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Alaska Fisheries Science Center
Steller Sea Lion Research Project Reports
Fiscal Year 2002

Lowell Fritz
(Compiler)

Alaska Fisheries Science Center
National Marine Fisheries Service
7600 Sand Point Way NE
Seattle WA 98115

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Introduction

The National Marine Fisheries Service's Alaska Fisheries Science Center (AFSC), along with its research partners in the North Pacific[1], is conducting scientific research to determine the causes of the decline and lack of recovery of the Steller sea lion (*Eumetopias jubatus*) population in western Alaska. The AFSC provides scientific and management advice to the NMFS Alaska Regional Office and to the North Pacific Fishery Management Council on this issue. In fiscal year 2002 (FY02), the U.S. Congress appropriated $40,145 K for Steller sea lion research to the following parties:

Steller Sea Lion Research Organization	FY02 Funds
NOAA NMFS, Ocean Service and Research	$25,650 K
North Pacific Universities Marine Mammal Research Consortium	$3,500 K
North Pacific Fishery Management Council	$2,000 K
Alaska Department of Fish and Game	$2,495 K
University of Alaska	$1,000 K
Alaska SeaLife Center	$5,000 K
Alaska Fisheries Development Foundation	$ 500 K

Of the $25,650 K allocated to NOAA, $6,000 K was provided to NOAA Office of Oceanic and Atmospheric Research to conduct retrospective and modeling research into the effects of long-term climate change on the ecosystem of the North Pacific Ocean and to conduct process-oriented field studies of the oceanography and production mechanisms in conjunction with AFSC sea lion or fisheries interactions projects. For this latter effort, $3,910 K (of the $ 6,000 K) was provided to NOAA OAR Pacific Marine Environmental Laboratory. In addition, $100 K was allocated to NOAA National Ocean Service to support Sea Grant's efforts in outreach and education on sea lion issues.

NMFS retained $19,550 K in FY02 to conduct research related to the decline of the Steller sea lion. The research framework developed in FY01 (and discussed in detail at http://www.afsc.noaa.gov/Stellers/coordinatedresearch.htm) was used to prioritize and plan the AFSC sea lion research in FY02. Proposals were solicited from AFSC staff in four basic areas of research: Steller sea lion core investigations (including evaluation of predation by killer whales and sharks), sea lion-fisheries interactions, biophysical and climate change, and forage

[1]Alaska Department of Fish and Game, Alaska SeaLife Center, University of Alaska, North Pacific Universities Marine Mammal Research Consortium, North Pacific Fishery Management Council, NOAA Office of Oceanic and Atmospheric Research, NOAA National Ocean Service, and Alaska Fisheries Development Foundation.

fish assessment. Working groups with individual team leaders were established to review and prioritize proposed research. Team leaders within each group were

- Steller Sea Lion Core Investigations: Tom Loughlin, NMML
- Fisheries Interactions: Anne Hollowed, REFM
- Biophysical-Climate Research: Jeff Napp, RACE
- Forage Fish Assessment: Bill Karp, RACE

The efforts of each team were coordinated within the Science Director's Office and a group of 60 Steller sea lion research projects were recommended for funding in FY02, which included four omnibus salary projects within the AFSC's National Marine Mammal Laboratory (NMML) and Resource Ecology and Fisheries Management (REFM) Division. Therefore, 56 scientific projects were identified and funded at the AFSC for sea lion research in the following areas:

Type of Research	**Number of Projects[2]**				**FY02 Funds**
	NMML	**REFM**	**RACE**	**ABL**	
Steller Sea Lion Core Research	21	1	2	2	$ 7,765 K
Predation	1			1	$ 810 K
Fisheries-Sea Lion Interactions		7.5	2.5	1	$ 4,450 K
Biophysical-Climate Research			6	1	$ 1,375 K
Forage Fish Assessment		4	3	3	$ 1,700 K
TOTAL	22	12.5	13.5	8	$16,100 K

Of the remaining $3,450 K of research funds at the AFSC, $1,850 K were transferred to the NMFS Alaska Regional Office to support sea lion related management activities and $1,600 K were retained at the AFSC for coordination and research support activities[3].

This report summarizes the activities, and in some cases, the principal results of the Steller sea lion research activities undertaken in FY02 by the AFSC. Only brief overviews of research activities and research findings are presented in this report, and the reader is encouraged to contact the individual researchers, visit the AFSC web site (http://www.afsc.noaa.gov), or review published literature for more detailed information. In addition, where applicable, plans for FY03 are also provided for each project.

[2]Does not include omnibus salary projects 02SSL-21, 02SSL-22, 02FIT-11 and 02FIT-12.

[3]$300K for refurbishment of the sub-port in Juneau AK for research offices, $300 K for AFSC research coordination, $350 K to purchase vessel monitoring systems for commercial vessels, $500 K to purchase vessel time, and $150 K to the Office of Protected Resources at NMFS Headquarters to support a position.

List of Common Abbreviations and Acronyms used in this Report

ABL	Auke Bay Laboratory
ADF&G	Alaska Department of Fish and Game
AFSC	Alaska Fisheries Science Center
AI	Aleutian Islands
ASLC	Alaska SeaLife Center
CTD	Conductivity-Temperature-Depth
ESA	Endangered Species Act
EBS	Eastern Bering Sea
EPA	Environmental Protection Agency
FIT	Fisheries Interaction Team
FY02	Fiscal Year 2002
FY03	Fiscal Year 2003
FY04	Fiscal Year 2004
FOCI	Fisheries Oceanography Coordinated Investigations
GIS	Geographic Information Systems
GOA	Gulf of Alaska
JISAO	Joint Institute for the Study of the Atmosphere and Oceans (UW)
MSSAM	Multispecies Assessment Model
MSU	Montana State University
MSVPA	Multiple Species Virtual Population Analysis
NMML	National Marine Mammal Laboratory
NMFS	National Marine Fisheries Service
NPFMC	North Pacific Fishery Management Council
NOAA	National Oceanic and Atmospheric Administration
NPZ	Nutrient-Phytoplankton-Zooplankton
PMEL	Pacific Marine Environmental Laboratory
PSMFC	Pacific States Marine Fisheries Commission
RACE	Resource Assessment and Conservation Engineering Division
REFM	Resource Ecology and Fisheries Management Division
ROV	Remotely operated vehicle
RPA	Reasonable and Prudent Alternative
SAFE	Stock Assessment and Fishery Evaluation
SEAK	Southeast Alaska
SSL	Steller sea lion
SSMA	Stock Assessment and Multispecies Assessment Program
SWFSC	Southwest Fisheries Science Center

SSLIBM	Steller Sea Lion Individual-based Model
SMRU	Sea Mammal Research Unit
TAMU	Texas A&M University
TDR	Time-Depth Recorder
USGS	U.S. Geological Survey
UBC	University of British Columbia
UAF	University of Alaska Fairbanks
UAA	University of Alaska Anchorage
USC	University of Southern California
USFWS	U.S. Fish and Wildlife Service
UW	University of Washington
UCD	University of California Davis

Steller Sea Lion Investigations

NMFS is the lead federal agency responsible for the management and recovery of the western (listed as endangered under the Endangered Species Act, ESA) and eastern (listed as threatened under the ESA) populations of Steller sea lions. The western population has declined by over 80% in the last three decades, and has continued to decline at more than 4% annually since 1990. The leading hypothesis to explain the current decline is lack of available prey, leading to nutritional stress, poor juvenile survival, and decreased reproduction. Decreases in sea lion prey availability could be caused by natural changes in the North Pacific ecosystem or could have resulted from competition with groundfish fisheries that developed during the same time period. Other factors are known to have contributed to the decline in the past, including incidental mortality of sea lions in groundfish fisheries, legal and illegal shooting, and commercial harvesting of sea lions. Additional factors, such as disease, pollution, predation by killer whales, and subsistence harvest by Alaska Natives, certainly cause sea lion mortality, but they do not appear at this time to be contributing to the decline or retarding recovery of the population.

Contrary to trends observed for the western population, the eastern population has increased over the past three decades to possibly the highest levels in recent history. For this population, counts and pup production have increased at 2-3% annually. The eastern population appears to be recovering from severely reduced levels in the early part of this century when the population was purposefully reduced.

In FY02, the Steller sea lion research program at the AFSC (NMML) conducted scientific research on each of the potential factors that could have contributed to the decline of Steller sea lions. As part of the core research program, researchers collected and analyzed biological information related to Steller sea lion:

- *Abundance:* To monitor population changes, better understand sea lion movement patterns, seasonal variation in distribution, and relationships between the distributions of sea lions, their prey, and fisheries.
- *Stock structure:* To elucidate sea lion demographic units and their trends, and develop protective measures that are appropriately scaled; in FY02, the AFSC established a molecular technology laboratory.
- *Diving ontogeny, foraging ecology and diet:* To describe the diet and prey of sea lions, predator-prey dynamics, energetics, and foraging distributions of sea lions; in FY02, the AFSC expanded satellite tagging efforts to include sub-adult sea lions and establish a nutritional ecology laboratory.
- *Mortality and life history:* To determine age-specific mortality rates and rates of reproduction for population modeling; in FY02, the AFSC continued pup branding and resighting efforts.
- *Contaminants and disease*: To formulate a plan to evaluate the impacts that these factors could be having on Steller sea lion populations.

<u>Abundance and Stock Structure</u>
Counts of adult and juvenile Steller sea lions (non-pups) at western stock trend sites in Alaska

(west of Cape Suckling through the Aleutian Islands) increased 5.5% in 2002 relative to 2000 (02SSL-04). This was the first increase observed in sequential surveys in over 20 years. However, non-pup counts in 2002 were still 5% lower than 1998 and 34% lower than 1991. In addition, counts of pups at rookeries in the Kenai-Kiska index area of the western stock in 2001 and 2002 declined 8% relative to 1998, and were 42% lower than counts in 1990 and 1991. The endangered western stock in Alaska currently numbers approximately 35,000 animals.

What is currently called the western stock of Steller sea lions is likely composed of two distinct populations: the central population from Cape Suckling through the Aleutian Islands and including the Commander Islands, and the Asian population, which includes all animals that breed on the Kamchatka Peninsula, Kuril Islands, and the Sea of Okhotsk. The distinction in distributions of mitochondrial DNA haplotypes between the central and Asian populations may be as large as that previously described for the eastern and western stocks (02SSL-10; Bickham, Texas A&M). Portions of the Asian population that breed on the Kamchatka Peninsula and in the Western Bering Sea are continuing to decline (02SSL-15 and 02SSL-16).

Diving Ontogeny, Foraging Ecology, and Diet

Significant changes in the movement and dive patterns of tagged juvenile Steller sea lions were observed at approximately 10 months of age (02SSL-08, ADF&G project 2001-91, and University of Alaska Anchorage projects 2001-02 and 2001-42). At this time, sea lions begin to make longer trips from shore and dive to deeper depths than when younger. This is most likely a result of weaning and increased independence of the juvenile from its mother. Weaning is a process, not an event, and decreasing proportions of a juvenile's energy come from milk over an extended period. Analysis of telemetry data (02SSL-08) indicates that between 6 and 18 months of age, sea lions increasingly use marine foraging habitats greater than 10 nautical miles (nmi) from rookeries and haul-outs, suggesting an increase in independent foraging. Consequently, the age of 10 months should not be considered a knife-edge boundary between suckling and fully weaned individuals, but as the beginning of a development process leading to adulthood 3-4 years later.

Prey species are patchily distributed, and sea lions appear to concentrate their foraging in the densest fish aggregations. This was shown for sea lions preying on pollock, herring and hake in inside waters of Southeast Alaska (02FIT-02). This suggests that sea lions seek the highest densities of fish on which to forage (a conclusion also reached by Sinclair and Zeppelin 2002), and that their foraging energy budgets could be compromised if the number of high-density patches were reduced.

There is new evidence supporting the hypothesis that sea lions and fisheries target the same resource: sea lions eat predominately commercial-sized pollock and Atka mackerel (02SSL-06). The mean length of walleye pollock consumed by Steller sea lions was 39.3 cm (range from 3.7 to 70.8 cm) and of Atka mackerel consumed was 32.3 (15.3 to 49.6 cm). The data indicate that the possibility of competitive interactions between sea lions and fisheries may be larger than originally thought.

