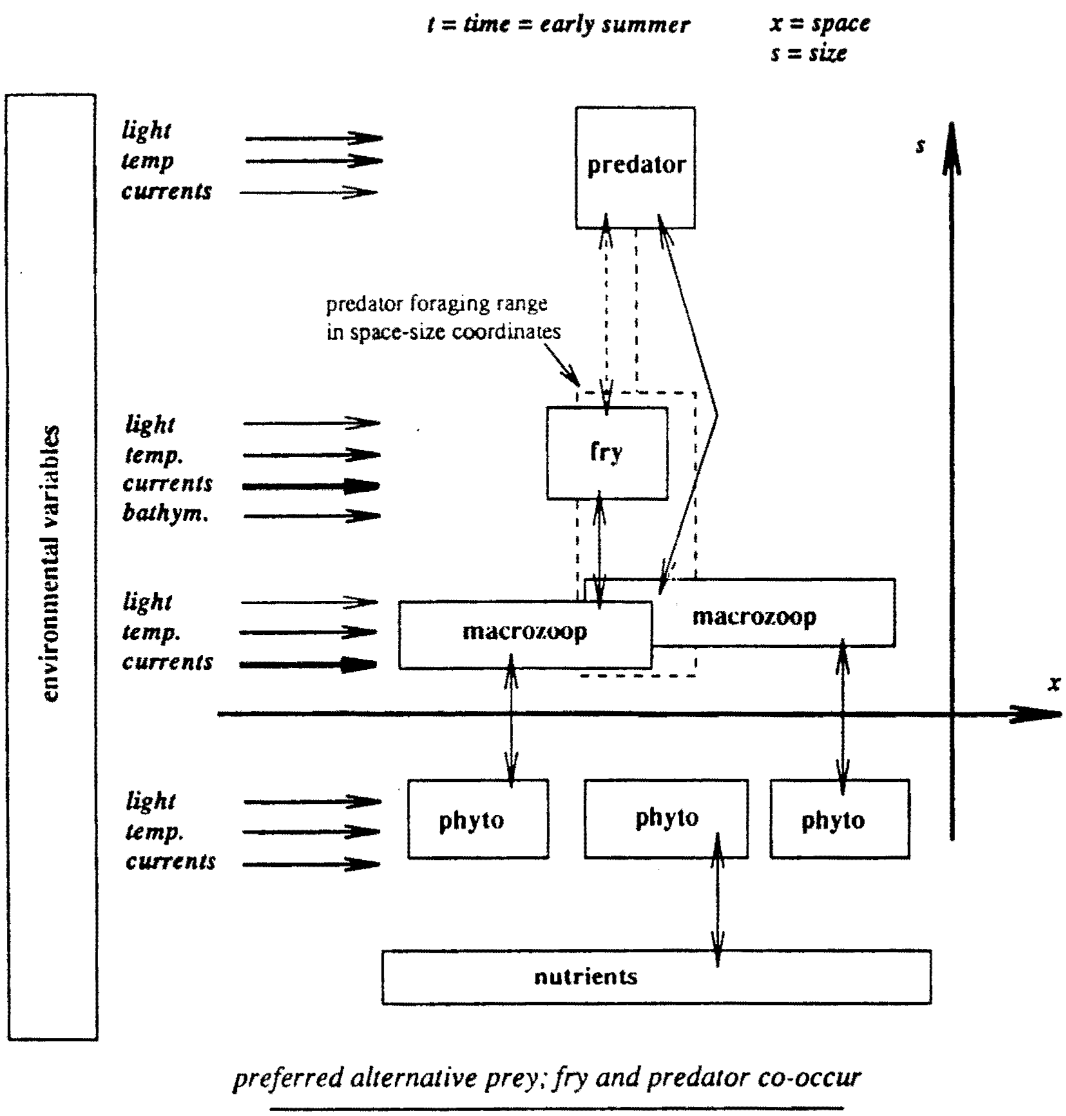


Figure 11. Pink salmon fry coupling model emphasizing alternative prey with fry and predator co-occuring.

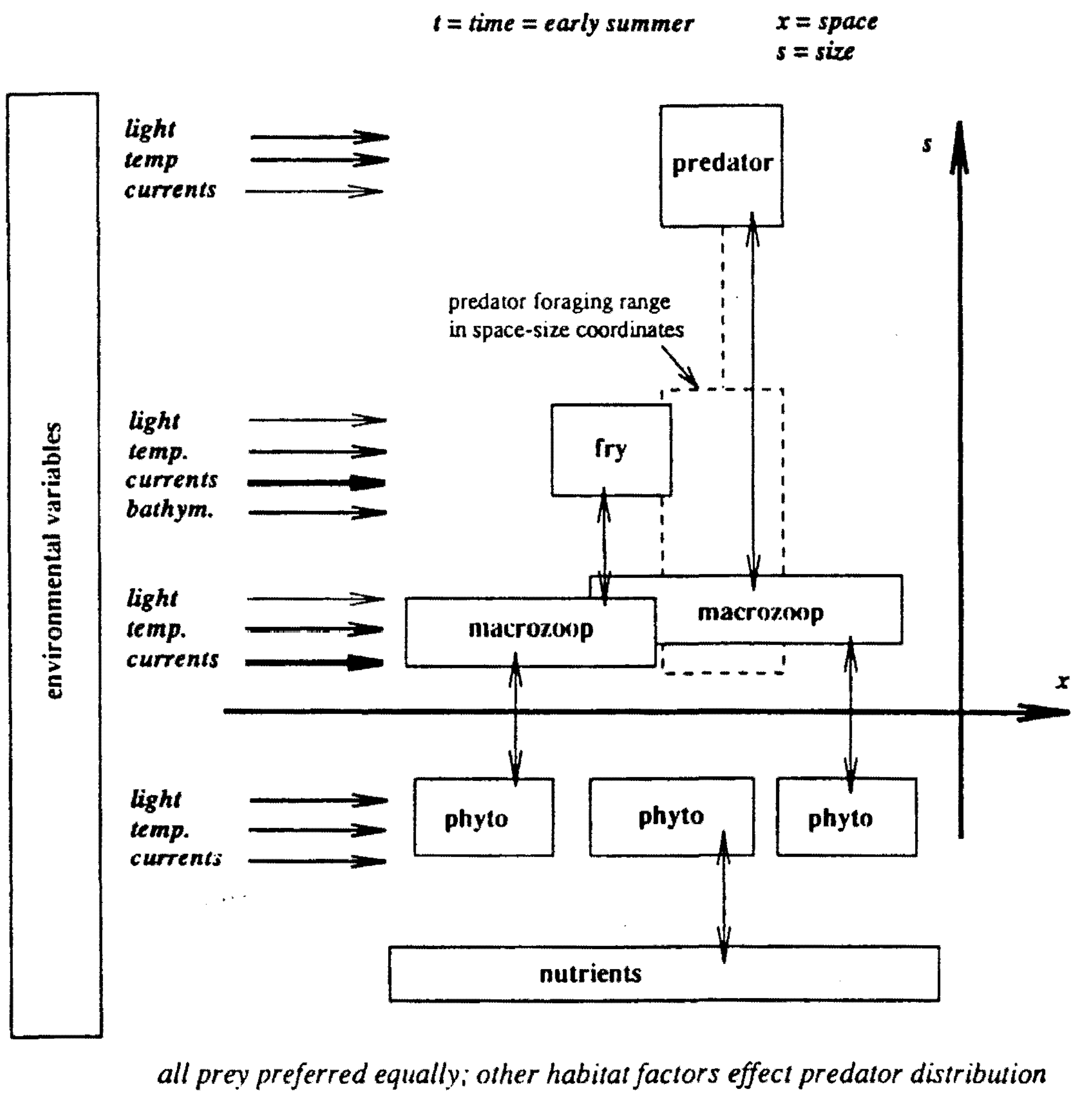


Figure 12. Pink salmon fry coupling model emphasizing equal prey with fry and predator co-occurring.

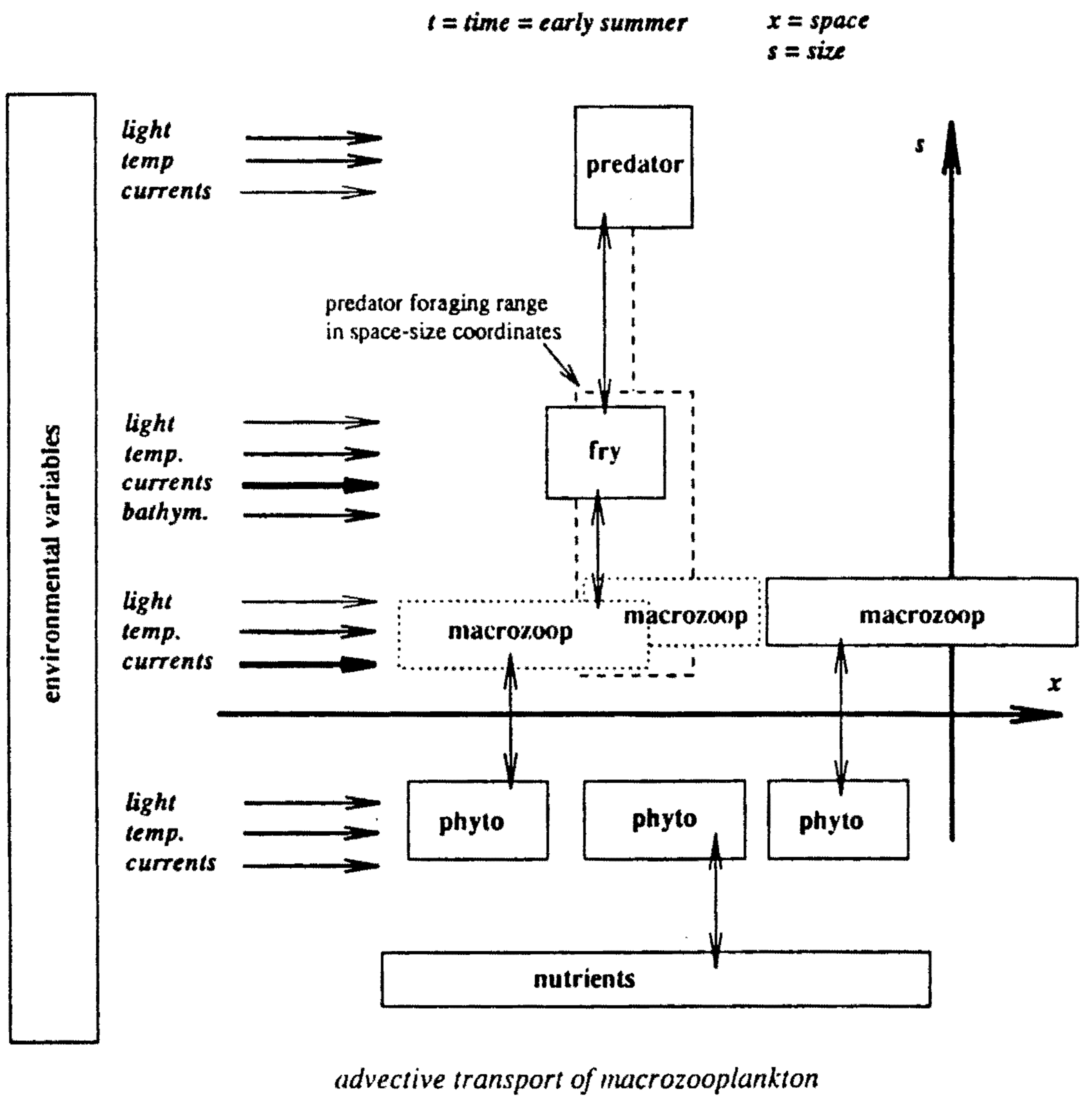


Figure 13. Pink salmon coupling model emphasizing advective transport of macrozooplankton stocks.