The energy content of fish species analyzed to date varies considerably throughout the year (reflecting their reproductive cycles). Fish tend to have maximum energy stores prior to spawning, principally in late winter through spring. Because of this considerable seasonal and spatial variation in energy content of a single species, casting one or more species as "junk" is too simplistic (02SSL-02 and 02FIT-09). In addition, pollock were found to have higher levels of fat soluble vitamins A and E than herring (Mystic Aquarium project 2001-19), which also helps refute the idea that consumption of fish generally low in fat (e.g., pollock) would have population level impacts for sea lions.

Mortality and Life History

In the declining western population of Steller sea lions, between 900 and 1,200 deaths of sea lions in 2001 could not be accounted for by predation or any other direct source (subsistence, incidental take, illegal shooting). These mortalities were in excess of those that would occur in a stable population, and may have been due to nutritional stress. Other than subsistence harvest, the eastern population of sea lions experiences the same types of direct takes, and potentially greater levels of predation by killer whales and sharks, yet it is increasing in size. These analyses support the hypothesis that indirect causes of mortality, such as reduced prey availability, are contributing to the decline and lack of recovery of the western population of sea lions.

Life table analyses suggested that a decline in juvenile survival could account for much of the decline observed in the 1980s. An update of these analyses with age-structured population data (02SSL-05, 02SSL-13, 02SSL-25) suggests that a decline in fecundity may have largely driven declines observed in the 1990s. This is significant since it suggests that direct sources of mortality, such as predation and illegal shooting, are not chiefly responsible for the decline. Instead, chronic stressors that decrease the sea lion carrying capacity of the environment, such as fisheries or changes in climate, are more likely at work.

Contaminants and Disease

In FY02, a plan was developed by Auke Bay Laboratory (ABL, 02SSL-01) to investigate contaminants and their effects in Steller sea lions in Alaska. This plan was the outgrowth of a workshop held in September 2001 to discuss the evidence for contaminant impacts on sea lions. In the plan, the evidence for contaminant exposure was reviewed and a research framework was developed to coordinate and facilitate the sea lion contaminant research being conducted by investigators throughout the state.

A new investigation of the impact that parasites and secondary infections could have on the fitness of individual sea lions (02FF-03) commenced in FY02. This work complements the ongoing surveys of exposure to diseases that is a part of the suite of biological data collected from sea lions when they are handled for branding or satellite tag attachment (02FF-09). These studies have yet to show that a disease or parasite infestation is responsible for the decline or lack of recovery of the population, but will be continued to allow for monitoring of these impacts in the future.

Availability of Contaminants to Steller Sea Lions (02SSL-01)

Principal Investigator: Ron Heintz
Division: ABL, RACE
SSL Projects Database #: 2001-130

Project Description

We propose to contrast the contaminant loads of Steller sea lion prey sampled from the Gulf of Alaska with loads of similar species found in southeastern Alaska. Foraging sea lions will be located and their prey sampled using the methods described in ABL's seasonality proposal. Collections of fish from the Gulf of Alaska will be provided by the University of Alaska from their Kodiak study site and off rookeries encountered in other cruises in summer 2002. Opportunistic samples collected around the Krenitzen Islands and Seguam Island may also be sampled. ABL will obtain samples from southeastern Alaska. Sample collections will be matched by species, time of collection, sex and age to test the hypothesis that contaminant loads in forage fish from the Gulf of Alaska and Aleutian Islands exceed those of southeastern Alaska. This is an extension of work initiated in FY01. Last year the project held a workshop to evaluate the potential for exposure, began drafting a work plan designed to address the contaminant hypothesis, and initiated the hiring of a marine mammal toxicologist to oversee the work plan. If ABL's seasonality proposals for the Krenitzen Islands and Prince William Sound are funded for FY03, then systematic analysis of prey will be expanded in those regions.

Differences Between Regions

Forage species in southeastern Alaska and in the northern Gulf will be sampled just prior to and during pupping to test the hypothesis that the availability of contaminants to whelping pups is highest in the northern Gulf. The sample sets will be matched so that fish of similar species, sex and age are analyzed to determine concentrations of persistent organic pollutants (POPs). Forage fish samples will be collected from locations where Steller sea lions are observed foraging. Collections from southeastern Alaska will be made concurrent with collections of sea lion seasonal prey sampling. Collections from the Gulf will be made during the spring EMAP cruise chartered by EPA. In addition, the University of Alaska will provide samples from their Kodiak study site.

Differences Among Species

Within the affected region, samples of the most important forage species will be analyzed to evaluate their contaminant loads. The hypothesis to be tested is that the preferred prey have the highest contaminant loads. We expect those species with the highest lipid content to bear the highest contaminant load per unit mass. The contaminant loads of the sampled species will be compared with existing Steller sea lion diet data to determine how prey preference influences potential for exposure.

Contaminants to Which Steller Sea Lions Are Exposed

Sample analysis will consist of methods which can identify the prevalence of organochlorines, pesticides and heavy metals in Steller sea lion prey species. Fast screening techniques will be used to identify the presence of planar chlorobiphenyl congeners and DDTs. A subset of the

samples will be tested for the presence of methyl-mercury and pesticides. Analyses must be performed by a laboratory with a proven performance record because most contaminants will likely be at trace levels or lower. The Northwest Fisheries Science Center (NWFSC) maintains such a laboratory, but analyses may be contracted outside the agency.

Activities in FY02

Funds for this project were received in May 2002 and ABL management permitted us to begin work on the project only after funds were processed in early June. Recruitment for a toxicologist began in the spring of 2002, and closed in late September. A certified list has yet to be received. In the 4 months we were able to use FY02 funds and with continued efforts from contracts developed in FY01, we were able to collect samples of prey from southeastern Alaska, prepare them for organochlorine analysis and evaluate their proximate compositions. These include 10 samples each of pollock, hake, herring and eulachon from the Brothers Islands. By the end of September, we acquired samples of pollock, Pacific cod, Atka mackerel and arrowtooth flounder from the western Aleutians which are currently being homogenized. In addition, we identified sea lion tissues that have been collected but lacked funding for contaminant analysis. We funded analysis of these samples by allocating funds to the NWFSC and contracting Dr. Kimberlee Beckmen to produce reports describing the results of these analyses.

A geographic information system (GIS) was completed that maps the trend counts for haul-outs and rookeries along with all the known land-based hazards for the eastern and western stocks. In addition, a Science Plan was completed which prioritizes future research regarding sea lions and contaminants, outlines the role of NOAA in this research and reviews the known exposures in sea lions and allied species along with their prey. Based on the findings of the science plan, we contracted Mystic Aquarium to extend their analysis of retinol in sea lion prey to include samples from the western Aleutians. Retinol is a potential biomarker of contaminant exposure, but little is known about its availability to sea lions. A meeting was held in conjunction with the Sea Lion Workshop in January 2002 to coordinate the activities of the Parasite Project (02-SSL03) the Contaminant Project (02-SSL01) existing ADF&G and Alaska SeaLife Center (ASLC) projects. The various groups agreed to cooperate in their sampling plans and share data.

A review of the science plan was presented at the Sea Lion Workshop in Anchorage in March 2002.

A paper derived from the Science Plan and titled *Contaminant Exposure and Effects in Pinnipeds: Implications for Steller Sea Lion Declines in Alaska* was submitted for publication to *The Science of The Total Environment*.

Results From FY02 Work

Results from FY02 were generated by the review of potential hazards in the Science Plan and observed in the contaminant GIS. Steller sea lion tissues show accumulation of butyltins, mercury, PCBs, DDTs, chlordanes and hexachlorobenzene. Steller sea lion habitats and prey are contaminated with additional chemicals including mirex, endrin, dieldrin, hexachloro-cyclohexanes (HCHs), dioxin compounds, cadmium and lead. In addition, many Steller sea lion haul-outs and rookeries are located near other hazards including radioactivity, solvents, ordnance

and chemical weapon dumps. PCB and DDT concentrations measured in a few Steller sea lions during the 1980s were the highest recorded for any Alaska marine mammal. Some contaminant exposures in Steller sea lions appear to be elevated in the Gulf of Alaska and Bering Sea compared to Southeast Alaska. Results of the chemical analyses performed late in this FY02 were presented at the Sea Lion Workshop in January 2003.

Milestones in FY03

Complete Analysis of Samples Collected in FY02

Sea lion prey samples collected from the western Aleutians will be processed by the NWFSC in FY03 to estimate loads of PCBs, DDTs, and HCHs. These data will be combined with those collected from fish in southeastern Alaska to determine if there are differences in the contaminant loads between these two regions. This will lead to the publication of data in a refereed journal. Samples for analysis by the NWFSC are still being prepared at ABL: manuscript preparation will likely begin in late FY03.

Production of GIS Describing Risk of Exposure to Steller Sea Lions

Data on contaminant loads in Steller sea lion prey will be loaded into the existing GIS which describes point sources of contamination. Efforts will also be made to have cooperating agencies provide data on exposure levels in sea lions.

National Marine Fisheries Service Nutritional Ecology Laboratory (02SSL-02)

Principal Investigator: Ron Heintz
Division: Auke Bay Laboratory, RACE
SSL Projects Database #: 2002-01

Project Description

The Nutritional Ecology Lab at the ABL provides AFSC researchers with chemical analyses of forage fish and sea lion tissues. These analyses include evaluations of proximate composition, lipid class and fatty acid analysis that can be combined with proposed studies to evaluate predator/prey relationships. For example, data from an ongoing study of the seasonal variation in the lipid content and composition of Steller sea lion prey in southeastern Alaska can be compared to a similar study performed by the University of Alaska in Kodiak to examine how nutritional resources available to different Steller sea lion stocks vary regionally. This year, we propose adding opportunistic samples from the Krenitzen Island archipelago in the Eastern Aleutian Islands, Seguam Island and the Bering Sea as well as expanding the number of nutritional measures to include proximate composition. We anticipate that forage fish assemblages will vary regionally, and our data will provide a common currency for comparing prey quality from disparate locations. If ABL seasonality studies proposed for FY03 in the Krenitzen Islands and Prince William Sound are funded, systematic analysis of seasonal variation in nutritional quality will expand to those locations.

Analyses are performed at the ABL by analytical chemists whose skills were tested by our work following the *Exxon Valdez* oil spill. High performance liquid chromatography is used to separate lipid classes which are quantified with an evaporative light scattering detector. Fatty acids from specific lipid classes are separated by gas chromatography and quantified by mass spectrometry. Estimation of the lipid and water content are routine procedures applied during the sample preparation stage. Analyses of ash and protein content, the latter facilitated by a recently acquired nitrogen analyzer, allow us to provide a complete proximate analysis.

In addition to the studies described here, data provided by this laboratory can supplement a variety of other fish studies. For example, we are currently evaluating the use of fatty acid analysis as a method for discriminating sleeper shark diets. We also anticipate that the developmental biology of forage species could be better understood by examining their lipid dynamics relative to zooplankton productivity. Funding of a full time nutritional ecology laboratory will provide AFSC with these capabilities in-house. Currently, these studies can only be supported part-time.

Activities in FY02

Samples were analyzed from four different projects. Over 800 forage fish samples were extracted, esterified and analyzed for fatty acid composition for the Southeast Alaska Steller Sea Lion Prey Study (02FIT-02). In addition, the proximate composition and energy content of these samples have been determined. Approximately 75% of these samples were collected in FY02 and the remainder in late FY01. These prey were collected from pelagic trawls and near-shore sampling and represent 12 species collected in two locations over six sampling periods. In

addition, 120 blood, liver and muscle samples collected from 40 sleeper sharks during the Sleeper Shark Study (02-PP-02) were processed. The purpose of these analyses is to evaluate the potential for Quantitative Fatty Acid Signature Analysis (QFASA) models as a tool for estimating shark diets. These fatty acid data will be combined with existing prey libraries to estimate sleeper shark diets, and the predicted diets will be compared with stomach content analyses performed in the field. A set of 40 samples, contributed by the Berners Bay (02FF-10) Eulachon Project, was processed to determine how spawning influences the vitamin and lipid content and fatty acid composition of male and female eulachon. All these data were combined with existing data sets into a prey database which now contains 1,300 proximate compositions, 368 lipid class analyses and more than 500 fatty acid analyses. Finally, the Parasite Project (02SSL-03) and BASIS (02-CD06) provided several hundred samples of sea lion prey from the western Aleutian Islands which will be processed in FY03.

A workshop was held on 3-4 October 2002 to develop an inter-laboratory comparison program to ensure conformity among all the labs currently performing fatty acid analysis on samples collected from the northern Gulf of Alaska. Currently four labs are funded to process fatty acid samples for sea lion projects. The workshop provided chemists from these labs an opportunity to compare methods and agree to compare analyses on a common substrate. Results of the inter-laboratory comparison will be evaluated at the January 2003 Sea Lion Workshop.

In addition to evaluating the proximate and fatty acid composition of sea lion prey, we began evaluating the lipid class composition young-of-the-year, juvenile and adult pollock. Combining these data with the proximate composition will provide a detailed model of how energy is allocated during the life history of this commercially valuable species.

A lipid chemist was recruited and hired, but did not begin service until the beginning of FY03.

Results From FY02 Work

Preliminary conclusions include

- Of the forage species collected over the broadest geographic and seasonal ranges (eulachon, herring, hake, capelin, and three size classes of pollock), eulachon consistently had the highest lipid content.
- Lipid levels in most forage species are highest at the beginning of gonadal recrudesence and lowest at maturity.
- The spatial component to variation in lipid content for a given species can be very important. For example, adult pollock from different locations can differ in their lipid content by as much as 100%.
- Spawning has little impact on the lipid content of adult eulachon; however, they lose significant amounts of lipid and energy during upstream migration. These energetic costs are apparently related to recrudesence, osmoregulation during spawning and predator avoidance.
- Shark blood has high levels of fatty acids that have been synthesized *de novo* in contrast to liver and muscle which contain greater amounts of dietary fatty acids.

Milestones in FY03

Characterize Interannual Variation in the Nutritional Value of Three Primary Sea Lion Prey in Southeast Alaska

Pollock, herring and eulachon collected on Southeast Alaska prey seasonality cruises (03FIT-02) will be processed to determine their proximate composition, energy content and fatty acid composition. Interannual variation in these data will be examined by comparing results from FY03 with data collected in FY02. These data are important for determining the chemical composition of sea lion prey, providing a basis for making regional comparisons of the quality of sea lion prey and understanding how prey quality varies temporally.

Characterize the Seasonal Variation in Nutritional Value of Four New Prey Types

Detailed analysis of the spatial variation in the nutritional value of Pacific cod, rockfish, arrowtooth flounder and skates, also important sea lion prey, will be examined following the Southeast Alaska prey availability longline survey in July 2003. This milestone extends our understanding of sea lion prey quality to species that have not been previously analyzed but have been identified as important in sea lion scat analyses. As with the previous milestone, they provide a basis for regional comparisons of the quality of sea lion prey.

Characterize the Nutritional Quality of Sea Lion Prey from the Western Aleutians

Samples of Pacific cod, Atka mackerel, arrowtooth flounder and pollock collected during RACE Division cruises during FY02 will be processed to examine their proximate composition and energy content. If lipid class analysis reveals that these samples were adequately preserved, then we will perform fatty acid analysis on them and start building a library for western Aleutian prey. In addition, a second set of 60 samples provided from RACE bottom trawl surveys in the Aleutians and Gulf of Alaska will be analyzed to determine proximate composition and energy content. There are few data regarding prey quality from this important part of the range of the western stock of sea lions. These data can be combined with data from Southeast Alaska to begin comparisons of regional variation in the sea lion prey quality. In addition, broad spatial comparisons will provide insight into how regional variation in productivity influences the biology of forage species.

Evaluate Sea Lion Diets Through Quantitative Fatty Acid Signature Analysis (QFASA)

ABL has been working closely with the ADF&G to develop appropriate data sets for modeling sea lion diets. The ADF&G has experience with the published models and is developing fatty acid data for sea lions from Southeast Alaska. ABL has been building a fatty acid library for sea lion prey from southeastern Alaska and has been evaluating many of the statistical properties of the fatty acid model. By late FY03 both groups will have acquired sufficient data to begin loading data into the model. This will be the first attempt to apply fatty acid models to sea lions and therefore represents an important step in the development of this new approach to diet analysis. Once developed, these models will be useful in characterizing diets of fish as well as those of sea lions.

Steller Sea Lion Related Research: Parasite-related Effects (02SSL-03)

Principal Investigators: Frank Morado and Michelle Moore
Division: RACE
SSL Projects Database #: 2001-124

Project Description

The impact of parasites on Steller sea lion (*Eumetopias jubatus*) populations is essentially unknown. Because parasites play significant roles in animal populations, the proposed work will contrast parasite ecology around Steller sea lion rookeries, and the potential impact of lungworms on juvenile fitness. In both instances, it is hypothesized that significant parasite burdens could affect the ability of juvenile Steller sea lions to find prey or evade predators either by robbing the host of nutrients or affecting respiration. The proposed work will be heavily dependent upon cooperation for sample collection and data sharing.

Disease-related mortalities may be quite striking because of the numbers of affected individuals. Such episodes are typically acute in nature, but their impact on wild populations can be estimated. Less difficult to measure and more diverse in their impact are indirect or secondary disease effects that can further stress a population that is attempting to recover from an epizootic. Under certain circumstances, population recovery may be delayed as a result of reduced growth rates, altered behavior, or poor recruitment resulting from loss of or reduction in fecundity. In addition, a disease may compromise the "fitness" of an individual such that the affected organism could succumb to other diseases or it may have greater difficulty in finding prey or evading predators. For a population that is experiencing poor recruitment such as the Steller sea lion, secondary or indirect disease/parasite effects could play a critical role.

Macroparasites and their associated sequelae (e.g., pneumonia, gastrointestinal ulcers, anemia, opportunistic infections, etc.) are known to produce mortalities, but significant parasite burdens are also capable of reducing fitness and growth rates, alter behavior or affect recruitment that can be manifested as loss of or reduction in fecundity. For example, lungworm infestations and its associated syndromes are potentially important Steller sea lion diseases. Heavy infestations of lung worms have the potential to cause mortalities, but lesser infestations may produce pneumonia that can in turn affect swimming performance and diving. Do lungworm infestations reduce respiration efficiency and to what extent does this compromise the sea lion's ability to find prey or evade predators?

The goals of this project are to 1) identify and contrast Steller sea lion parasite faunas between rookeries; 2) identify and contrast fish parasites in close proximity to and distant from sea lion rookeries; and 3) investigate the prevalence and distribution of lungworm in Steller sea lion pups, juveniles and adults throughout its range. The unique parasite environment around rookeries may compromise the health and survival of pups and juveniles, and parasite-associated pneumonia may significantly reduce respiration, increasing the difficulty in capturing prey or evading predators in infected individuals.

The proposed work will focus on Steller sea lion and fish collections from Seguam Pass, eastern

Aleutian Islands and Kodiak Island that presently are attempting to address sea lion/fisheries interactions (e.g., Atka mackerel, Pacific cod and walleye pollock, respectively). The above three AFSC focus areas are important because they represent locations in which Steller sea lion populations are still experiencing declines in numbers. Fish and Steller sea lion sampling from Southeast Alaska are desirable, especially from and near Forrester Island because Steller sea lion populations are stable or increasing and would serve as a reference population. At the present time, Prince William Sound sampling is not targeted but may become an issue in subsequent years.

Activities in FY02

Dr. Michelle Moore was recruited as co-investigator for the project and an intern was hired to facilitate sample processing and analysis. Protocols were evaluated and refined on scat samples collected during the 2001 National Marine Mammal Laboratory (NMML) Steller sea lion central Aleutian Island survey. Also during 2002, six primary and alternative sites from throughout the Aleutian Islands were selected for scat collections and coordinated with NMML staff. Based on the 2002 scat target sites, collection of four species of major Steller sea lion prey was coordinated with Resource Assessment and Conservation Engineering Division (RACE) staff. In addition, effort was directed at cultivating cooperative studies that would lead to more complete utilization of both fish and Steller sea lion samples. These cooperative studies are necessary to better understand the possible effects of parasites on Steller sea lion health, the trophic transfer of parasites and pollutants. Because of logistical and practical problems (e.g., inability to collect adult parasitized sea lions), it was not possible to collect adult parasites from Steller sea lion to confirm the identity and origin of observed parasite eggs and larvae from Steller sea lion scat samples.

FY02 Results

During 2001, 60 scat samples from six rookeries were collected (Table 1). After protocol refinement, two scat samples from each of six collection sites were analyzed for the presence of adult parasites and other parasite life history stages (e.g., eggs, proglottids). Only one adult hookworm was isolated from the examined 2001 scat samples; it is currently being identified. A number of parasite eggs were isolated and tentative identification suggests that adult Steller sea lion are parasitized by currently unidentified acanthocephalans, ascarid nematodes, liver and intestinal trematodes. Individual egg densities varied from less than 5 to over 90,000 (e.g., liver fluke eggs) per gram of scat. It is suggested that increasing numbers of eggs and larvae in scats correlate to increased numbers of adult parasites that may impact Steller sea lion health.

In 2002, a total of 90 scat samples were collected for parasite analysis from six targeted and one additional Steller sea lion rookeries (Table 1). To complement the 2002 scat collections, a total of 176 Steller sea lion prey fishes were collected from four of six target rookeries during the 2002 RACE Aleutian Island groundfish survey (Table 2). Analysis of both 2002 scat and fish samples have not been initiated.

A major accomplishment during FY02 was the collaboration between Kathy Burek (Alaska Veterinary Pathology Services), Ron Heintz (ABL), Adam Moles (ABL), Margaret Krahn (NWFSC) and Fisheries Resources Pathobiology to share samples and data. The collaboration is

necessary to facilitate the exchange of ideas and samples to better understand the effects of parasites in Steller sea lion health, the ecology of parasites around selected Aleutian and Southeast Alaska Steller sea lion rookeries, and the trophic transfer of parasites and pollutants to sea lions. The first positive result of the collaboration was the receipt of four Steller sea lion pup intestines collected by Kathy Burek that demonstrated the presence of adult hookworms (*Uncinaria* sp.). These samples were instrumental in establishing shed eggs in scats and fecal samples with a known adult parasite. The associated pathology was limited to slight to moderate, focal intestinal hemorrhage, but *Uncinaria* is known to produce significant mortalities in California sea lions, northern fur seals, but not Steller sea lions. Hematological/physiological data were collected from two of the affected pups and will be important in attempting to determine the effects of hookworms on pup Steller sea lion health. In addition, Kathy Burek forwarded 50 fecal samples from juvenile Steller sea lion that are accompanied by hematological/physiological data.

Milestones in FY03

FY03 is the last year of the project and to date, 13 (9%) scat and 20 (38%) fecal samples have been analyzed. Considerable effort was initially directed at parasite identification and in developing a reliable quantitative method. Previous methods did not sufficiently retain parasite products and keys were not available that permitted quick identification of Steller sea lion parasite eggs, larvae or proglottids. A total of 66 fish was examined for juvenile parasites, whose adult stages may be found in the Steller sea lion. However, these collections were a particular problem because not all targeted fish species were available or present in sufficient numbers at all target sites for adequate sample comparison.

Table 1. FY01 and FY02 NMML scat collections.

Year	Collection Site	Sample Size
2001	Akutan/Cape Morgan	9
	Ugamak North	9
	Ugamak South	9
	Chernabura	10
	Seguam Island/Saddleridge Pt.	9
	Chowiet	14
2002	Akun Island/Billings Head	11
	Attu Island/Cape Wrangell	7
	Buldir Island	8
	Kiska Island/Lief Cove	12
	Seguam Island/Saddleridge Pt.	15
	Adak Island/Lake Pt.	18
	Ayugadak Pt.	19

Table 2. Fish collections from 2002 RACE Aleutian Islands groundfish survey.