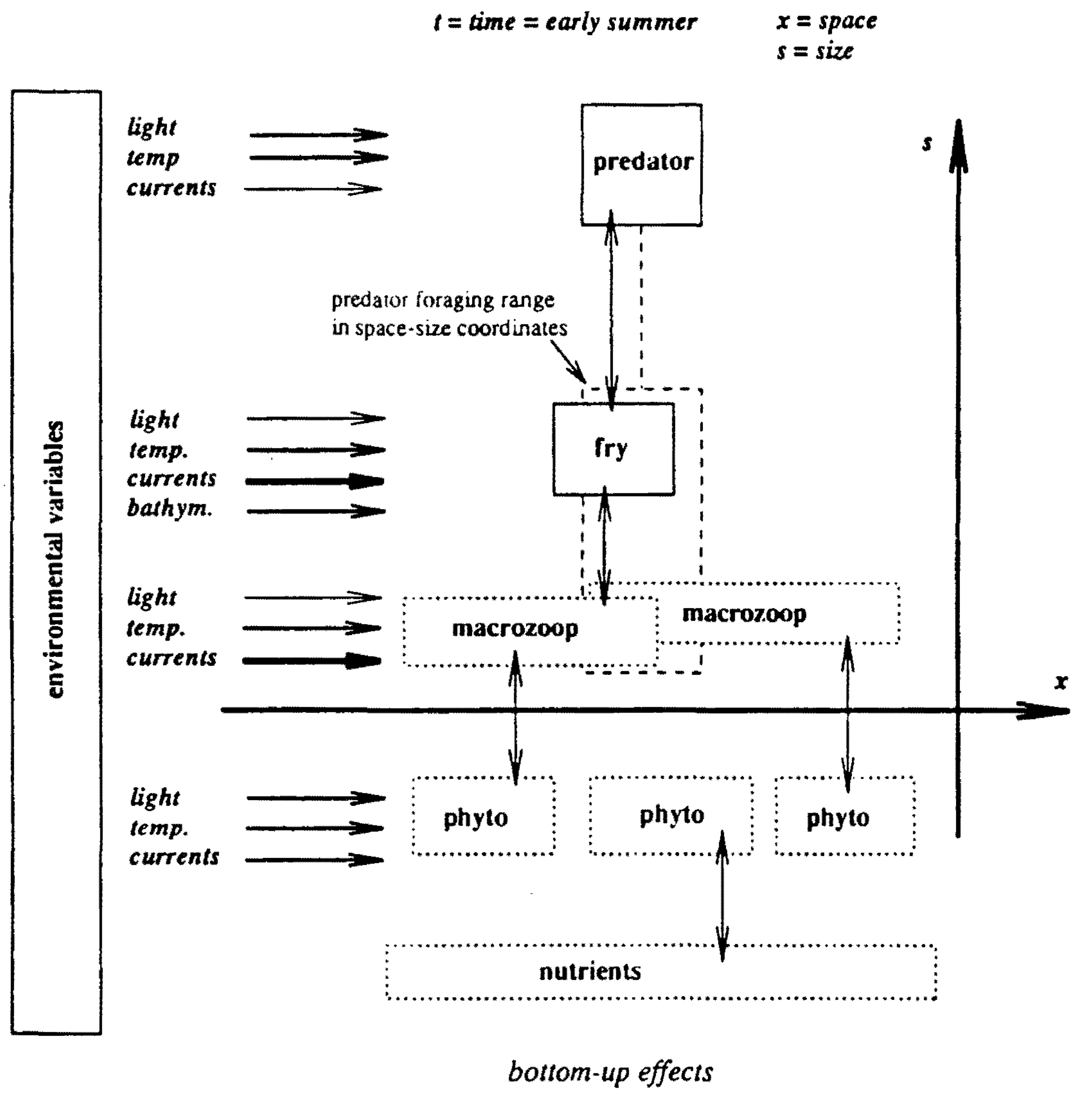


Figure 14. Pink salmon fry coupling model emphasizing bottom up constraints.

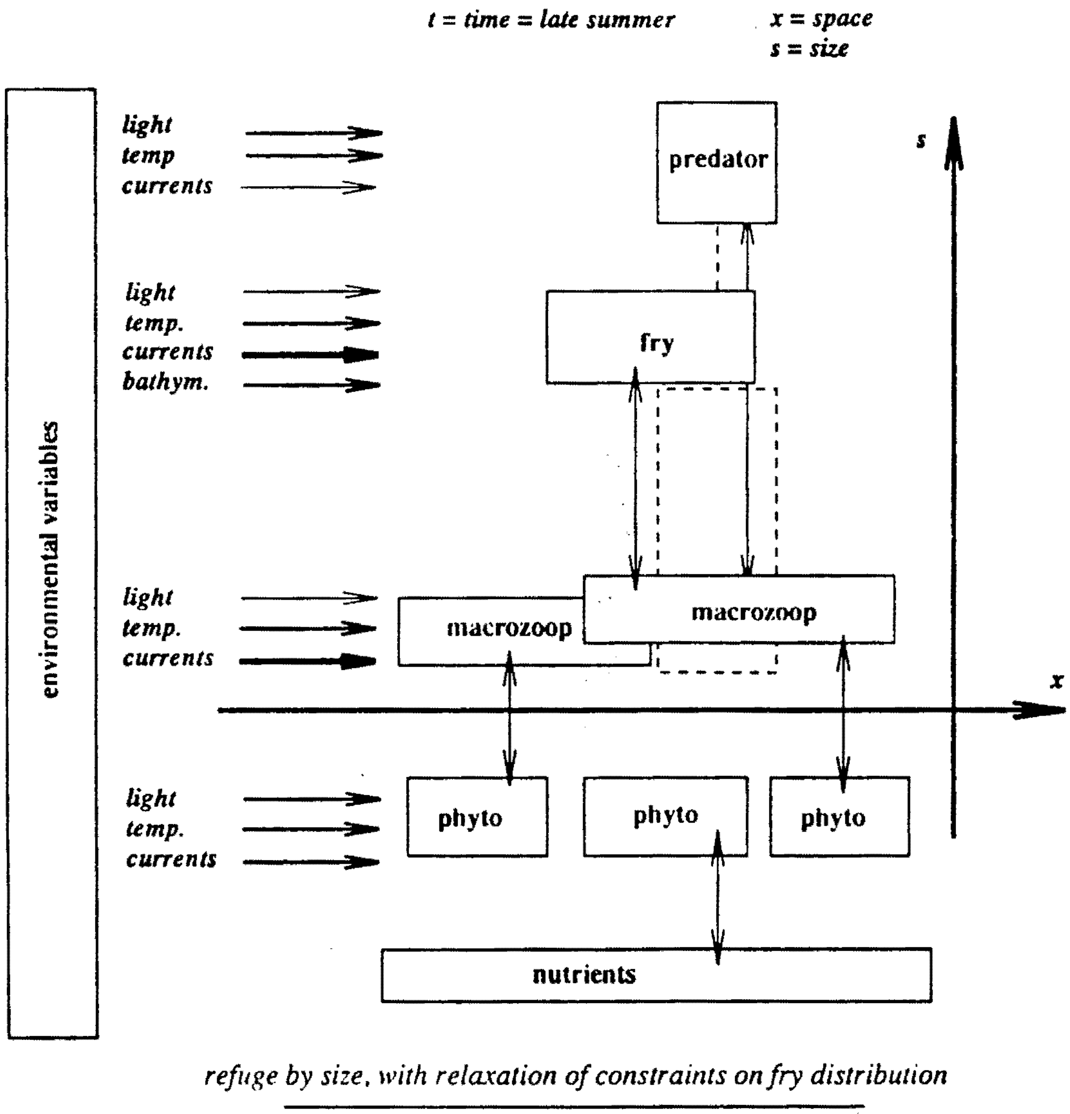


Figure 15. Pink salmon fry coupling model emphasizing a predation refuge by size.

in space and time, and things that are not can not interact since they occur in spatially disjoint domains. With this it is convenient to show the range of predation for predators on the space-size plane. Interactions are shown by arrows, coupled interactions with double-ended arrows, forcing interactions with single-ended arrows. The width of the arrow represents relative strength of interaction.

The coupling and the anticipated nowcast for five different coupling models is envisioned as: 1) predator preference for alternative prey creates a refuge from predation for fry regardless of the degree to which fry and predator co-occur (Figure 11); 2) alternative prey are equally preferred and a spatial refuge is generated by other factors effecting predator distribution in conjunction with the much greater spatial extent of the alternative prey (Figure 12); 3) advective transport reduces zooplankton abundance in regions occupied by fry, with consequent loss of alternative prey refuge and slowing of fry growth (Figure 13); 4) bottom up effects reduce zooplankton abundance (Figure 14); 5) fry grow out of range of vulnerability and in the process loose prior constraints on spatial distribution (Figure 15).

The nowcast/forecast modelling problem is to anticipate 1) the joint space-size distributions of the populations and 2) the magnitudes of their interactions (e.g., foraging) for any survey site. The associated monitoring problem is to simultaneously measure these space-size distributions and the interactions in a manner sufficient for assessment of the accuracy of the model nowcast.