Location	Pacific Cod	Atka Mackerel	Arrowtooth Flounder	Walleye Pollock
Akun Island	2	24	15	23
Adak Island	14	14	9	0
Buldir Island	3	30	0	0
Attu Island	7	0	10	12
Total	26	68	34	35

Monitor Population Trends (02SSL-04)

Principal Investigators: Thomas Loughlin and John Sease
Division: NMML
SSL Projects Database #: 2001-99

Project Description

Population status and trends are obtained during breeding season surveys (June/July) throughout Alaska biennially (2002; planned in 2004 and 2006) and range-wide every 5 years. This is done to monitor status and trends of both eastern and western populations of Steller sea lions range-wide, with a focus on Alaska. Non-pups on land at all rookeries and haul-out sites are counted from photographs obtained during aerial surveys. Pups are counted from land and from photographs, depending on location. Photographs are obtained by both 35 mm and medium-format photography and then animals are counted from the projected image in the laboratory. Results are typically available within 3 months of the surveys and are available on the AFSC web site. Results of breeding-season surveys are first provided during the annual meeting in September of the North Pacific Fishery Management Council. Relative abundance and distribution are also obtained during other times of the year when appropriate. NMFS also supports quarterly abundance and distribution studies in specific, smaller areas, such as Kodiak Island waters and the Juneau area.

Activities in FY02

The NMML aerial survey of non-pups took place 14 to 25 June, covering the Alaska portion of the western stock from the eastern Gulf of Alaska (144° W long.) through the western Aleutian Islands. NMML flew on 11 of 12 days, missing one day because of weather, accruing approximately 60 flight hours. The aerial survey included replicate visits to 28 sites in the Gulf of Alaska and 30 sites in the eastern and east-central Aleutian Islands to allow estimating survey variability. NMML personnel counted pups at 21 western stock rookeries during two simultaneous ship-based expeditions from 24 June to 10 July. One vessel surveyed the Aleutian Islands (Attu to Dutch Harbor), the second vessel surveyed the Gulf of Alaska (Dutch Harbor to Prince William Sound). Land-based field parties counted pups at three other rookeries (Fish, Marmot, and Ugamak Islands).

Results From FY02 Work

The June 2002 aerial survey resulted in a total count of 26,599 non-pup Steller sea lions on 259 surveyed sites in the western stock. The count at the 84 western-stock rookery and haul-out trend sites was 19,337 non-pups, an increase of 5.5% from June 2000. This was the first region-wide increase observed during more than two decades of surveys. The 2002 non-pup count was still down 5% from 1998 and 34% from 1991. Pup counts for the western-stock showed continuing decline in pup production, down 11.2% since 1998.

Plans for FY03

The NMML is not scheduled to conduct any aerial survey activity during FY03. Pup counts will be conducted in conjunction with other on-rookery research activities at several (e.g., 5 or 6) rookeries during late June and early July 2003.

Demographic Studies at Fish, Marmot, and Ugamak Island Rookeries: Field Camps (02SSL-05)

Principal Investigator: Thomas Loughlin
Division: NMML
SSL Projects Database #: 2001-100

Project Description
Observers record number and distribution of sea lions during the breeding season at Fish, Marmot, and Ugamak Islands using binoculars and spotting scopes. Identifiable animals are recorded for presence or absence, and all age classes are recorded by sex, when possible. Counts are conducted for daily, weekly, and monthly variability. The goal of this study is to monitor population demography and to determine the survival and mortality rates of sea lions branded as pups. All three islands have long-term observational studies dating to the 1970s. Data exist on the distribution and abundance of sea lions at these sites which are not available for other sites in Alaska. Branding and tagging studies occurred at all three sites at different times allowing for studies on individuals over time. These sites have also provided compelling corroborative information on the reduction in juvenile survival as the likely cause of the decline. These sites will continue to be monitored during the breeding season to provide population demographic data and to follow the new cohorts of branded animals discussed in Project 02SSL-12.

Activities in FY02
Three teams spent 2 months on Fish, Marmot, and Ugamak Islands during May - August 2002. Observers recorded sightings and breeding activities of branded sea lions. They also noted the quality of the brands and photographed them for corroborative purposes. Observers also did daily counts of numbers of adults, pups, and juveniles at the rookery.

Results From FY02 Work
Observations of branded animals are part of a long-term study and the first results will not be available until 2004.

Milestones in FY03 and Beyond:
Plans for FY03: Three teams will spend 2 months on Fish, Marmot, and Ugamak Islands during May - August 2003. Observers will record sightings and breeding activities of branded sea lions and do daily counts of numbers of adults, pups, and juveniles at the rookery. The same events will occur over the next 5 years, at least, or for as long as the branded animals survive. Data are stored on the NMML LAN for analysis by NMML staff of survival and reproductive success at a minimum of 4 years after each animal is marked.

Products will be reports and peer-reviewed publications of sea lion survival and age-specific reproductive rates, but the first report will not appear until at least 2005, or 5 years after initial branding. Females typically reproduce in their 4th year so a report on reproductive success is at least 3 years into the future.

Use of Scat and Other Sources to Identify Sea Lion Prey (02SSL-06)

Principal Investigators: Thomas Loughlin and Elizabeth Sinclair
Division: NMML
SSL Projects Database #: 2001-101

Project Description
Scat are collected at all rookeries and haul-out sites visited by NMML biologists during pup and telemetry studies to describe and monitor sea lion prey by area and season range-wide, and to determine the relative importance of different prey. Each scat is bagged separately, identified by location, then frozen for analysis in the laboratory. In the laboratory, they are defrosted and hard parts removed through varied sieves. The hard parts, including otoliths (rarely), bones, scales, mouth parts (cephalopods), and other identifiable remains are summarized to determine the frequency of occurrence of prey. For those prey in which the otolith or other cranial elements are present, numbers of prey, physical size of the prey, and perhaps age of the prey can be determined. These data are used to enhance the understanding of the role of Steller sea lions in the marine ecosystem, to assess the variability in the availability of prey over time, and the interactions of commercial fisheries and Steller sea lions over time and area.

Activities in FY02
Steller sea lion scats were collected at rookery and haul-out sites located on islands from Attu Island, in the Western Aleutian Islands, to Prince William Sound, during seven research operations. Approximately 1,143 scats were collected during these operations, which ranged from November 2001 to July 2002. All scats were shipped to NMML for analysis in the laboratory. Fish otoliths and cephalopod beaks were identified, counted and measured by personnel at NMML. Bones were identified under a contract with Pacific ID.

Results From FY02 Work
Scats collected during FY02 are currently being washed through sieves in the laboratory to remove prey hard parts for subsequent identification, enumeration and measurements. To date, more than 634 scat samples have been processed to recover prey hard parts.

Milestones in FY03
Steller sea lion scats will be collected at rookery and haul-out sites located on islands from eastern Aleutian Islands to Prince William Sound during several research operations. Analysis will be the same as in FY02.

Product Descriptions
Scat information is typically available one year after collection and available to the public soon after when it is placed on the NMML web page for public use. NMML staff publish frequently in *NOAA Technical Memorandums* to disseminate information quickly and then at about 5 year intervals in the peer literature. These publications and dissemination through the web are timely to facilitate sea lion and fishery management in Alaska.

Diet and Fatty Acids (02SSL-07)

Principal Investigators: Thomas Loughlin and Elizabeth Sinclair
Division: NMML
SSL Projects Database #: 2001-102

Project Description
Most animals produce a fatty acid signature which is typically a reflection of the prey they consume. Often these fatty acid signatures are species-specific and can be used to characterize diet of the predator. Sea lion blubber (fat) is obtained from dead sea lions or from those anaesthetized for telemetry studies. The blubber is then chemically analyzed to determine the fatty acid profile. NMML is attempting to utilize this relatively new technique to enhance the understanding of Steller sea lion food habits. All techniques to measure food habits have inherent biases, including stomach contents, scat, fatty acids, stable isotopes, and others. To obtain the most thorough understanding, all techniques must be used, when feasible. Thus, NMML in collaboration with the ADF&G and the ABL are enhancing their abilities to describe food habits using these fatty acid profiles. The project is in the exploratory stages and will likely last at least 5 years.

Activities in FY02
Steller sea lion blubber and blood samples were collected for fatty acid analysis during land-based and underwater (SCUBA) captures of juvenile sea lions in FY02. Samples were obtained from 42 individuals (25 males, 17 females) captured around Kodiak Island and the Unimak Pass area of the Eastern Aleutian Islands. The samples were collected during February/March (n=25) research activities and during July (n=17) research activities. Samples were frozen and shipped to ADF&G for analysis.

Results From FY02 Work
Both NMML and ADF&G collected samples from Steller sea lions for fatty acid analysis during FY02. Because of concerns regarding variation in the results of the fatty acid analyses between laboratories, NMML and ADF&G agreed that ADF&G will analyze samples for fatty acid signatures. ADF&G will also analyze the fatty acid signatures from blood, as well as blubber, to compare the results obtained from these sample types. A fatty acid coordination meeting was convened at NMML in October 2002 to discuss and attempt to resolve some of the potential differences in results between laboratories.

Plans for FY03
Blubber and blood samples will be collected for fatty acid analysis during captures of juvenile Steller sea lions and, opportunistically, from dead Steller sea lions during FY03. Work on this project in FY03 will continue with funding under 03SSL-06.

Use of Telemetry to Study Foraging Ecology and Behavior (02SSL-08)

Principal Investigators: Thomas Loughlin, Brian Fadely and Jeremy Sterling
Division: NMML
SSL Projects Database #: 2001-104

Project Description

One of the over-riding themes associated with the Steller sea lion decline has been the possible effect of commercial fisheries. This project directly addresses the issue by providing information on Steller sea lion foraging ecology, including locations, dive depth and duration, changes in dive characteristics by age and sex, the overlap between foraging location and fishing location, and other pertinent information. Adult and juvenile Steller sea lions are captured by remote inject of an immobilizing agent (adults), hoop-net captures on land, or SCUBA captures under water (6 months to 2+ years of age). Once captured, satellite-linked time-depth recorders (SDRs) and other telemetric instruments are glued to the animals back between the shoulders and released. These instruments collect information on animal dive characteristics, time on land and at sea, and other data, which are then transmitted to the Argos satellite which calculates location based on the received messages. These data are then provided by Argos to NMML for analysis and interpretation. The studies began in the late 1980s on adult females during the breeding season and were enhanced in the 1990s by improved technology and capture techniques (the later by ADF&G's development of the SCUBA capture technique). Presently the focus of both ADF&G and NMML is on sea lions 6 months old to 2+ years of age since they are postulated to be the age classes accounting for the decline. Earlier studies by NMML focused on females during the breeding season. Future studies will likely revisit adult females during the non-breeding season, and young animals in the 3- and 4-year-old age classes, those that are presently too large to capture by either hoop net or SCUBA or too small to safely use chemical immobilizing agents.

Activities in FY02

Three cruises to capture sea lions for instrumentation were conducted during FY02; to the Kodiak and Krenitzen Island areas in November 2001 and February-March 2002, and to the Kodiak Island area during July-August 2002. Kodiak captures were timed to coincide with survey activities of fish biomass and oceanographic sampling conducted by the Gulf Apex Predator (UAF) or RACE (NMFS) programs. Captures in November were performed using hoop nets on land, February-March captures were performed using hoop nets and SCUBA capture techniques, and July-August captures were performed solely with SCUBA capture techniques. Captured sea lions were also weighed, measured, and blood and other tissue samples were obtained for dietary, health, and genetics studies. SDRs (Wildlife Computers ST-16) or satellite relay data loggers (SRDL, Sea Mammal Research Unit) were glued to the dorsal pelage with fast-setting epoxy resin (Devcon ®). Sea lions captured at Kodiak Island area sites also had VHF transmitters glued just posterior to the SDR, and their flipper tag number written on their left mid-trunk side with hair dye. Plastic colored and numbered Allflex ® tags were attached to the trailing edge of each front flipper, unless the sea lion had been previously tagged as a pup.

Results From FY02 Work

A total of 38 instruments were deployed by the NMML during FY02. In November 2001 a young-of-the-year (YOY) male was instrumented at Twoheaded Island, and in the Unimak Pass region two female YOY were instrumented on Ugamak beach A5. One of the instrumented Ugamak animals had been captured and branded (A13) at the Ugamak Island rookery as a newborn pup in July 2001. During February and March 2002, a total of 25 sea lions, each estimated to be 9 months old, were successfully captured, instrumented and sampled. Of those, three were hoop net captured on land and 22 were captured with the underwater noose technique. At Kodiak Island area haul-outs, 10 sea lions were outfitted with SDRs, and five were fitted with SRDLs for Steller Sea Lion Research Initiative (SSLRI) award recipients Dr. Jennifer Burns and Mike Rehberg of the University of Alaska, Anchorage. In the eastern Aleutian Islands, SDRs were attached to 10 sea lions (1 at Basalt Rock, 9 at Aiktak). Two sea lions captured, sampled and instrumented on this trip had been branded or tagged as pups. During July and August 2002, a total of 17 juvenile sea lions were captured among Marmot Island (n=5), Chiniak Island reefs (n=2), and Two-headed Island (n=10) sites. Ten sea lions were outfitted with SDR/VHF transmitters (Marmot Island n=3, Chiniak Island n=2, Two-headed Island n=5). Two sea lions had been captured and instrumented previously during the March 2002 capture trip. In addition to analyses of travel and diving behavior, algorithms were developed to provide daily positional updates, displayed through a series of interactive maps for public viewing at the Steller sea lion telemetry research website, accessible from the NMML web site.

Milestones in FY03

This is an ongoing project. Contingent upon funding received, two to three capture trips are anticipated for FY03, again targeting juvenile sea lions up to 3 years old. An additional project will begin FY03 (03SSL-29) in which sub-adult sea lions will be targeted for capture using modified float cage and squeeze cage techniques developed for California sea lions. This will enable collection of data on the at-sea distributions and diving behavior of an age class of sea lions for which no data currently exist. Analyses will be performed to describe movement and diving behavior in relation to age and condition, prey distribution, bathymetry, and oceanography.

Product descriptions

Telemetry information is typically available one year after collection and available to the public on the NMML web site for public use. Telemetry data are analyzed by NMML staff and products include peer reviewed articles and numerous internal data summaries used for managers for fisheries management. NMML staff publish frequently in *NOAA Technical Memorandums* to disseminate information quickly and then at about 5 year intervals in the peer literature. These publications and dissemination through the web are timely to facilitate sea lion and fishery management in Alaska.

Growth, Condition, and Disease (02SSL-09)

Principal Investigators: Thomas Loughlin and Brian Fadely
Division: NMML
SSL Projects Database #: 2001-105

Project Description

As nutritional limitation has been presented as one hypothesis for mediating juvenile survival through ecosystem changes or competition with fisheries, monitoring the health status and body condition of sea lions is critical for obtaining a complete understanding of potential responses to changing environmental conditions. This project collects health and condition data from sea lions sampled throughout the western range for interpretation with respect to age, sex, and location, season and year of capture. This information will complement data collected in other studies. Captured animals have a combination of blood and other tissue samples taken, and morphometric and other condition measures made in order to obtain a health and condition profile. A subset of pups captured for branding or tagging are sampled, as are most pups, juveniles and adults captured with hoop nets or immobilizing agents on land, or by SCUBA captures underwater. Blood samples are taken for clinical blood chemistry and hematology analysis, and for other analyses by collaborating researchers. Body size measures are taken (e.g., mass, length, girth) and body composition will be estimated through deuterated water injection or bioimpedance analysis. This will facilitate interpretations of weaning status and diving behavior obtained from parallel studies, and ultimately responses to environmental factors or fishery management manipulations. As more sea lions pups are branded and are resighted or recaptured at older ages, health and condition profiles will provide a valuable baseline upon which to interpret population status. Additional work will involve modeling individual and population level condition responses with respect to foraging behavior, population trends and environmental conditions.

Activities in FY02

Measurements and samples were obtained from two simultaneous ship-based NMML expeditions from 24 June to 10 July, one vessel surveyed the Aleutian Islands (Attu to Dutch Harbor), the second vessel surveyed the Gulf of Alaska (Dutch Harbor to Prince William Sound). During scat sampling at rookeries and haul-outs for dietary studies, scats meeting specific sampling quality criteria were subsampled for hormonal (Patience Browne, U.C. Davis) corticosteroid (Dr. Shannon Atkinson, ASLC) and parasite analyses (Dr. Frank Morado, Alaska Fisheries Science Center). Placentas appearing relatively fresh were collected and frozen for subsequent analyses by ASLC and UCD. Pups appearing to be recent mortalities were necropsied to obtain tissue samples for analyses by Dr. John Wise (Yale University) and Dr. Jennifer Burns (UAA), and to infer possible mechanisms of death. Additional pup measurements and samples were obtained from rookeries in Russia, Southeast Alaska, and Oregon. Measurements and samples from juvenile sea lions were obtained from three cruises to capture sea lions conducted in the Kodiak and Krenitzen Island areas in November 2001 and February-March 2002, and in the Kodiak Island area during July-August 2002. Captures in November were performed using hoop nets on land, February-March captures were performed using hoop nets and SCUBA capture techniques, and July-August captures were performed

solely with SCUBA capture techniques. A subset of these captured juvenile sea lions were instrumented with satellite-linked time-depth recorders. Additional samples were obtained from ADF&G capture operations in Prince William Sound, Southeast Alaska, and the Aleutian Islands. Plasma and serum samples obtained from pups and juveniles were provided to other sea lion investigators at Mystic Aquarium (vitamin analysis), ASLC (immunology), ADF&G (thyroid, fatty acids), and UCD (hormone analysis).

Results From FY02 Work

From the 39 rookeries visited in the U.S. portion of the western stock, 787 pups were handled to obtain 591 measurements, 150 blood samples, and 560 tissue samples for genetics analysis by SWFSC and TAMU. Four placentas were retrieved from among two sites, and 3 pup necropsies were performed. From the 509 scats collected for diet analyses, 48 were subsampled for hormonal (Patience Browne, UCD), 50 for corticosteroid (Shannon Atkinson, ASLC), and 90 for parasite (Frank Morado, AFSC) analyses. From the Russian portion of the range, 111 blood samples were obtained for analyses. Of the 51 juvenile sea lion captured and measured by the NMML in FY02, blood and tissue samples were obtained from 47. Four juveniles captured and sampled had been previously captured as pups or as juveniles by dive capture.

Plans for FY03

Contingent upon funding, two or three cruises will deploy to the Kodiak Island and eastern Aleutian Island areas to capture, measure, and obtain samples from juvenile sea lions. Measurements and samples will also be obtained from two pup counting and sampling cruises throughout the northern Gulf of Alaska and the Aleutian Islands during June and July. Laboratory analyses of samples and analyses of results will continue. Work on this project will continue in FY03, but funding for it is contained entirely within Foraging Ecology (03SSL-08) and Pup Counts and Branding (03SSL-25).

AFSC Genetics Laboratory and Stock Identification at Texas A&M University (02SSL-10)

Principal Investigators: Thomas Loughlin, Rolf Ream, Michael Canino and John Bickham
Division: NMML, RACE, Texas A&M University
SSL Projects Database #: 2001-106

Project Description

AFSC Genetics Laboratory

This is a joint project by the National Marine Mammal Laboratory and the Resource Assessment and Conservation Engineering Division to establish a molecular laboratory platform in support of ongoing and future Steller sea lion and related fisheries research. Preliminary requirements are for a basic laboratory capable of conducting some existing molecular research currently done elsewhere under contract, and developing new molecular markers and techniques in support of research activities at the AFSC. Siting the lab at the AFSC will provide exposure for a number of potential user groups at the Center, and facilitate the integration of molecular methods with ongoing research projects.

Specific projects the first year will include analysis of sea lion fecal samples which contain small quantities of DNA. The NMML is using this DNA for identification of mitochondrial DNA (mtDNA) haplotypes and gender in the Aleutian Islands and the Gulf of Alaska. Analysis of mitochondrial haplotypes from fecal samples allows for a non-invasive approach to the population genetics of the species and will help determine if broad-scale movements occur during winter. Gender determination gives an indication of the sex composition at each site allowing interpretation of seasonal use of the habitat for each sex. Combined with prey identification from fecal samples, gender determination also allows for detailed descriptions and analyses of food habits by sex.

Texas A&M University (TAMU)

The goal of this study is to obtain genotype designations for as many loci (genes) for as many individual sea lions as possible. This allows comparison of the gene frequencies among populations and statistical testing for differences. The determination will be made using tissue samples collected throughout the sea lion's range from isolated sea lion populations for analysis of genetic markers (mitochondrial DNA and nuclear DNA).

Activities in FY02

For the AFSC segment, equipment was purchased to start genetic analysis in early FY03.

For TAMU, a report dated 13 March 2002 presented the results of the 2002 Steller sea lion genetics project. This included mainly animals collected during the summer of 1991. The report included the control region sequences from 100 Steller sea lion pups taken from five rookeries including Akutan Island (Cape Morgan, n=17), Marmot Island (n=2), Seal Rocks (n=3), and Ugamak Island (North rookery, n=73). The addition of these data to the genetics database increased the sample size from rookeries to 1,007 individuals. TAMU researchers performed the usual phylogenetic analysis of haplotypes using the NJ-tree approach but also constructed a

minimum spanning network. They also preformed population analyses using F_{st} as a distance measure. In the 2002 report they also presented the results of a cytochrome b sequence analysis. In that study 112 Steller sea lions which had previously been reported as having the BB haplotype were sequenced for 1,140 bases of the cyt b gene. They observed 11 "cryptic" haplotypes among these individuals. The purpose of that study is to increase the resolution of the haplotype tree and to better differentiate patterns of gene flow and subdivision among populations.

In 2002 the contractors submitted one paper for publication which is listed below:

Trujillo, R. G., T. R. Loughlin, N. J. Gemmell, J. C. Patton, and J. W. Bickham. Macrogeographic variation of nuclear microsatellite loci and mitochondrial control-region sequences in an endangered marine mammal, *Eumetopias jubatus*. Journal of Mammalogy (in press).

Plans for FY03

Specific projects will include analysis of sea lion fecal samples which contain small quantities of DNA. The NMML is using this DNA for identification of mitochondrial DNA (mtDNA) haplotypes and gender in the Aleutian Islands and the Gulf of Alaska. Analysis of mitochondrial haplotypes from fecal samples allows for a non-invasive approach to the population genetics of the species and will help determine if broad-scale movements occur during winter.

Dr. Bickham (TAMU) is now working on a report for 2003 which will present the results of genetic studies performed on animals collected in 2001, 2002, and archived samples. The samples include a total of 1,092 samples including 446 from 2001 and 646 from 2002. The 2003 report will include control region sequences from some portion of these animals, cytochrome b sequences from all BB animals, cytochrome b sequences from all of the previously reported control region haplotypes (at least one individual per haplotype), and preliminary results of nested clade analysis (which employs both cyt b and control region data).

Stock Structure: Determine Exchange Rates Among Putative Stock Boundaries Through Genetic Analysis (02SSL-11)

Principal Investigator: Barbara Taylor and Greg O'Corry-Crowe
Division: SWFSC
AFSC Contact: Douglas Demaster
SSL Projects Database #: 2001-107

Project Description
The AFSC and the genetics laboratory of the SWFSC's Marine Mammal Division are collaborating on a study of the population genetics of Steller sea lions in Alaska. The SWFSC's laboratory director, Dr. Andrew Dizon, has agreed to make staff available to run mtDNA analyses on tissue plugs from Steller sea lions to ascertain the merits of the current stock structure recognized by NMFS. The funding provided by the AFSC will be used to cover salaries of laboratory technicians and data analysts, as well as to cover the cost of laboratory supplies in FY02. A similar analysis by Dr. Dizon's laboratory is underway for harbor seal populations in Alaska.

Activities in FY02
SWFSC received genetic samples for sites in both the western and eastern stock for analysis during the fiscal year. At the end of the year, samples were delivered from collections made in July from selected rookeries in the western stock for analysis during FY03.

Results From FY02 Work
SWFSC presented preliminary results of a study to estimate dispersal rates using mitochondrial DNA (mtDNA). Bickham and colleagues have used this marker to show the evolutionary relationships between rookeries across the range of the species. SWFSC used the marker to estimate parameters needed for models that estimate risk; that is, estimate dispersal rates between rookeries. They used a longer sequence for 80 samples from both Ugamak and Akutan and found that dispersal between these rookeries is demographically trivial (d = 0.0009/year) and that a sample size of at least 50 was required to achieve sufficient statistical power to detect this population structure using a traditional hypothesis testing approach.