Model Development

A three stage model development approach was put forth in the SEA Science Plan: ocean model, physical-biological model, and nekton model. This is illustrated in Figures 16 and 17. Since all effects from the ocean state are forcing, numerical simulations of the ocean state can be developed without regard to biological data or biological modelling. Dispersion of zooplankton and of lower trophic levels, over time intervals that are small relative to mortality rates and regeneration rates, can be handled approximately as diffusion with advection by ocean currents. Over longer time intervals the processes of feeding, predation, and regeneration must be included to properly account for changes in population

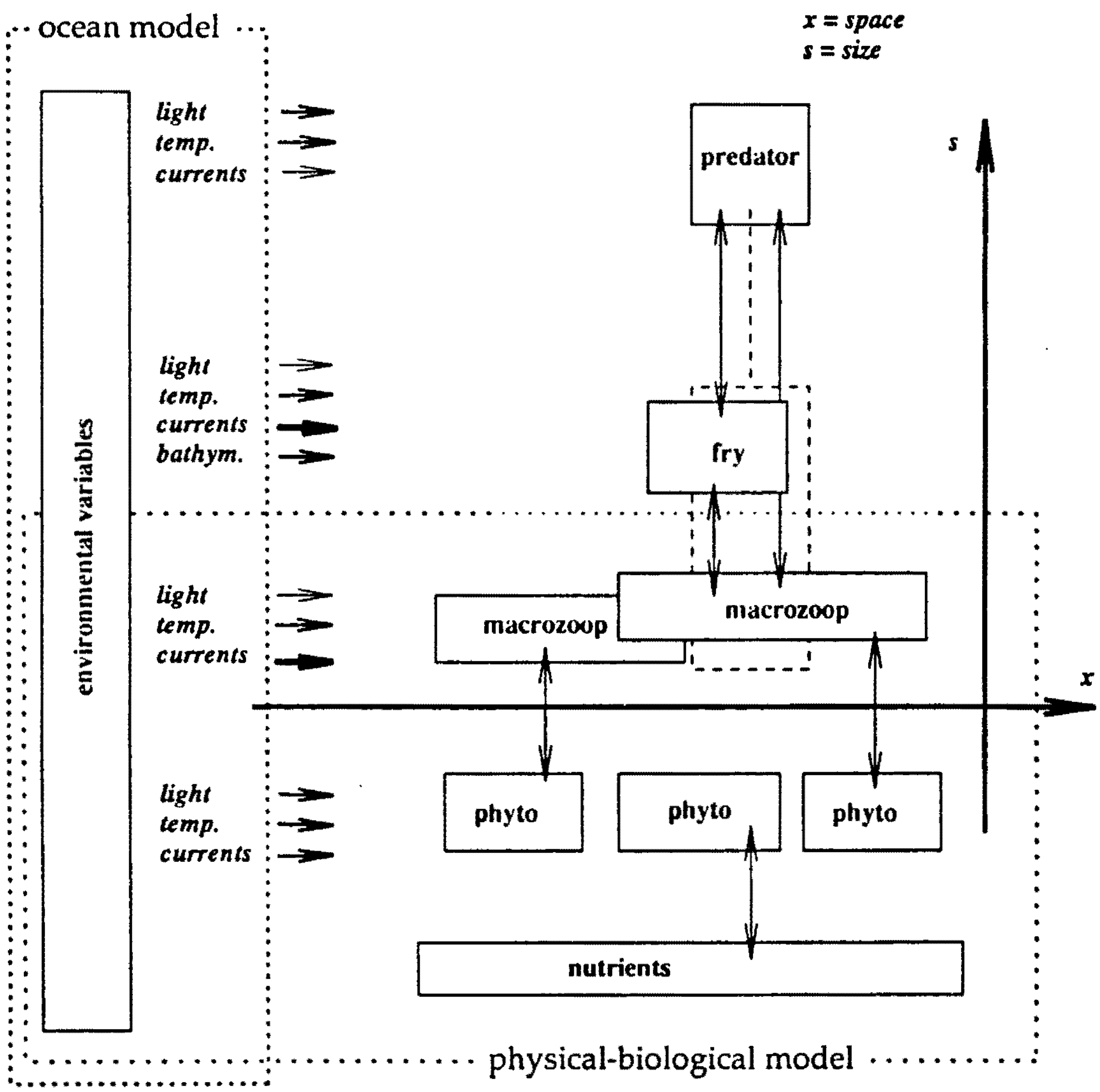


Figure 16. Combining sub-models for ocean state, bottom up forcing and prey/predator relationships.

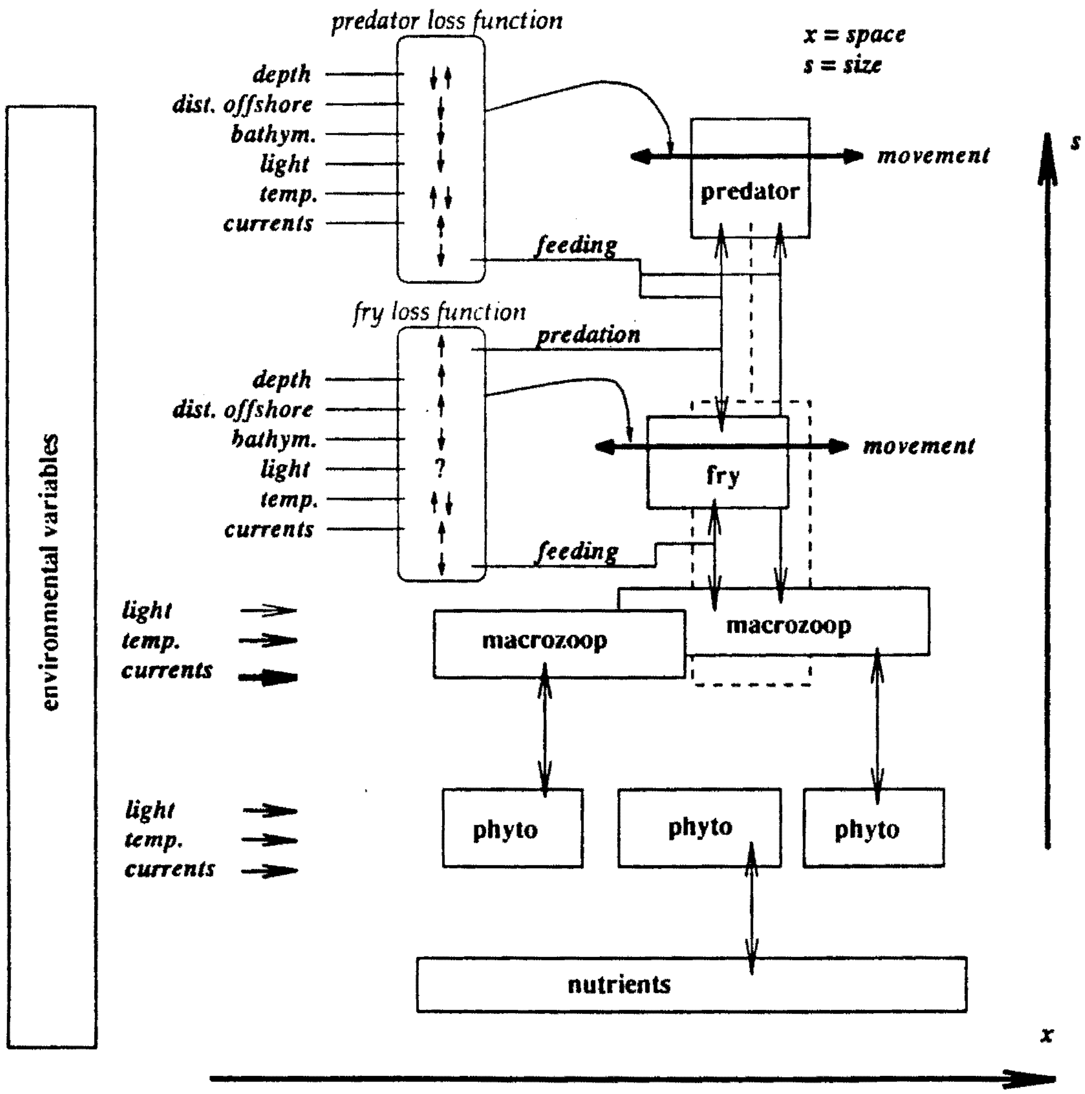


Figure 17. Combining sub-models for environmental forcing, bottom up and top down control arrayed over different combinations of factors influencing predator and fry distributions.

size and distribution. However, the instantaneous rates of feeding and predation do not, to first order, affect dispersion, whereas dispersion is a major determinant of feeding rates and predation rates.

Models for nekton, on the other hand, must include the ability for fish dispersal in a manner that reflects choices among alternative habitats. These choices made jointly by potential predator and prey fish populations are the fundamental determinants of whether predation occurs and the rates of predation. On the other hand, a nekton model must include the likely possibility that instantaneous foraging rates and predation rates are factors themselves in the choice among habitats. The actual distributions of potential predator and prey populations are treated as unknown density functions, whereas the environmental variables and the density functions for plankton are known. Feeding rates and predation rates are computed in terms of the known variables and the unknown fish densities using conventional foraging models. The enclosed arrows indicated how the habitat factors are combined into a *loss function* for each nekton stock. For example, increased feeding rate reduces loss (arrow down), whereas increased predation rate increases loss. The arrows for physical features reflect present conjectures. For example, fry prefer lower current velocities (loss increases with current velocity), prefer nearshore regions (loss increases with distance offshore), but not shallow regions (loss decreases with bottom depth), and stay near the surface (loss increases with depth). The dual arrows for temperature reflect the use of both upper and lower bounds for a preferred temperature range. The process of predator and prey simultaneously seeking to minimize their losses is expressed by means of a diffusion-advection equation, with advection driven by motion to move toward regions of less loss (analogous to moving to lower potential energy).

For FY95 model development addresses establishing modelling capabilities that are required by SEA but not yet available for Prince William Sound. The approach is to invest first in those areas that are the most well developed technically and hence represent the least risk. Consequently, for FY95 ocean, physical-biological, and nekton model development is pursued at a cost ratio of 3:1:1. This is consistent with the dependence of both physical-biological models and nekton models upon the ocean state. Ocean modelling is well established and the modelling capabilities will be obtained by the beginning of FY96.

Prototype Models, Interim Products

A priority for FY95 is the development of prototype models and their use as an integrated part of the FY95 sampling effort. Based upon progress in model development and results from field observations during FY94 the following set of interim nowcasts/forecasts has been developed. The temporal and spatial allocation of monitoring resources relative to these interim models is not yet finalized.

1. Forecast the time for the beginning of vertical migration for macrozooplankton.
2. Forecast the relative vertical migration flux as a function of spatial position of macrozooplankton into the surface waters.

Nowcast/Forecast: There is insufficient data at this time to predict the size of the overwintering populations. However, a forecast of the timing and spatial distribution of the vertical migration can be made. Interim forecasts of spatial distribution of vertical flux can be made assuming that only regions with bottom depth greater than 300m contribute, and that there is a monotonic relationship between the available water column beyond 300m and the vertical flux. Forecasts of onset of the vertical flux will be based on temperature. Since the ocean modelling work is just beginning, forecasts of the occurrence of migration triggering temperatures will be based on AVHRR data, CFOS buoy data, Coast Guard and NOAA measurements, and SEA surveys.