SWFSC also analyzed samples from the eastern stock from 106 sea lion pups sampled at Lowrie Island in the Forester Island group and 99 pups sampled at the Hazy Islands in the same year. They estimated the level of differentiation (F_{st}) between these two areas and presented preliminary estimates of dispersal between these rookeries.

Although the current pattern of genetic variation among Lowrie and Hazy Islands likely reflects the historical relationships between these two areas as well as current patterns of dispersal, the SWFSC used current abundance estimates to simulate population differentiation over time for a range of hypothesized dispersal rates. Counts adjusted by York et al.'s (1996) correction gave the following numbers of adult females: Lowrie = 3,254 and Hazy = 1,610. The SWFSC used mutation rates estimated for another estimate of dispersal between Ugamak and Akutan (μ = 0.00004). For each simulation the populations were sampled at a sample size of 60 and the level

of genetic differentiation for the simulated population was saved. This temporal sampling resulted in a distribution of F_{st} for a given dispersal rate that could then be compared with the observed F_{st}. Dispersal rates between 0.001 and 0.01 yielded good chances to obtain the observed F_{st} between Lowrie and Hazy (0.0035), which translates to approximately between 5 and 50 female dispersers/year between the mean adult female abundances of about 2,432.

Plans for FY03

The objectives for FY03 include the analysis of large numbers of samples ($\geq$70) from the majority of Steller sea lion rookeries in Alaska for variation in mtDNA, and the estimation of rates of female dispersal among neighboring rookeries using these data. A number of approaches for estimating dispersal using genetic data will be explored, including a number of different clustering analyses (e.g., Boundary Rank) on the same data in order to provide a framework for the identification of management stocks.

More detailed studies will be conducted on a number of rookeries, where large sample sizes ($\geq$100) will be analyzed to determine the detailed pattern of site fidelity and philopatry within rookeries as well as the pattern of dispersal among rookeries. Pairs of rookeries will be chosen for this research based on known trends in recent decades, the extent of other research of relevance to population structure and dispersal conducted at these rookeries (e.g., branding, tagging and telemetry), and the possibilities of collecting large numbers of tissue samples.

Milestones in FY03

- First Quarter Milestone (October - December 2002)- FY 03: present preliminary findings of stock identification studies on Steller sea lions at management meetings, 13 January 2003
- Report on the analysis of stock structure and dispersal patterns in Steller sea lions. October 2003

Survival/Mortality of Marked Sea Lions and Food Habits of Sea Lions in Oregon and California (02SSL-12)

Principal Investigator: Robert DeLong and Thomas Loughlin
Division: NMML
SSL Projects Database #: 2001-109, 2001-155

Project Description

In 1987-88 NMML branded 800 pups at Marmot Island, then reinitiated branding studies in 2000 at Marmot and Sugarloaf Islands, and in 2001 at Ugamak and Fish Islands, and Seal Rocks in Alaska and Rogue Reef, Oregon. ADF&G has also initiated branding studies in Southeast Alaska. Both groups use the same techniques and marking. Pups are branded with individually identifiable numbers and letters on their left shoulder then observed in subsequent years to determine vital rates. Observers are stationed at the branding sites in subsequent years to monitor sea lion survival. Nearby rookeries and haul-out sites are also monitored for their occurrence. Survival, mortality, and other vital rates will be calculated on the gathered data. A considerable commitment of time and energy over many years from both NMML and ODFW are required. These studies are a continuation of the 1990s studies by the ODFW, and were recommended by the Steller Sea Lion Recovery Team peer review panels. They will provide needed information on age-specific mortality and survival rates, movement patterns, reproductive parameters, age and growth, and other data.

Activities and Results in FY02

On 13 July 2002, 140 Steller sea lion pups were branded at St George Reef near Crescent City, California, with the brands 1Y to 140Y. Seventy-three of the pups were females with an average weight of 26.3 kg, 65 were males with an average weight of 30.5 kg, and for 2 pups sex was not recorded. This site will alternate with Rogue Reef in southern Oregon as the monitoring sites for sea lion survival in the California Current ecosystem over the course of this project.

SeeMore Wildlife Systems, Inc., under contract to NMML, installed a remote viewing camera at the site to monitor marked animals. The images are transmitted to Gold Beach, Oregon, where a contract employee monitors this site and the images transmitted from Rogue Reef where a camera was installed last year.

Estimates of survival or other vital parameters will become available following 3-5 years of monitoring.

Plans for FY03

Due to budget cutbacks in FY03, this project did not receive direct Steller sea lion research support. However, resighting efforts of pups branded in 2001 and 2002 will continue with other support within NMML.

Juvenile Survival Through Photography (02SSL-13)

Principal Investigators: Thomas Loughlin, Anne York and Eli Holmes
Division: NMML
SSL Project Database #: 2001-100

Project Description

A slow response of population size to change is a common characteristic of long-lived species and presents one of the major challenges for their conservation. In contrast to population size, rapid age structure shifts in response to perturbations are well known. Matrix population models were developed to study transient spikes in age-structure as a tool for rapidly detecting the effects of management actions. Since it is impractical to measure age-structure in the field, surrogate stage-ratio metrics (e.g., ratio of juveniles to adults) that would be both sensitive to survivorship changes and practical to measure in the field were developed. These methods and metrics were tested for their ability to detect a known perturbation to survivorship and/or fecundity that occurred in the early to mid-1990s. Using the historical oblique aerial photographs taken during population censuses, historical changes in stage-ratios were estimated between 1985 and 1998. The observed changes strongly resembled the transitory spikes in age structure that occur after a large perturbation as predicted by the matrix model. The model was then fit to the observed changes in stage-ratios, pup numbers, and population sizes. The maximum likelihood fits corroborated previous evidence that declines in juvenile survivorship and adult fecundity drove the precipitous declines in the 1980s and a subsequent moderate increase in the same led to the lessened rate of decline in the 1990s. Laboratory personnel will measure these ratios from current and past aerial surveys and they will be attempt to use them to predict changes in the growth rate of Steller sea lion populations.

Activities in FY02

Analysis of previously collected data was completed and a paper was submitted to *Conservation Biology*. In that paper, time-varying matrix models were used to study age-structure information as a tool for improving detection of survivorship and fecundity change and status. Population and newborn counts were supplemented with information on the fraction of the population that was juvenile, obtained by measuring animals in aerial photographs taken during range-wide censuses. By fitting the model to 1976-1998 data, the investigators obtained maximum likelihood estimates and 95% confidence intervals for juvenile survivorship, adult survivorship and adult fecundity in the mid-1980s, late 1980s and 1990s. They found that the severe declines in the early 1980s were associated with severely low juvenile survivorship while declines in the 1990s were associated with disproportionately low fecundity. They repeated these analyses, fitting only to the count data without the juvenile-fraction information, to determine whether the age-structure information changed the analysis and/or changed the certainty and speed with which demographic-rate changes could be detected. The juvenile-fraction data substantially improved the degree to which estimates from the model were consistent with field data, and significantly improved the speed and certainty with which changes in demographic rates were detected.

Plans for FY03

NMML proposes updating the measurement for 2000 and 2002 and comparing them with measurements from medium-format photography.

Remote Video (02SSL-14)

Principal Investigator: Thomas Loughlin
Division: NMML
SSL Projects Database #: 2001-113

Project Description
NMML contracted with SeeMore Wildlife Systems, Inc. (SWS) to install its proprietary, patent pending system that optimizes remote wildlife imaging for remote research use. The images created with the system will be produced by a system employing wireless video transmissions and robotic cameras specifically designed to optimize remote imaging in severe marine environments where no local electrical power or hard-wire communication methods are available. The goal of this study is to develop the capability to monitor remote haul-out sites to assess population dynamics, movement patterns, and marked individuals. SWS provides NMFS with a license to view and control live video images of the Steller sea lion haul-out area on Benjamin Island. The content is in the form of real-time video and audio from Benjamin Island. SWS will use its remote wildlife monitoring system, equipment, labor, technical expertise, and creative control to create remotely controllable video and audio content from Benjamin Island which will be viewed in real time at the NMFS office in Juneau, Alaska. SWS provides a live color video and audio content from Benjamin Island to the University of Alaska where it is monitored and analyzed by Dr. Brendan Kelly and his students. The video content is capable of wide angle and telephoto views with a motion range of 1-64X or greater. Users can control pan, tilt, and zoom of the video content.

Activities in FY02
The camera was operational from approximately September through May 2002, during the time that sea lions occupy the site.

Results From FY02 Work
The resultant images were available to the principal investigator for collection of resight data, brand resights, population dynamics and behavior. These data are presently under analysis. The images were also broadcast over the internet and accessible to the public for their use and instruction.

Russian Steller Sea Lion Studies (02SSL-15)

Principal Investigators: Thomas Loughlin, Don Calkins and Vladimir Burkanov
Division: NMML
SSL Projects Database #: 2001-114

Project Description

The goal of this study is to monitor Steller sea lions in Russian waters during the 2002 breeding season and to monitor and report on the survival of sea lions marked as pups in Russian waters. The following specific projects were proposed for FY01: 1) Analyses of existing information on effect of branding or tagging Steller sea lion pups on Medny Island (Commander Islands, Russia) rookery in 1991-1999; 2) Continue monitoring of Steller sea lion abundance and breeding success on Medny Island during June to August 2002. Data collected included the number, sex, and approximate age, location, date, and time of the observations, resightings data of tagged/branded animals, and killer whale-Steller sea lion interaction; 3) Monitor and record Steller sea lion abundance and breeding success on Tuleny Island (Sakhalin, Russia) rookery during June to August 2002. Information to include the number, sex, and approximate age, location, date, and time of the observations, resightings data of tagged/branded animals, and killer whale-Steller sea lion interaction; 4) Collect information of abundance and breeding success of Steller sea lion on Yamsky Islands (northern coast of the Sea of Okhotsk) during June to August 2002. Information to include the number, sex, and approximate age, location, date, and time of the observations, resightings data of tagged/branded animals, and killer whale-Steller sea lion interaction; and 5) Brand and measure newborn pups on Yamsky Islands, Kozlov Cape, and Medny Island rookeries end of June early July 2002 (50-100 randomly selected 3-4 weeks old pups both sexes for each site). Information to include date, location, sex, weight, length, girth, brand/tag number for each pup.

Activities in FY02

Surveys of Steller sea lions were conducted in the western Bering Sea and the northern part of the Okhotsk Sea during the sea lion pupping period of June-July 2002. Specifically, the surveys in the western Bering Sea included the eastern coast of Kamchatka (from the southern tip to the Navarin area) and the Commander Islands. In the Okhotsk Sea, the surveys included all Steller sea lion sites in the northern part of the Okhotsk Sea, including Yamsky Islands, Ioni Island, the Lisynskogo Peninsula, and Zavyalov Island. Counts included the total number of live and dead pups, territorial males, juveniles, and other nonpups.

Observational studies were completed at Medney Island, Tuleny Island, Brat Chirpoev Island, Antsiferov Island, Lovushki Island, and Raikoke Island. These observation studies lasted from 4 to 6 weeks during the end of May to early July at all sites except the Medney Island and Tuleny Island sites where the observations lasted for 2 months, approximately from the end of May to early August. The project also provided travel to at least 10 qualified scientists to attend the Russian Marine Mammal Council meeting at Lake Baikal in September 2001.

Results From FY02 Work

All collected data are presently being analyzed. A report of activities and results is expected in early FY03.

Efficacy of Russian Conservation and Fisheries Management Practices (02SSL-16)

Principal Investigators: Thomas Loughlin and Vladimir Burkanov
Division: NMML
SSL Projects Database #: 2001-115

Project Description
One of the recommendations of the Steller Sea Lion Recovery Team was for NMFS to monitor rookery and haul-out sites in Russia to assess population dynamics, movement patterns, and compare these parameters to management measures invoked by the former Soviet and current Russian governments. This study provides for a contract with Natural Resource Consultants to review and evaluate Russian data on fishery management practices in the Russian Far East and their possible impact on Steller sea lion population dynamics. It may be that a data set exists with Russian scientists related to fishery exclusion zones in the Russian Far East that may be used to measure possible impact of these Russian measures on Steller sea lion population dynamics and distribution. The contract examines the available Russian database. Steller sea lion counts by age and sex group at each of the Russian rookeries in the Kuril Islands and Kamchatka Peninsula will be analyzed for trends by area. These will then be compared to Russian protective zones around different sites and comparisons made. The sites will be sorted by size of protective area and appropriate statistical comparisons made between sites. Natural Resources Consultants was chosen based on their extensive experience in fisheries and Steller sea lion studies over the past 30 years in Alaska and extensive knowledge of working with Russian scientists. The firm currently has a working relationship with Russian scientists, Russian Steller sea lion biologists on staff, and has the needed logistical support to conduct this work.

Activities in FY02
The contractor obtained fisheries assessment and catch data from Russian government agencies in Moscow and the Russian Far East in Petropavlovsk, Sakhalin, and Chukotka for the Bering Sea, Kuril Islands region, and Sea of Okhotsk. These reports are being analyzed in relation to existing data held by the contractor on Russian pinniped abundance and distribution in the Far East. A synthesis of these fishery data is under way and will ultimately be compared to marine mammal abundance. Lastly, these data sets will then be overlaid with the Russian conservation zones and correlations determined.

Results From FY02 Work
A report summarizing FY02 activities is expected in the second quarter of FY03.

Milestones in FY03
The contractor obtained fisheries assessment and catch data from Russian government agencies in Moscow and the Russian Far East in Petropavlovsk, Sakhalin, and Chukotka for the Bering Sea, Kuril Islands region, and Sea of Okhotsk. These reports are being analyzed in relation to existing data held by the contractor on Russian pinniped abundance and distribution in the Far East. A synthesis of these fishery data is under way and will ultimately be compared to marine

mammal abundance. Lastly, these data sets will then be overlaid with the Russian conservation zones and correlations determined.

Socioecological Effects of Fisheries Management (02SSL-17)

Principal Investigators: Thomas Loughlin and Marie Lowe
Division: NMML
SSL Projects Database #: 2001-116

Project Description
This study is conducted by The Museum of The Aleutians under the guidance of Dr. Richard Knect. The purpose is to examine socioecological change between 1960 and 2001 for the community of Unalaska, the most populated area of the Aleutian Islands. The researchers hope to evaluate the results of this study alongside biological and economic statistical data on fisheries fluctuations since 1960 to provide insights into the development of the relationship between social and ecological processes. Specific questions asked will include: How have Unalaskan's fishery and use patterns changed since 1960? What important socioecological events define this time period for this group? How have they responded to these events? Socioecological change will be defined as the changing relationship between fishery resource fluctuations and wider social, economic and political forces. The study will address how the lives of a local population are a nexus of experience and knowledge in this relationship between changes in the biophysical environment on which they depend for their livelihood and wider socioeconomic and political forces constraining and influencing the decision-making in their lives. Local knowledge has the potential to diversify perspectives on scientific inquiry into the human impact on the natural environment, on the management of natural resources and in a local course of action for sustainable development. Specifically, the study will focus on the changes in long-term local fishery extraction and use patterns over time. Project activities will be pursued in a collaborative manner between representatives from the anthropological and biological sciences and community consultants. These activities will be conducted with the understanding that the local socioeconomic practices and attendant values and beliefs concerning those practices constitute the local knowledge under investigation.

Activities in FY02
The contractor interviewed local residents, analyzed existing data, and prepared a draft report (see below).

Results From FY02 Work
A draft report of work in progress was provided to the NMML in FY02; the final is expected in the second quarter of FY03. The report explained that the social center of the Aleutians, the community of Unalaska and Port of Dutch Harbor, has undergone profound change in the years 1960 to 2002 because of the development of industrial fishing in that area. Three distinct historical periods have been identified as defining this time period for local residents:

1) The development of the king crab fishery.
2) The king crab boom and subsequent bust.
3) The Americanization of groundfish fisheries and development of the pollock industry.

Developments in industrial fishing in Unalaska have changed it from a rural, mostly Alaska Native village in which subsistence was the primary mode of production, to a gold rush frontier town in which a quick dollar could be made in seasonal work to a corporate/suburban community supported by year-round processing. Attendant social changes to the local population during this time period included:

- Local residents were gradually displaced from political life in Unalaska and replaced with seafood processor representatives who work for the benefit of their companies and not necessarily for the town or its resources.
- There was a lack of development of a substantial and political small boat fleet to defend local employment that was not dependent upon the interests of multi-national corporations.
- The king crab boom attracted the "frontiersmen" type, some of whom were a chaotic influence on small town life and its natural resources and some of whom settled in the area and are now staking a claim in both local politics and small boat fishery issues.
- There was an influx of migrant labor with the great increase in shore-side processing, some of whom also have decided to settle and raise their families in Unalaska.
- An increase in affluence of the local community which provided for more facilities and services, but also for more laws and regulations.
- A move away from the social dynamic of the single, male laborer dominating the character of the community to more families.

Ecological changes during this time period included:
1) A very sharp division between the dominance of crab stocks and groundfish stocks.
2) Local ecological change in Unalaska Bay, affecting some populations such as shrimp and creating unhealthy conditions for clam and mussel beds.
3) Fluctuations in salmon, halibut and herring stocks.
4) Noticeable increase in whale activity.

Correlations between social change and ecological change cannot be drawn at this time. Integration of biological statistics for the years in question should be pursued and more attention should be given to the evidence for either human or environmental impacts on fisheries fluctuations. Local knowledge of sea lion behavior and populations is scant, but higher in terms of life and historical cycling of sea lion prey.

Plans for FY03
This study concluded in FY02. A final report will be provided early in FY03.

Medium Format Aerial Photogrammetry of Steller Sea Lion Rookeries to Enumerate Non-Pups and Pups (02SSL-18)

Principal Investigators Wayne Perryman and John Sease
Division: SWFSC, NMML
SSL Projects Database #: 2001-117

Project Description
Funds were transferred to the Marine Mammal Division of the SWFSC for the purpose of conducting an aerial photographic survey of non-pup and pup Steller sea lions in the western population in the summer of 2002. This was the fourth year of a continuing study. Surveys were conducted with an AeroCommander aircraft (i.e., high-wing, low speed, survey plane) and photographs of rookeries and haul-outs were taken using 5-inch format, military reconnaissance cameras (with image-motion compensation). These funds were used to cover the cost of temporary staff, travel, and aircraft charter. The work is being done cooperatively with the ADF&G.

Activities in FY02
SWFSC personnel conducted medium-format aerial surveys of approximately 200 sites Alaska-wide from 21 June to 6 July 2002. The survey began in Anchorage, worked westward to Attu, and finished in Southeast Alaska. The survey plan and replicate visits to selected sites were scheduled to supplement the NMML aerial survey. The counting of pups and non-pups from the same photographs is in progress.

Results From FY02 Work
Preliminary results are available only for Southeast Alaska. These results suggest that non-pups continue to increase by approximately 1-2% per year, as they have for more than a decade. Numbers of pups in Southeast Alaska increased by about 11% from 1998 to 2002. This is consistent with an average rate of about 3% per year observed over the last decade.

Milestones and Products in FY03
No aerial survey will be conducted in FY03. Funds in FY03 will be used to maintain equipment, purchase supplies, and obtain training.

Steller Sea Lion Bibliography (02SSL-19)

Principal Investigator: Thomas Loughlin
Division: NMML
SSL Projects Database #: 2002-02

Project Description
NMML prepared a comprehensive bibliography of Steller sea lion publications in 1993. The bibliography is continually being updated and will be completed in early 2002 when it will be available on the NMML web site and in published form.

Activities in FY02
One contract individual was acquired who updated the database and had it placed on the NMML web site.

Results From FY02 Work
The bibliography was updated and placed on the NMML web site at :
http://nmml.afsc.noaa.gov/AlaskaEcosystems/sslhome/Biblio1.htm

Plans for FY03
This is an ongoing project and will continue at about the same level in FY03.

Definition of Rookeries (02SSL-20)

Principal Investigator: Thomas Loughlin
Division: NMML
SSL Projects Database #: 2002-03

Project Description
The status and trend of Steller sea lions in Alaska has typically been reported based on geographical units that were defined using natural geographic breaks, such as major oceanographic passes between islands, and clumping of island groups: 1) central Gulf of Alaska, 2) western Gulf of Alaska, 3) eastern Aleutian Islands, and 4) central Aleutian Islands. This later grouping scheme was expanded into eight subareas for the entire state. This study analyzes Steller sea lion rookeries by groupings which have ecological similarities for the purpose of establishing management areas containing one or more rookeries. For the broad areas of consideration habitat, diet, and population dynamics were chosen and then subdivided into more meaningful units. Available literature and NMFS databases are being used to group information into regions. Habitat includes the distance to the continental shelf, substrate type, compass orientation, and direction of major oceanic currents nearby. Diet includes different characterization of diet based frequency of occurrence of prey found in sea lion scat during the 1990s and geographic location, and diet diversity. These subareas will be analyzed using cluster analysis and appropriate statistical analysis then plotted using geographic information systems (GIS) to form meaningful groupings.

Activities in FY02
ArcView and ArcMap software were purchased for use in the completion of project goals.

Results From FY02 Work
The project was nearly finalized during the fiscal year. A Microsoft PowerPoint presentation of the preliminary results was presented at various meetings and feedback from participants provided useful suggestions for further evaluation. The final version of the product is expected in early FY03.

Plans for FY03
The project is expected to be completed in early FY03 with no additional funds required.

Steller Sea Lion Alaska Ecosystem Program (02SSL-21)

Principal Investigator: Thomas Loughlin
Division: NMML

Project Description
Aggregate labor costs for existing staff (as of 2/15/02) supporting Steller sea lion core studies within NMML. Staff are shared across various projects in differing proportions, depending on project timing, logistics and priorities,

Activities and Results in FY02
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Sinclair, **E. H.** and **T. Zeppelin**. 2002. Seasonal and spatial differences in the diet of western stock Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83: 973-990.

Sinclair, **E. H.** and P.J. Stabeno. In press. Mesopelagic nekton of the southeastern Bering Sea and physical mechanisms associated with their distribution. Deep Sea Research.

Production of a 15 minute DVD/VHS movie titled "Steller sea lions: Employing technology for conservation" October 2002. Available from the NMML or viewed as streaming video from the NMML web site (http://nmml.afsc.noaa.gov/AlaskaEcosystems/sslhome/satellite/stellermovie.htm).

New Staff for Alaska Ecosystem Program Steller Sea Lion Studies (02SSL-22)

Principal Investigator: Thomas Loughlin
Division: NMML

Project Description
Expansion of staff in Kodiak, Anchorage and Seattle for additional work on scat and food habits information and analysis of data relevant to marine habitat use (telemetry information). Due to budget constraints in late FY02, no action was taken on 4 of the 6 proposed new positions.

Activities in FY02:

Food habits: GS-9 term in Kodiak: hired
GS-9 term in Seattle – no action taken

GIS: GS-9 term in Kodiak - no action taken
GS-11 permanent in Seattle – no action taken

Statistical: GS-13 permanent in Anchorage: hired
GS-12 permanent in Seattle - changed to GS-7 - no action taken

Telemetry Research and Development (02SSL-23)

Principal Investigator: Thomas Loughlin
Division: NMML
SSL Projects Database #: 2002-04

Project Description
Advancements in microchip technology have enabled the use of novel instruments on sea lions. There is presently a need for small video cameras for attachment to sea lions to monitor foraging bouts. Additionally, these cameras, and other instruments (e.g., TDRs) must be retrieved once the animal returns to land. Since recapture is rarely an option, a remotely releasable device must be developed. Some work has occurred in this area over the past few years, but much needs to be done. NMML will solicit manufacturers to participate in this work and that of the video cameras for attachment to sea lions (contract approximately $150K).

NMML intends to pursue the use of alternative transmitters to determine foraging ecology. Presently NMML uses transmitters developed by Wildlife Computers which summarize and bin data. They do not provide dive profiles, such as in a TDR. The Sea Mammal Research Unit of Great Britain has developed satellite transmitters that provide more in-depth dive information. NMML intends to test the utility of these new satellite transmitters on Steller sea lions.