3. Forecast of the relative time-varying spatial distribution of macrozooplankton.

Nowcast/Forecast: Because ocean modelling has been delayed the interim model products must be formulated in ways that do not require essentially no ocean current information. One approach is to use diffusion alone with no advection as a "null hypothesis."

Null Nowcast/Forecast: Assume that the contribution to distribution from ocean currents is of no consequence and that the distribution of macrozooplankton is predominantly due to diffusion. Beginning with initial conditions for macrozooplankton density from either measurements or the forecasts above, predict the time evolution of zooplankton density using diffusion as the sole determinant.

Local Forecast: ADCP measurements of the ocean currents can be used to forecast the near term changes of measured plankton distributions by combining diffusion with the observed velocity fields. Of most significance are ADCP measurements in regions that would replenish the outmigration channels from sources of macrozooplankton elsewhere in the Sound and measurements in regions that flush these channels.

AVHRR Forecast: Some information regarding water mass movement can be extracted from sea surface temperature images. Whenever such information is available it can be used to indicate, albeit with uncertainty, the dispersal of plankton.

Phytoplankton and Nekton Moderated Forecasts: The null and AVHRR cases can be extended over time intervals of sufficient length to include in the forecast the impact of the co-occurring planktivorous fish and phytoplankton or microzooplankton prey upon growth and/or regeneration of macrozooplankton. In particular, this moderated forecast for the diffusion alone provides an approximate forecast for whether top-down or bottom-up processes contribute significantly to distribution.

4. For a specific time and location in the outmigration channel, forecast the inshore-offshore distribution of fry and predators, the fry foraging rate and predator foraging rates on fry and macrozooplankton.

During FY94 there were some refinements of the basic SEA hypotheses.

- The acoustics surveys of the nearshore identified a spatial segregation of fry and predators associated with a tidal rips or fronts. This finding suggests that the fry may have a refuge from predation when there is a partitioning of the water column by differences in currents.

- The predation survey documented the shift of the foraging behavior of walleye pollock from age 0 fish to macrozooplankton during the macrozooplankton bloom. That is, age 0 fish have a refuge due to the occurrence of an alternative prey for their predators.

– The sharp decline in predation mortality of fry due to pollock for fry greater than 60mm length. In effect, there is a refuge associated with sufficient size.

These refinements add further structure regarding foraging and dispersal processes. This is precisely the type of process identification needed by the diffusion-advection nekton model. These findings provide the starting points for using the one-dimensional numerical solution developed during FY94, and interim results in the form of nowcasts/forecasts can be generated for both distribution and foraging of fry and their predators. These results will depend upon measurements of current velocity and temperature since there will be no ocean model results. The validation will depend upon the simultaneous measurement across the physical variables and at least three trophic levels.

5. Estimates of carrying capacity.

Information on the density, distribution, advective replacement or losses, and growth rate of macrozooplankton can be used to estimate the carrying capacity of the bloom for those populations competing for macrozooplankton prey. It is an example of a "what-if" simulation.

6. Nowcast/Forecast of fry size and of "time-to-60mm."

This is a nowcast of the current fry size and a forecast of the additional time required to reach a specific size. This result requires combining bioenergetics models with spatial distribution models as well as with foraging models.

7. Nowcast of the spatial distribution of fry of length greater than 60mm.

The nowcast of inshore-offshore distribution described above assumes an active response to predators. Once a "refuge size" is attained, this response, if actually operating, should moderate. The nowcasts for the less than and the greater than cases illustrate the many ways that nowcasts of spatial distributions of interacting populations can be used to validate and parameterize assumptions regarding the occurrence and magnitude of foraging interactions.

Adaptive Sampling, Realtime Data, Validation and Parameterization

During FY95 the repeater network will be completed to a state where realtime data can be transmitted between survey vessels, fixed sampling stations, and Prince William Sound Science Center (PWSSC). PWSSC provides a link between the survey vessels and any data source or data recipient on the Internet. The nowcasts and forecasts of the interim models are useful for adaptive sampling only if the results can be immediately available in the field. Similarly, the nowcast requires near realtime data from the survey. Consequently, the realtime data communication network is essential to utilizing the model results in an integrated manner. This is in addition to the other roles for the network in an adaptive study plan, such as providing near realtime AVHRR data to survey vessels and making the results from one vessel available to all field vessels.

CHAPTER 3
Science Support

The collaborative science pursued by SEA95 (and beyond) is organized by several key activities that can be grouped under the heading of science support. Vessel and aircraft use is shared among the projects and coordinated in the field by cruise plans and daily radio communication. Field teams using hatchery facilities are also in communication with vessels and aircraft in the region. The SEA sampling approach exploits a variety of strategies and technologies to address hypothesis testing. These strategies include continuous logging (real time and delayed) of oceanographic and weather variables at hatcheries and from moorings, acquisition of AVHRR and other satellite data, monthly multi-vessel cruises, and aircraft over-flights of the region.

All observations collected by SEA investigators are screened for errors and submitted to an open and distributed data base. The intent of the data base is to provide centralized and standard access to all observations for hypothesis testing, and project planning and reporting. Quality control is achieved by a data manager in collaboration with all investigators submitting data.

SEA incorporates numerical modelling as a priority integrating tool/activity for the entire program. While it is understood that not all investigators have the background to address the formal development of numerical models, all investigators will participate in some aspects of the modelling, particularly in the interpretation of modelled results and the development of potential restoration scenarios that will be evaluated by numerical simulations. This integrating activity is forced by an increased understanding of mechanisms and processes influencing production of pink salmon and herring in the region.

SEA Management

The SEA Program is led by a Lead Scientist assigned by the Trustee council from among SEA project investigators. The program is managed internally by an Executive Committee composed of single representatives from Alaska Department of Fish and Game, the Prince William Sound Science Center, and the University of Alaska Fairbanks. The ADF&G representative also speaks for the Prince William Sound Aquaculture Corporation and the U.S. Forest Service. There are alternates for each position. The Executive Committee is chaired by the SEA Lead Scientist.

The Executive Committee assists the Lead Scientist with program reporting and planning activities. These tasks include (but are not limited to) assistance with developing integrated end-of-year reports and creating the single, integrated DPD. Executive Committee members assume responsibility for representing the principal investigators in their respective agencies in accomplishing these tasks.

The SEA program operates as a consensus body of all principal investigators to address directions from the Trustee Council about inflating or reducing budgets. Internal decisions about program redirection and the addition or loss of research components/funding are discussed in meetings (face-to-face or conference calls) chaired by the SEA Lead Scientist or his/her designee. The results of these deliberations are discussed further with the EVOS sponsoring agency and the Council's Chief Scientist as the means for establishing each year's programmatic direction and overall budget line.

Cooperative field studies are overseen by a designated Chief Scientist in the region who serves as the contact point for decisions that arise locally from vessel and aircraft operations. The Chief Scientist in the field is responsible to and appointed by the SEA Lead Scientist for each month's activities. When the Lead Scientist is at sea, he may also serve as Chief Scientist. Multi-vessel, aircraft and hatchery operations are coordinated by radio reporting once or twice daily. Work aboard each vessel/aircraft is coordinated by a Senior Scientist responsible for tracking and reporting daily activities to the Chief Scientist in the field. Senior Scientists prepare cruise plans detailing personnel, equipment, and a sampling schedule for stations and transects. Senior Scientists are also responsible for submitting a cruise report describing the numbers and kinds of observations, and any preliminary results at the end of each trip.

Vessel/Aircraft and other Logistics

TRAWLING, SEINING AND FISHERIES ACOUSTICS

The prey-predator component of SEA will involve four sampling vessels in 1995. A mid-water trawl vessel will conduct hydroacoustic surveys (95320N) and fish sampling (95320E & 95320I) in offshore areas of the passages in PWS (Table 9). The mid-water trawl vessel will also sample zooplankton (95320H), nutrients (95320G), and temperature/salinity (95320M) (Table 10). Nearshore fish sampling will be conducted by crews working from a seiner, a pair trawler and two small skiffs (95320A & 95320E). The *R/V Orca Challenger* will conduct nearshore hydroacoustic surveys (95320N and CTD work 95320M). A logistic support vessel will provide a base of operations for the two skiff crews and the *Orca Challenger* crew (Tables 11 and 12). The logistic support vessel will also provide a platform for a sample processing crew responsible for all samples collected nearshore (95320A, 95320E, 95320I, & 95320T). The activity of all vessels will be directed by a Chief Scientist located primarily on the logistic support vessel. The vessels will sample in northwestern and southwestern PWS from April 20 through June 11 (Table 13).

All herring field work is dependent upon other components of SEA and the Forage Fish project. Because of the costs of a field program, juvenile herring will not have a separate field component in 1995. In 1995, personnel from the herring project will collect juvenile herring while participating in cruises for Prey/Predator (95320E) studies during April through June 1995. Larval herring will be sampled aboard the vessel commanded by the Oceanography project (95320M) which will sample the entire Sound on a broad scale. Additionally, personnel from the herring project will participate on cruises staged by the Forage Fish project in May, July, August and October. These cruises will probably concentrate their efforts in the vicinity of bird rookeries in the central part of the Sound.

While we do not believe this to be the ideal sampling plan to fulfill our goal of determining the location of juvenile herring, we believe this schedule is the most cost effective means to obtain sufficient information for project design and implementation in 1996. We will also supplement these collection with aerial surveys to determine broad scale distribution patterns of juvenile and adult herring schools.

Table 5: SEA personnel on board mid-water trawl vessel in 1995.

Title	Affiliation	Project	Activity
Fishery Biologist I	ADFG	95320E	Fish sampling
Fishery Technician II	ADFG	95320E	Fish sampling
Acoustician	PWSSC	95320N	Acoustics
Oceanographer	UAF	95320H	Zooplankton, nutrients, CTD

Table 6: Equipment on board mid-water trawl vessel in 1995.

Description	Unit	Number	Owner
120/420 kHz echosounders	each	1	PWSSC
CTD	each	1	UAF
0.5 m opening/closing plankton net	each	1	UAF
0.5-m ring net	each	1	UAF
Nisken Bottle	each	1	UAF
Tucker Trawl	each	1	UAF
20/14 mid-water wing trawl	each	1	ADF&G

Table 7: **SEA personnel on board logistic support vessel in 1995.**

Name	Affiliation	Project	Activity
Fishery Biologist II	ADFG	95320E	Field Coordinator
Fishery Biologist I	ADFG	95320A	Juv. salmon sampling
Fishery Technician II	ADFG	95320A	Juv. salmon sampling
Fishery Technician II	ADFG	95320A	Juv. salmon sampling
Fishery Biologist I	ADFG	95320E	Nearshore predator sampling
Fishery Technician II	ADFG	95320E	Nearshore predator sampling
Fishery Technician II	ADFG	95320E	Fish sample processing
Fishery Technician II	ADFG	95320E	Fish sample processing
Technician	UAF	95320T	Herring sample processing
Acoustician	PWSSC	95320N	Acoustic survey
Acoustician	PWSSC	95320N	Acoustic survey
Total 11 personnel			

Table 8: **Equipment used by crews based on logistic support vessel in 1995.**

Sampling Crew	Description	Unit	Number	Owner
Orca Chal.	120/420 kHz echosounders	each	1	PWSSC
Juv. Crew	Juv. salmon purse seine	each	1	ADFG
Juv. Crew	Zooplankton pump	each	1	ADFG
Pred. Crew	Fyke nets	each	4	ADFG
Pred. Crew	Hoop traps	each	24	ADFG
Pred. Crew	Var. mesh gillnets	each	16	ADFG

Table 9: **Sampling schedule for the salmon and herring Prey\Predator study in 1995.**

Dates	Sampling Area	Activity
April 25 - May 1	Broad-scale Predator Distribution	Entire PWS
May 1 - May 17	Estimate Predation Rate/Diel Feeding Study	Northwest PWS
May 18 - May 23	Broad-scale Predator Distribution	Entire PWS
May 24 - June 7	Estimate Predation Rate/Diel Feeding Study	Northwest PWS
June 9 - June 16	Diel Feeding Study	Southwest PWS

SEA field studies will cooperate with other EVOS investigations of Prince William Sound when schedules and space availability permits in 1995. Our mutual understanding of the ecosystem function in the region will be enhanced by sharing results from all studies. Once the Forage Fish/Bird program has developed its hypotheses and defined its sampling requirements, SEA will try to accomodate requests for personnel on SEA vessels and special sampling. For the immediate 1995 spring, summer and early fall sampling season, the integration with Forage Fish/Birds will be attempted at the level of cruise planning and implementation. For the years that follow, SEA and Forage Fish/Birds will interact much more closely in planning logistics, defining shared sampling goals, and in the collection and interpretation of data. The most obvious overlap programs are marine acoustics. The 95320N project leader is working closely with his counterpart in Forage Fish/Birds to develop an effective shared program that includes calibration, equipment and truthing issues.

OCEANOGRAPHY

Total time at Sea is expected to be 60-70 days for the 7 months of March through September 1995, with the possibility of shorter cruises (3-4 days) in January or February. The tentative cruise schedule is for an 8 to 10 day cruise each month, starting around the middle of the month. These cruises address broad spatial coverage of the Sound, and also include several stations in the adjacent Gulf of Alaska outside Hinchinbrook Entrance.

Stations and transects will encompass many of those sampled during the 1994 field season, including stations SEA 22 and CFOS 13 which have been sampled extensively since November 1990. Since stations and transects included in this document encompass more than can be accomplished in a single 10 day cruise, it will be up to the Chief Scientist (with significant input from PIs) for each cruise to develop the specifics. In general, a set series of transects and stations will be occupied during every cruise, with some discretionary time allotted for special experimental work and weather.

Oceanographic Observations

Measurements at oceanographic stations will include CTD, vertical zooplankton net hauls (including upper 50 m using 0.5 m ring net and deep sampling utilizing closing ring nets), nutrients from bottle samples, fluorescence, and oxygen (from both bottles and a continuous profiler mounted on the CTD).

Observations made underway with continuously recording instrumentation include, direct ocean current measurements with a 150 kHz ADCP, hydroacoustic measurements of plankton and nekton distribution and abundance using 120, 420, 720, and 1000 kHz instruments, zooplankton abundance using an optical plankton counter (OPC), CTD and phytoplankton measurements with a towed CTD and fluorometer.

Measurements made when the ship is anchored up will include opportunistic sampling for stable isotope analysis of pelagic, benthic and demersal fishes and other nekton.

Oceanographic Stations

A large subset of the following station listing will be occupied on each cruise throughout the spring, summer and fall. The stations listed below were occupied during the spring, summer and fall of 1994. CFOS 13 and SEA 22 have been sampled frequently since 1990. Occupation of about 50 -75 stations during each 10 day cruise is a reasonable expectation given the nature of the observations and weather considerations. Additional stations might be occupied, depending on available time and the need for special observations related to other SEA studies. Changes will be made at the discretion of the chief scientist for each leg of a cruise.

STATION	LONGITUDE	LATITUDE
CFOS13	146° 55.68'	60° 35.07'
CFOSBY	147° 12.2'	60° 36.3'
SEA1	148° 10.0'	60° 47.7'
SEA2	148° 10.0'	60° 46.7'
SEA3	148° 10.0'	60° 45.9'
SEA4	148° 04.9'	60° 46.2'
SEA5	147° 55.0'	60° 47.6'
SEA6	147° 55.0'	60° 46.5'
SEA7	147° 55.0'	60° 45.2'
SEA8	148° 03.3'	60° 40.0'
SEA10	148° 4.4'	60° 37.0'
SEA11	148° 00.0'	60° 37.0'
SEA12	147° 56.5'	60° 37.0'
SEA12B	147° 45.0'	60° 37.0'
SEA13	148° 00.0'	60° 34.0'
SEA14	147° 56.9'	60° 34.0'
SEA15	147° 53.0'	60° 34.0'
SEA15B	147° 45.0'	60° 34.0'
SEA16	147° 54.5'	60° 31.1'
SEA17	147° 52.0'	60° 31.1'
SEA18	147° 50.0'	60° 31.1'
SEA18B	147° 45.0'	60° 31.1'

STATION	LONGITUDE	LATITUDE
SEA20	147° 52.2'	60° 26.8'
SEA21	147° 50.0'	60° 26.8'
SEA22	147° 41.0'	60° 40.5'
SEA22B	147° 58.7'	60° 24.1'
SEA23	147° 55.6'	60° 24.1'
SEA24	147° 53.5'	60° 24.1'
SEA25	147° 58.0'	60° 18.1'
SEA26	147° 59.6'	60° 12.8'
SEA27	147° 53.6'	60° 10.2'
SEA28	147° 46.1'	60° 08.2'
SEA29	147° 48.3'	60° 06.8'
SEA30	147° 50.0'	60° 05.8'
SEA31	147° 47.1'	60° 01.9'
SEA33	147° 41.9'	60° 00.9'
SEA34	147° 49.0'	59° 58.6'
SEA35	147° 54.1'	59° 55.6'
SEA36	148° 04.3'	59° 54.6'
SEA37	148° 00.4'	59° 53.0'
SEA38	147° 57.0'	59° 51.6'
SEA39	147° 55.4'	60° 03.9'
SEA41	148° 12.9'	59° 59.8'
SEA40	148° 02.0'	60° 07.9'
CS1	147° 21.9'	60° 34.5'
CS2	147° 14.0'	60° 31.8'
CS3	147° 05.5'	60° 28.7'
CS4	146° 56.8'	60° 25.5'
CS5	146° 47.5'	60° 22.5'
CS6	147° 08.6'	60° 35.1'
CS7	147° 02.7'	60° 35.1'
CS8	146° 51.5'	60° 35.1'
CS9	146° 44.4'	60° 35.1'
CS10	146° 37.5'	60° 35.1'
CS11	146° 44.4'	60° 31.0'
CS12	146° 56.2'	60° 22.3'
CS13	146° 56.2'	60° 20.3'
HE1	146° 1.5'	60° 13.6'
HE2	146° 49.5'	60° 12.3'
HE4	146° 54.0'	60° 11.5'
HE5	146° 58.5'	60° 10.5'
HE6	147° 03.0'	60° 09.7'
HE7	147° 07.2'	60° 08.8'
HE8	147° 11.0'	60° 08.4'
HE9	146° 49.0'	60° 18.8'
HE10	146° 51.5'	60° 15.0'
HE11	146° 49.4'	60° 15.7'
HE13	146° 53.5'	60° 15.7'
HE14	146° 49.3'	60° 13.0'

STATION	LONGITUDE	LATITUDE
HE15	146° 53.4'	60° 13.0'
HE16	146° 40.0'	60° 13.0'
GOA1	146° 40.0'	60° 11.8'
GOA2	146° 40.0'	60° 09.6'
GOA3	146° 40.0'	60° 04.7'
GOA5	146° 40.0'	60° 02.4'
GOA6	146° 40.0'	60° 00.0'
GOA7	146° 40.0'	59° 57.5'
GOA8	146° 40.0'	59° 54.9'
GOA9	146° 33.0'	60° 03.8'
GOA10	146° 33.0'	60° 06.0'
GOA11	146° 33.0'	60° 10.1'
GOA13	146° 33.0'	60° 14.2'
MS1	147° 43.8'	60° 05.0'
MS2	147° 40.5'	60° 09.1'
MS3	147° 38.1'	60° 13.5'
MS4	147° 35.7'	60° 16.8'
MS5	147° 30.6'	60° 08.4'
MS6	147° 17.4'	60° 19.2'
NS1	146° 55.8'	60° 46.8'
NS2	146° 55.8'	60° 3.2'
NS3	146° 55.8'	60° 39.0'
NS4	146° 55.8'	60° 31.2'
NWS1	147° 13.8'	60° 42.0'
NWS2	147° 13.8'	60° 46.2'
NWS3	147° 13.8'	60° 49.8'
NWS4	147° 22.2'	60° 46.8'
NWS5	147° 28.8'	60° 44.4'
NWS6	147° 28.8'	60° 43.8'
OB1	145° 5.8'	60° 36.6'

Oceanographic Transects

The following transects will be occupied on each cruise throughout the spring, summer and fall. Additional transects might be occupied, depending on available time and other SEA needs. Changes will be made at the discretion of the chief scientist for each cruise.

NUMBER	BEGINNING LAT/LONG	END LAT/LONG	LOCATION
T1	60° 35.0' 146° 00.0'	60° 35.0' 147° 20.0'	Orca Bay-Naked Is.
T2	60° 36.0' 147° 20.0'	60° 49.0' 146° 55.8'	Naked Is.-Bligh Rf
T3	60° 49.0' 146° 55.8'	60° 19.0' 146° 55.8'	Bligh Rf-Zaikoff Pt.
T4	60° 22.5' 146° 48.0'	60° 36.0' 147° 26.5'	Hinchinbrook-Naked Is.
T5	60° 42.0' 147° 14.0'	60° 50.0' 147° 14.0'	Naked Is.-Glacier Is.

NUMBER	BEGINNING LAT/LONG	END LAT/LONG	LOCATION
T7	60° 50.0' 147° 14.0'	60° 40.5' 147° 40.0'	Fairmont Is.-Lone Is.
T10	60° 48.0' 148° 10.0'	60° 46.0' 148° 10.0'	Esther Rock-Culross Is.
T11	60° 46.0' 148° 10.0'	60° 4.0' 148° 01.0'	Culross Is.-Perry Is.
T12	60° 37.0' 148° 08.5'	60° 31.0' 147° 55.5'	Upr. Passage-Crafton Is.
T14	60° 30.0' 147° 55.5'	60° 31.0' 147° 45.0'	Crafton Is.-Knight Is.
T15	60° 31.0' 147° 58.5'	60° 24.0' 147° 53.5'	Knight Is. Passage
T17	60° 24.0' 147° 53.5'	60° 18.0' 147° 58.0'	Knight Is. Passage
T18	60° 18.0' 147° 58.0'	60° 13.0' 148° 05.0'	Knight Is.-Pt. Countess
T19	60° 12.5' 147° 53.0'	60° 8.0'147° 53.5'	Mummy Bay-Evans Pt.
T21	60° 08.0' 147° 50.0'	60° 03.9'147° 55.5'	N. end Latouche Is.
T24	60° 03.9' 147° 11.5'	60° 00.5' 148° 14.5'	LoneTree Pt.-Bainbridge
T26	60° 00.5' 148° 14.5'	59° 55.5' 148° 15.5'	Bainbridge-Pt. Elrington
T27	59° 55.5' 148° 15.5'	59° 54.6' 148° 04.3'	Pt. Elrington-Danger Is.
T28	59° 54.6' 148° 04.3'	59° 50.6' 147° 55.5'	Danger Is.-Montague Is.
T29	59° 50.6' 147° 54.1'	59° 58.6' 147° 49.0'	Montague Straight
T31	60° 00.5' 147° 48.5'	60° 05.0' 147° 43.0'	Montague Straight
T34	60° 05.0' 147° 44.5'	60° 09.0' 147° 25.0'	Pt. Helen-Montague Is.
T36	60° 09.0' 147° 33.5'	60° 17.0' 147° 42.0'	Montague Straight
T37	60° 07.0' 147° 42.0'	60° 20.05'147°14.5'	Knight Is.-Montague Is.
T38	60° 21.7' 147° 12.0'	60° 30.5' 147° 24.5'	Montague Is.-Smith Is.
T39	60° 22.5' 146° 45.0'	60° 22.5' 147° 03	HE/Montague
T40	60° 22.5' 147° 03.0'	60° 16.9' 146° 42.5'	Montague Pt. Hinchinbrook
T41	60° 15.7' 146° 42.5'	60° 15.7' 146° 55.5'	Hinchinbrook-Montague
T42	60° 13.0' 147° 01.0'	60° 13.0' 146° 11.0'	Hinchinbrook-Montague
T44	60° 14.0' 146° 33.0'	60° 15.0' 146° 33.0'	Gulf Alaska-Hinchinbrook

SEA Program Oceanographic Shipboard Equipment

1. Seabird 911 CTD with continuous oxygen sensor mounted on a sampling rosette equipped with 12 Niskin bottles
2. R D Instruments 150 kHz acoustic doppler current profiler with armored conducting cable towed in an Endeco v-fin towing body.
3. Biosonics 120, 420, 750 and 1000 kHz digital transducers towed in Biosonics towing body (bodies)
4. Chelsea Instruments Aquapack CTD/fluorometer, Focal Technologies optical (zoo)plankton counter towed in a Chelsea Instruments Aquashuttle
5. 0.5 meter diameter ring nets
6. 0.5 meter diameter closing ring nets
7. Bongo nets, tucker trawl, otter trawl, (MOCNESS with suitable vessel & winch)
8. Turner Designs fluorometer
9. Portable oxygen meter

10. Electric/hydraulic winch equipped with conducting steel cable for Seabird 911 deployment and real time data collection
11. Electric/hydraulic winch equipped with conducting steel cable for Aquashuttle instrument package deployment and real time data collection
12. Hydraulic Winch for zooplankton net work both at stations and while underway
13. 3 Magellan Portable GPS Units or 2 units with splitters
14. 6 Laptop and/or desktop 486 computers
15. A minimum of 2 and preferably 3 cranes

Personnel for Each Cruise

One Chief Scientist (the chief scientist pool consists of Cooney, Eslinger, McRoy, Norcross, Salmon, Kline).

Two Physical Oceanographers (someone from the physical oceanographic project of SEA).

Two Chemical Oceanographers/Phytoplankton Ecologists (someone from the phytoplankton and nutrient project of SEA).

One or two Biological Oceanographer(s) (someone from the zooplankton ecology project of SEA).

One Fisheries Acoustician (1 or 2 from the nearshore fish project of SEA).

AIRCRAFT OBSERVATIONS

Small plane over-flights of Prince William Sound are planned to support research investigating avian predation on herring spawn, bird predation on hatchery released pink salmon and distributions of spawning herring and juvenile herring. In addition, some intensive studies of ocean circulation and distributions of plankton, fishes and birds will be partially supported by aircraft observations.

Aerial surveys will coordinate their efforts with vessel collections (when appropriate and weather permitting) examining bird predation on herring spawn and questions about habitat utilization by juvenile herring. Video observations are augmented by GPS linkage and updated every two seconds along prearranged transects. GPS location information is written directly to each video frame. A computer log of user-entered field notes will be kept simultaneously by observers in the plane.

General survey areas include north Montague Island (birds on herring spawn), near PWSAC hatcheries located at Evans and Esther Islands and at Cannery Creek in Unakwik Inlet (for bird predation on fry) and along other shorelines as needed to describe the distributions of adult and juvenile herring nearshore habitats and support other SEA studies (nearshore fishes, physical oceanography).

Weekly (and often more frequent) flights originating from Cordova and beginning in mid-April will utilize about 290 hrs of small plane time over study areas in Prince William Sound. Investigators from 95320 T, Q and Y will be responsible for planning, executing and reporting the results of all aircraft surveys.

HATCHERIES

During 1995 we will use a hatchery site as a base for time series studies of the plankton community. The AFK hatchery in Sawmill Bay will be the site for water sampling for measurements of dissolved inorganic nutrients and biomass and species composition of phytoplankton and zooplankton. Basic hydrographic data (temperature and salinity) will be collected at the time of sampling (usually daily) This sample collection effort requires 2 people in residence for the duration of the spring increase in phytoplankton and zooplankton (late March through June). The hatchery study sites offer a good spatial comparison for the continuous phytoplankton and hydrographic data collected by the CFOS buoy. The site allows generalizations based on the buoy site plus it adds the detail of community composition.

Also at both AFK and WN hatcheries there will be an observer to record predation on juvenile salmon releases by seabirds. These data will provide some estimate of the importance of birds as predators on the fish.

Data Base and Information Services

There are three broad categories of tasks within Information Systems: resources and operations; data for SEA from resources outside the SEA survey effort; and the SEA scientific data base.

Resources and Operations

SEA computing resources and operations are at the Prince William Sound Science Center. The Center serves as the project hub for field studies and data acquisition. It is also one of the primary sites for analysis and model development. In addition to computing and data storage services, the Information Systems effort provides networking and telecommunications access for SEA. The scope of the endeavor includes a metropolitan area network linking and supporting SEA investigators at the Center and at ADF&G in Cordova, wide area network connectivity to UAF, and Internet connectivity (Figure 18). Dial-in facilities are incorporated to extend access to Internet-inaccessible sites. A CDROM mastering capability provides an alternative to on-line connectivity and provides cost-effective archiving.

The Information Systems effort is also responsible for a field data communications system designed to support adaptive field sampling strategies. Because of temporal variability, adaptive strategies require that new information be incorporated in near realtime. A consequent requirement is a near realtime send and receive data communication system linking sources of data, data analysis sites, and survey systems. During FY94 the core components and licenses for a UHF packet-radio field data communications system and repeater network have been completed. This establishes baseline capability to support three application areas to be further developed in FY95: a single survey vessel, moored and drifter buoys, and an autonomous monitoring system (Figure 19).

Non-SEA Data Resources

EVOS restoration work requires not only the coordination of all of the data resources of EVOS but also the comprehensive and timely inclusion of data from other sources. At the time of the inception of SEA there was no current or planned effort, either by EVOS or others, to support on-line archives or gateways to existing data resources important for ecosystem assessment of Prince William Sound. To realize the objectives of SEA it was therefore necessary to provide these

SEA Wide Area Network

components in place at end FY94

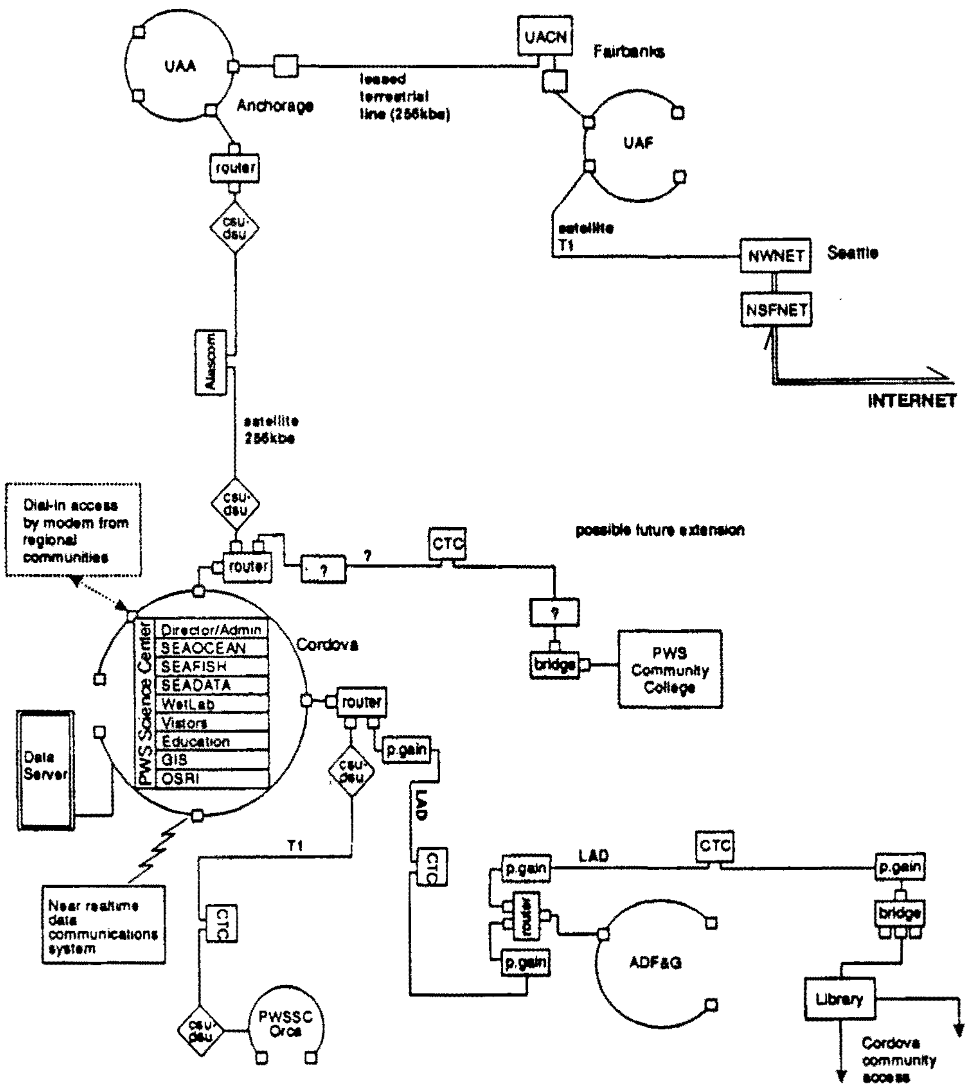


Figure 18. The SEA wide-area network to distribute data locally within Cordova and non-locally to the University of Alaska Fairbanks.

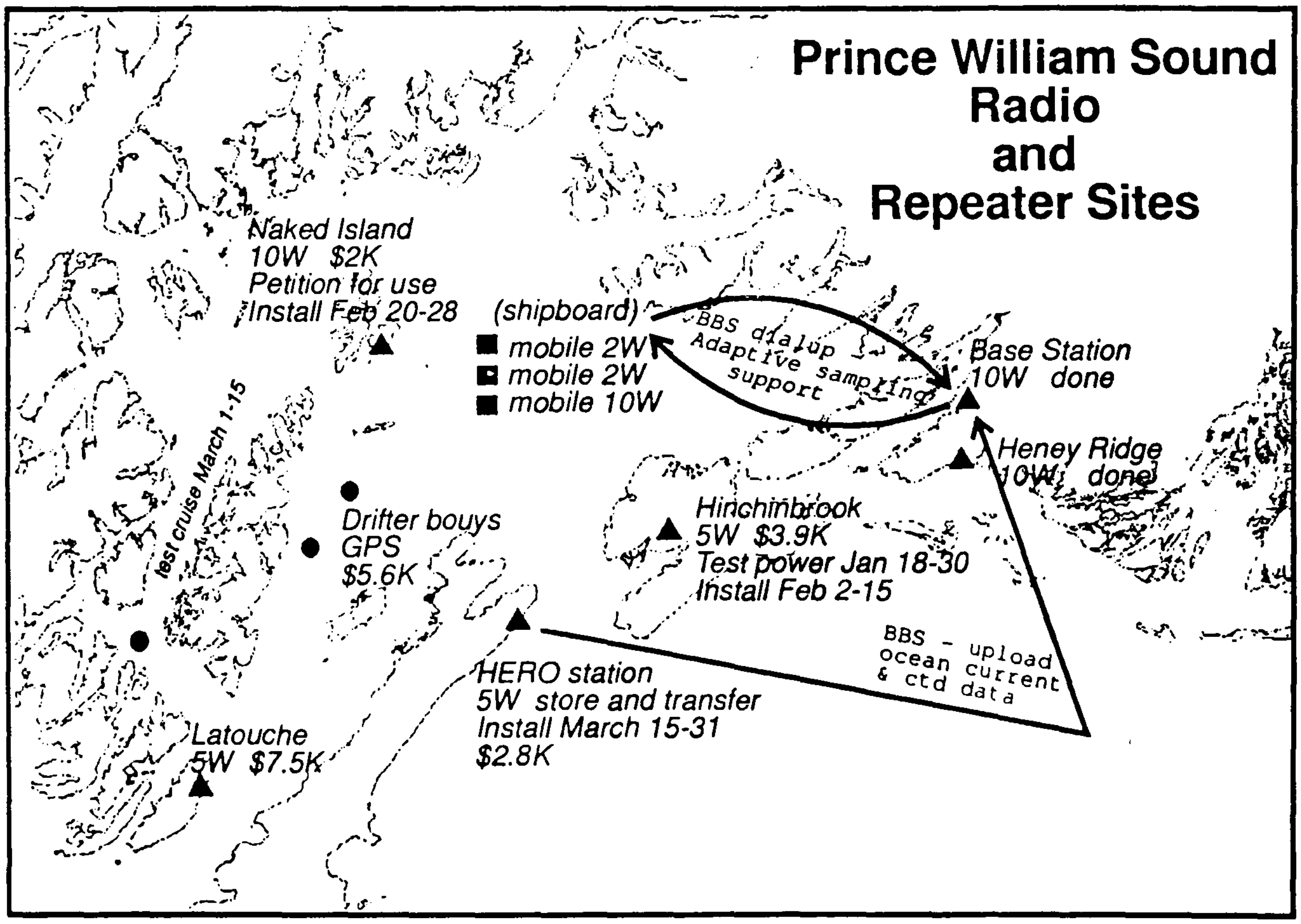


Figure 19. Distribution of real-time data network components for SEA configured in Prince William Sound.

essential resources as part of the SEA effort. As part of the Information Systems project, sea surface temperature for the North Gulf of Alaska from the AVHRR sensors is provided in near realtime to the SEA database for a significant portion of the year. Ocean color from SEAWiFS will be also be collected following launch of the SEAWiFS satellite. (Funding limitations preclude full-year coverage and near realtime data from SEAWiFS.)

A second, smaller effort is targeted at the historical AVHRR data and at historical and current data resources other than by satellite remote sensing. The focus of this latter for FY95 is National Weather Service data. A further objective for FY95 is the task of identifying and coordinating data resources needed to support the ocean circulation modelling effort.

Scientific Database

Central to the definition of SEA is establishment of a scientific data base. The technology for scientific data bases as well as the definition itself are evolving rapidly. The two primary competing technologies are object-oriented and extended-relational systems. There are advantages to each. Object-oriented approaches accommodate the structure of scientific data but require that this structure be fully identified and built into the system from the outset. Extended-relational data models are more flexible but have little correspondence to the structure of scientific data. There are new companies and new releases of existing data bases each addressing the expanding need for scientific data bases.

In FY94 the infrastructure and basic functionality to support a scientific database was established along with a flat file archive of part of the SEA data (Figure 20). The objectives for FY95 are on-line query and retrieval of datasets according to attribute, along with query tools supporting model development and interim modelling efforts. The approach in general is to meet immediate requirements with basic and established technologies that are easily reconfigured, and to maintain a parallel development effort doing prototyping and evaluation with new and emerging approaches. The results from the prototyping and evaluation work will be the basis for the implementation plans for the following year. The selection and development of the database are primarily funded by other projects and grants. EVOS supports primarily the database design and analysis for the SEA

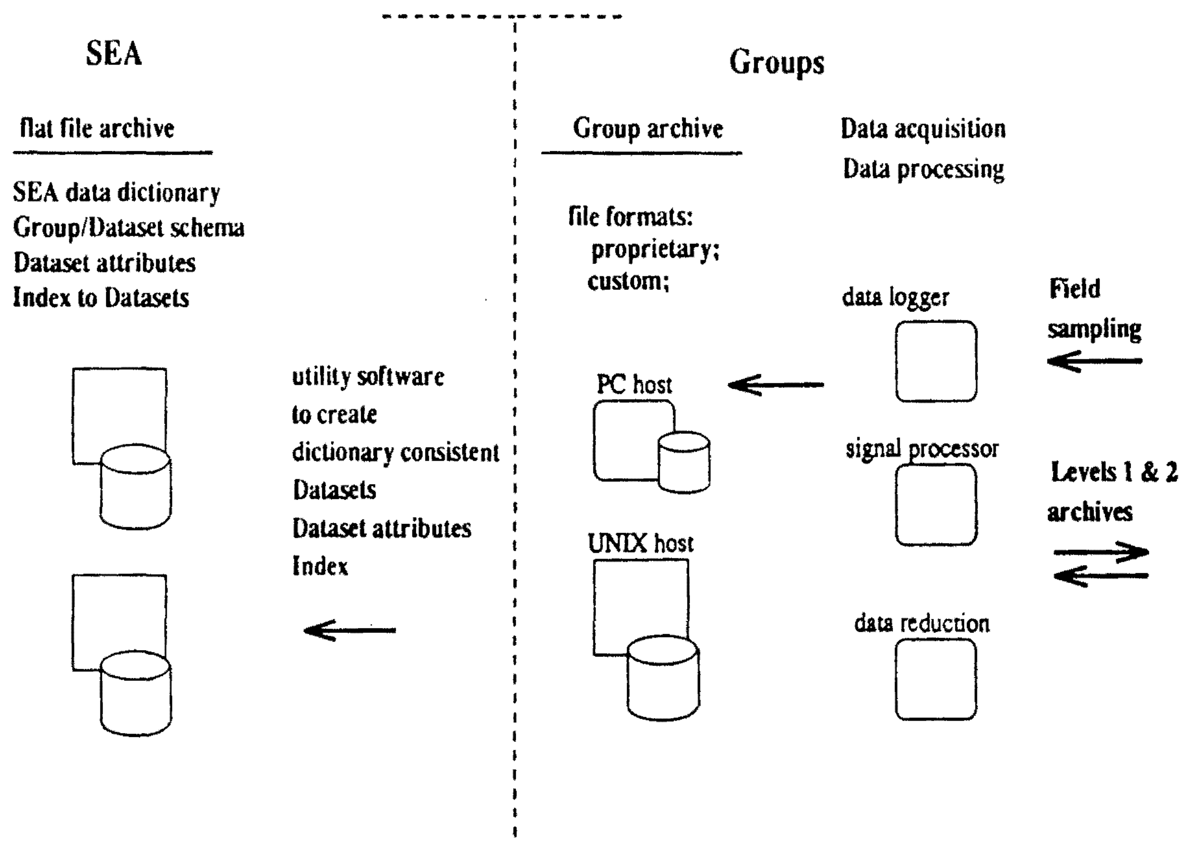


Figure 20. Aspects of the flat-file archive for SEA data.

data and the definitions of the SEA application interfaces needed to support the SEA restoration objectives.

The structure of the SEA data and the database implementation plan are diagrammed in Figures 20 and 21. SEA data is the result of field studies and data processing of independent groups. The data for each group has a unique format that reflects unique hardware and signal processing software, unique aspects of the science, and simply custom. The data are typically archived in this format. The first task in the integration of SEA data is to accommodate this disparity of initial data formats among groups. Similarly, each group may have preferences regarding the format for data from other projects.

The plan for FY95 is to develop a Data Dictionary for SEA, define the Datasets that will make up the SEA database, specify the Dataset Attributes to be included in the Dataset Index, and specify the metadata that is to be included in each Dataset.

The Data Dictionary covers all of SEA, while a Dataset is defined by a project. The Dictionary specifies all that is needed about a quantity to uniquely determine its meaning and format, for example, variable type and units. The definition of a Dataset specifies a schema, that is, the set of items from the Dictionary that are included in the Dataset, along with a specification of the metadata to be included such as calibration information, sensor identification information, creator of the Dataset, and the person responsible for revisions of the Dataset. The Dataset Attributes are a set of fields that are to be used in the Indexing of Datasets. Attributes are in general quantities that are derived from the actual data in the Dataset, such as maximum and minimum time, latitude, longitude, entries that identify the sensor or sampling hardware and method, platform, boat, and the like. A Dataset can be defined however one wishes. For example, multiple sensors can be covered in the same Dataset, as in CTD data. Attribute tables can differ among Datasets, although there is a core table that would be inherited by all Datasets such as range for position and time.

The collection of all of the Dataset Attributes is the Dataset Index. The Index is something that is easily manipulated in any relational database and is the means by which the SEA archive is queried to find Datasets that meet any condition that can be specified in terms of Dataset Attributes. Searches on Dataset Attributes

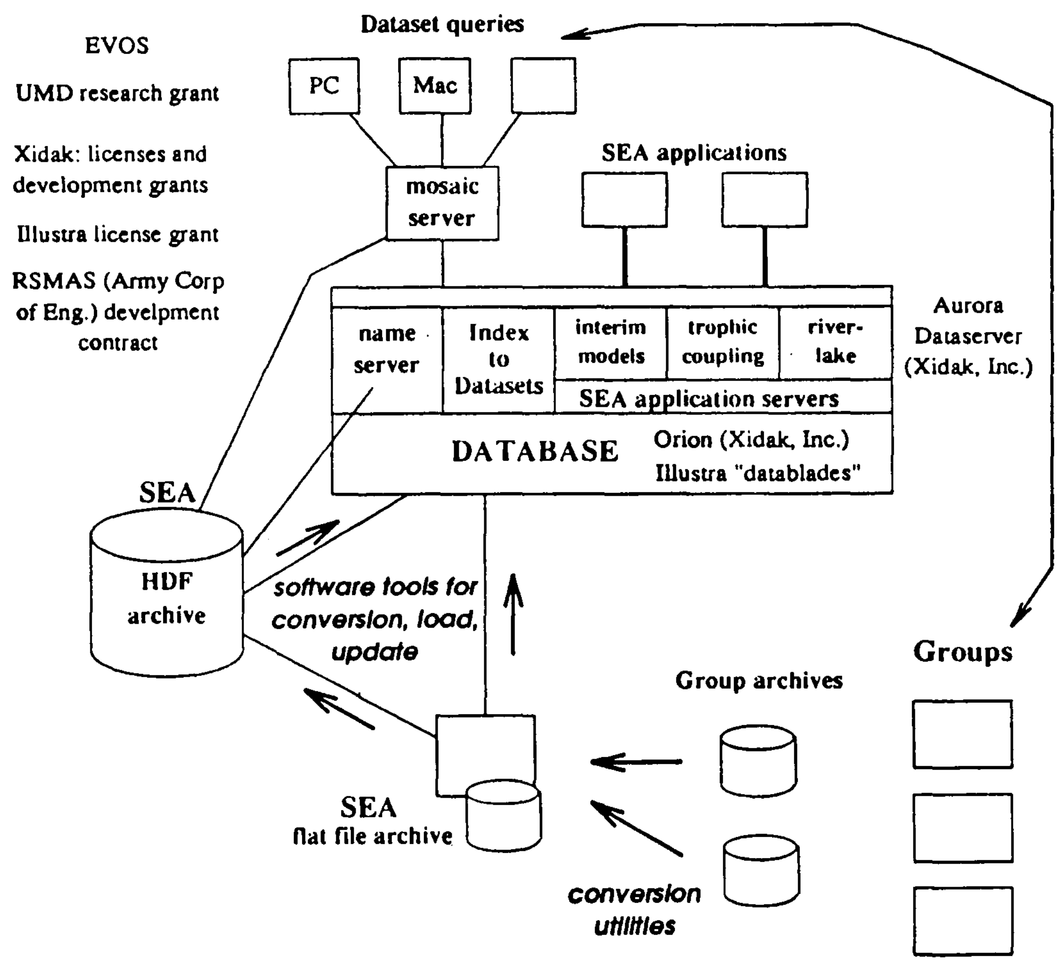


Figure 21. Relationships between the SEA data base, flat-file archives, data servers and data set queries from SEA investigators.

return pointers to Dataset files. Dataset files can be located anywhere on the network. A search that involves information not in the index requires a more sophisticated database and database interface. The Aurora Dataserver combined with the Orion relational database is one such system.

The specific implementation plan for SEA is summarized in Figure 13. The plan builds upon adopted standards and established methods for short-term requirements.

For a given project, once the Dictionary is complete for that project and once the Datasets and Attributes are defined, a set of software utilities will be created to convert data in a group format into an ASCII file format with sufficient structure to contain all metadata and Dataset Attribute information. The function of this format is to provide Datasets that are close to that used by the group but that are complete regarding Attribute and metadata information and are consistent with the Dictionary. These archives can be updated by the group using the software tools.

The next level is the same archive converted to a standard scientific data format. The choice here is HDF, in large part because it has been adopted by EOS and consequently has received considerable new development effort. The choice, however, is not critical, for it is possible through conversion tools to use CDF, NetCDF, and HDF formats interchangeably. Since the SEA flat file archive is a stable format and complete and consistent, building software utilities to write HDF files is straightforward. It is similarly possible to automatically load the database from either the flat files or HDF files. However, using HDF improves the stability and applicability of the database loading tools. The approach for SEA is to not have a rigidly defined relational database. Instead, the database is an intermediate tool supporting query and special interfaces to the data in support of restoration tasks. The files resident on project host machines in either native or HDF format are the archive.

Figure 13 illustrates that there are two distinct database applications: the Data Index on the one hand, and the union of all of the data on the other. In the first application a relational database is used with the data attributes contained in the Data Index. This provides the means to search and retrieve data at granularity down to that of single Datasets. This capability covers many of the SEA requirements regarding a system level perspective on the data, for it provides the means to search for datasets that are coincident in space and time but that span all the biological and physical variables of the system. The results of such a search are pointers to actual Datasets in either HDF or flat file format. The Datasets themselves would be retrieved.

This first capability is the primary objective for FY95. It is a straightforward application of relational database technology. This capability can be configured so that search and query is readily accomplished over the network from personal computers as well as from workstations. For example, an interface using Mosaic and Collage will work with PCs, Macs, X-terminals, and UNIX workstations.

More advanced applications of the data require searches at a granularity finer than that of the Dataset. Such applications are searches specifying, for example, a single species, a single depth stratum, a temperature range, or population density greater than or less than a specific threshold. These searches involve subsetting of the Dataset and require a database management system combined with what is often referred to as a scientific dataserver. A dataserver is an interface to the data that addresses the complexities of scientific data that are beyond the scope of the relational model. The plan for FY95 is to make steady progress toward the realization of this capability for FY96 through co-development efforts with developers and by collaborations in prototyping projects with cost sharing.

Two such efforts are underway, one for the use of the Aurora dataserver and the Orion extended-relational database with Xidak, Inc., and a second for the use of the Illustra object oriented database. In both cases the project is the recipient of grants consisting of no-cost software licenses. During FY94 the project also received a grant from Xidak for the support of a graduate student investigator. For FY95 there is considerable cost sharing for the development of the ecosystem database tools. The project is supported by a one-semester grant supporting a graduate student research project for the prototype development of the HDF-Illustra interface. This support is from the University of Maryland through the Advanced Visualization Lab. The project is cost sharing database development with a similar effort sponsored by the Army Corp of Engineers through a collaboration with Rosenstiel School of Marine and Atmospheric Science at the University of Miami.

CHAPTER 4
FY95 Program Schedule

Milestones for Overall Contract Obligations

Funding for the PWS System Investigation (SEA95) was authorized by the EVOS Trustee Council in August (interim) and November (remaining) of 1994. Release of all "remaining" funds is contingent on the recommendation of the EVOS Chief Scientist following a peer review of this single, integrated DPD. It is expected that this review will be completed in mid February and that all remaining funds authorized by the Council will be available for staging and undertaking the FY95 field season . SEA95 program milestones/schedules are as follows:

February 1995	Continue the development and evaluation of ecosystem-level models of ocean state and biological interactions
	Continue the submission of SEA94 data to the SEA data base
	All field studies initiate staging for shipboard and aircraft activities.
	Submit invitation for vessel bids
	Submit single integrated 1995 DPD for peer review
March 1995	Select vessel/aircraft contracts
	Initiate vessel/aircraft studies by all or selected field components
	Begin FY96 planning
April 1995	Submit draft SEA94 report
	Continue field studies
	Begin analysis of 1995 field data and submission to the SEA data base
May 1995	Continue field studies and data analysis
	Submit request for funding FY96, 97, 98

June 1995	Continue field studies and data analysis
	FY96 Draft Restoration Plan
	Receipt of RFP for SEA96 studies
July 1995	Continue field studies and data analysis
August 1995	Continue field studies and data analysis
	Finalize Draft FY96 Restoration Plan
	First draft of SEA96 proposal for 3-year study
September 1995	Complete field studies
	Continue data submission
	Prepare for the SEA95 workshop review

APPENDIX I

Individual Detailed Project Descriptions for the 95320 Program

95320A	Juvenile Salmon Growth and Mortality	M. Willette
95320E	Juvenile Salmon and Herring Integration	M. Willette
95320G	SEA: Phytoplankton and Nutrients	D. Eslinger C. P. McRoy
95320H	SEA Zoo: The Role of Zooplankton	R. T. Cooney
95320I	SEA Confirming Food-Web Dependencies	D. Schell T. Kline
95230J	Modelling and Information Services	V. Patrick
95320K	Experimental Fry Releases	E. Prestegard
95320M	Observational Physical Oceanography	D. Salmon
95320N	SEA Nekton/Plankton Acoustics	G. Thomas
95320Q	Avian Predation on Herring Spawn	M. Bishop
95320T	Juvenile Herring Growth and Habitats	B. Norcross E. Brown
95320U	Somatic and Spawning Energetics	A. Paul
95230Y	Avian Predation on Hatchery-Released Fry	D. Scheel