Inclusion of new techniques to analyze satellite transmitter data obtained from marine mammals will be explored. These techniques include use of satellite-transmitted data on environmental parameters, computer software for analysis, and still/video imaging for project presentations. Various government and university researchers will be contracted with the intention of incorporating their expertise in the analysis and interpretation of sea lion foraging and movement behavior.

Activities in FY02
NMML purchased innovative satellite telemetry devices for deployment on Steller sea lions and for testing on northern fur seals. Included were 4 digital video cameras for underwater viewing of sea lion foraging, 20 Sea Mammal Research Unit (SMRU) satellite remote dive loggers at $4.5K each, and five dive-dependent acoustic transmitters at $6.9K each.

A Request for Proposals was advertised in the middle of the fiscal year for development of a remote release device that can be used to collect instruments on land that are attached to Steller sea lions. Advanced Telemetry Systems, Inc., of Isanti, MN, won the contract late in the fiscal year and will begin their development project during FY03. The contract was for $211K.

NMML is also developing innovative capture techniques to work on older, larger animals during the non-breeding season by modifying existing capture techniques used by NMML in Seattle to capture adult male California sea lions. When completed these modified traps will be in place in Kodiak and Seward, Alaska, with the intent of safely capturing adult female and older juvenile sea lions for various studies.

Results From FY02 Work

One of the cameras was tested on a northern fur seal and three of the SMRU tags were placed on young sea lions during July in the western Aleutian Islands. Ten more are planned to be deployed during early and mid-FY03. The acoustic tags were tested during July on northern fur seals on the Pribilof Islands and results are being analyzed. The contractor for the remotely releasable device will be contacted early in FY03 and progress monitored. A contractor was selected from several potential bidders to modify extant pieces of the Kodiak breakwater for trap development. The modified trap should be operational by the end of FY03.

Plans for FY03

Equipment developed in FY02 will be tested and deployed in FY03.

Harbor Seals as a Surrogate Species for Steller Sea Lion Research (02SSL-24)

Principal Investigator: John Bengtson
Division: NMML
SSL Projects Database #: 2002-05

Project Description
This project is a collaborative study of harbor seal population dynamics and foraging ecology. Harbor seals overlap with Steller sea lions in Alaska and feed on many of the same prey. This study on harbor seals will provide important insights into and background for interpreting Steller sea lion population trends.

The study areas with declining sea lion populations are 1) Prince William Sound, 2) the Kodiak archipelago, 3) the eastern Aleutian Islands, and 4) Seguam and neighboring islands. The contrasting area, where Steller sea lions are increasing, is Southeast Alaska. Harbor seal populations have declined in at least two of the same areas as Steller sea lions (Prince William Sound and part of Kodiak archipelago). Like Steller sea lions, harbor seals form an important component of the upper trophic communities in all of these areas. Because of the potential ecosystem links between the declines in these two predator species, it is especially important to monitor accurately their population abundance and trends.

The NMML Polar Ecosystem Program monitors the abundance and long-term trends of harbor seals throughout their range in Alaska. This work requires extensive aerial surveys of five regions, one in each year of a five-year rotation. Funds for the present project enabled NMML to eliminate a shortfall in FY02 for harbor seal aerial surveys and to resume critical telemetry studies for which funding had been unavailable in the previous year.

Activities in FY02
In August of 2002, harbor seal haul-out sites in the northern half of Southeast Alaska were surveyed. The survey region extended from Kayak Island (Cape Suckling) to Frederick Sound. This region was divided into eight zones, each surveyed by an observer in a separate aircraft from 5-15 August. As of October 2002, the survey data were being completed (counting seals from photographs) and entered into databases. A telemetry study was also conducted at two sites (Gambier Bay and Seymour Canal) in the survey area. Sixteen harbor seals were tagged with radio transmitters and monitored by automated receiving stations placed at five haul-out sites near the capture locations. Data from the receivers will be retrieved in mid-October 2002. The radio-tagged seals were also monitored for presence at the haul-out sites by observers during the aerial surveys.

A major portion of the project funds ($400K) was awarded to the ADF&G to support collaborative studies.

Results From FY02 Work
The survey of northern Southeast Alaska produced a set of harbor seal counts and related covariate measurements that, when combined with a correction factor derived from the

concurrent telemetry study, will enable estimation of the total population of harbor seals in this region. This surveys and telemetry study will provide crucial additions to a long-term time series from consistent and thorough surveys of harbor seals in the two regions of contrasting sea lion population trends (where the overall long-term trends in harbor seal abundance are not presently known). When combined with results from NMML surveys in the remainder of the range of harbor seals in Alaska (Gulf of Alaska, Aleutian Islands, and Bristol Bay), results from the present study will support critical comparisons of the status of these two top predators.

Plans for FY03

Because of the large area occupied by harbor seals in Alaska, five annual surveys are required to complete one state-wide census. To maintain the continuity of this important piece of information about top predators in the Alaska marine ecosystem, it is essential to complete the next survey in the sequence (southern half of Southeast Alaska) during FY03. This study will continue in FY03, though without Steller sea lion research funds.

Pup Counts and Branding (02SSL-25)

Principal Investigator: Thomas Loughlin
Division: NMML
SSL Projects Database #: 2001-112

Project Description

Population status and trends are obtained during breeding season surveys (June/July) throughout Alaska biennially (2002; planned for 2004 and 2006) and range-wide every 5 years. This is done to monitor status and trends of both eastern and western populations of Steller sea lions range-wide, with a focus on Alaska. Non-pups on land at all rookeries and haul-out sites are counted from photographs obtained during aerial surveys. Pups are counted from land and from photographs, depending on location. Photographs are obtained by both 35 mm and medium-format photography and then animals are counted from the projected image in the laboratory. Results are typically available within 3 months of the surveys and are available on the AFSC web site. Results of breeding-season surveys are first provided during the annual meeting in September of the North Pacific Fishery Management Council. Relative abundance and distribution are also obtained during other times of the year when appropriate. NMFS also supports quarterly abundance and distribution studies in specific, smaller areas, such as Kodiak Island waters and the Juneau area.

This project collects health and condition data from sea lions sampled throughout the western range for interpretation with respect to age, sex, and location, season and year of capture. This information complements data collected in other studies. Captured animals have a combination of blood and other tissue samples taken, and morphometric and other condition measures made in order to obtain a health and condition profile. A subset of pups captured for branding or tagging are sampled, as are most pups, juveniles and adults captured with hoop nets or immobilizing agents on land, or by SCUBA captures underwater. Blood samples are taken for clinical blood chemistry and hematology analysis, and for other analyses by collaborating researchers. Body size measures are taken (e.g., mass, length, girth) and body composition will be estimated through deuterated water injection or bioimpedance analysis. This will facilitate interpretations of weaning status and diving behavior obtained from parallel studies, and ultimately responses to environmental factors or fishery management manipulations. As more sea lions get branded as pups and are resighted or recaptured at older ages, health and condition profiles will provide an invaluable baseline upon which to interpret population status. Additional work will involve modeling individual and population level condition responses with respect to foraging behavior, population trends and environmental conditions.

In 1987-88, NMML branded 800 pups at Marmot Island, then reinitiated branding studies in 2000 at Marmot and Sugarloaf Islands, and in 2001 at Ugamak and Fish Islands, and Seal Rocks in Alaska. ADF&G has also initiated branding studies. Both groups use the same techniques and marking. Pups are branded with individually identifiable numbers and letters on their left shoulder as pups and then observed in subsequent years to determine vital rates. Observers are stationed at the branding sites in subsequent years to monitor sea lion survival. Nearby rookeries and haul-out sites are also monitored for their occurrence. Survival, mortality, and other vital

rates will be calculated on the data gathered on sea lions branded as pups. This study is expected to last at least 10 years. A considerable commitment of time and energy over many years from both NMML and ADF&G are required. These studies are a continuation of 1970s studies by ADF&G and those by NMML, and were recommended by the Steller Sea Lion Recovery Team peer review panels. They will provide needed information on age-specific mortality and survival rates, movement patterns, reproductive parameters, age and growth, and other data.

Activities in FY02

NMML counted pups at 21 western stock rookeries during two simultaneous ship-based expeditions from 24 June to 10 July. One vessel surveyed the Aleutian Islands (Attu to Dutch Harbor), the second vessel surveyed the Gulf of Alaska (Dutch Harbor to Prince William Sound). Land-based field parties counted pups at three other rookeries (Fish Island, Marmot Island, and Ugamak Island). To avoid additional disturbance, the NMML did not count pups at seven rookeries in 2002, and instead used counts from June and July 2001 to create a composite 2001-02 pup count. SWFSC surveyed Steller sea lions from the eastern stock in Southeast Alaska, counting both pups and non-pups from medium-format vertical photographs. After land-based counts were completed, pup measurements and tissue samples were obtained at selected sites, and pups were marked by brands or tags. Additional activities such as collection of relatively fresh placentas, necropsies on freshly dead pups, and collection of scats were performed as appropriate. Dedicated observation efforts for previously branded or tagged sea lions were made during three cruises based out of Dutch Harbor, Kodiak, and Prince William Sound during May, and during all other Steller sea lion research cruises.

Results From FY02 Work

The composite 2001-02 pup count for the western stock, which included counts from 24 rookeries in 2002 and 7 in 2001, showed continuing decline in pup production. For the Kenai-to-Kiska Index Area, the area with longest series of region-wide counts, pup numbers were down 7.8% from 1998, 24.5% from 1994, and 42.4% from 1990-91. Pup counts increased in one region (western Gulf of Alaska: +5.5%) from 1998 to 2002, but declined in the five other regions. The western Aleutian Islands experienced the worst decline (39%) from 1998 to 2002. Preliminary results suggest that numbers of pups in Southeast Alaska increased by about 11% from 1998 to 2002, consistent with an average rate of about 3% per year observed over the last decade. From the 39 rookeries visited in the western stock, 787 pups were handled to obtain 591 measurements, 150 blood samples, and 560 tissue samples for genetics analysis by SWFSC and Texas A&M. Four placentas were retrieved from among two sites, and three pup necropsies were performed. A total of 194 pups were branded at Marmot and Sugarloaf Island rookeries, and 200 pups were flipper-tagged. From the 509 scats collected for diet analyses, 48 were subsampled for hormonal (Patience Browne, UCD), 50 for corticosteroid (Shannon Atkinson, ASLC), and 90 for parasite (Frank Morado, AFSC) analyses. From the six cruises in the northern Gulf of Alaska and eastern Aleutian Islands during FY02, 277 branded and 26 flipper-tagged sea lion observations were made. Of the brand resights, 19 were of sea lions captured and marked during dive captures, 3 were from the Marmot Island 1987-88 cohorts, 36 from the Marmot Island 2000 cohort, 8 from the Marmot Island 2002 cohort, 1 from the Forrester Island 1995 cohort, 11 from the Sugarloaf Island 2000 cohort, 56 from the Ugamak Island 2001 cohort, and 4 from the Seal Rocks (Hinchinbrook Entrance) 2001 cohort.

Plans for FY03

Cruises dedicated to observation of branded and tagged sea lions will again cover the northern Gulf of Alaska and eastern Aleutian Islands during May, and observation efforts will continue from field camps and other research cruises during the year. Two pup counting and sampling cruises will visit rookeries on the odd-year sampling rotation in the Aleutian Islands and Gulf of Alaska. Analyses of pup survival, health and condition, and count trends will continue.

Product Descriptions

Pup and non pup counts are available to the public usually in September following the count and appear on the NMML web page for public use. NMML staff publish frequently in *NOAA Technical Memorandums* to disseminate information quickly and then at about 5 year intervals in the peer literature. These publications and dissemination through the web are timely to facilitate sea lion and fishery management in Alaska.

Effects of Fishing Using Covariate Analysis (02SSL-26)

Principal Investigator: Daniel Goodman, Montana State University
Division: NMML
AFSC Contact: Thomas Loughlin
SSL Projects Database #: 2001-111

Project Description

The North Pacific Fishery Management Council has recently recommended the implementation of a number of conservation measures directed at mitigating potential adverse impacts of the groundfish fishery in Alaska on the western stock of Steller sea lion. However, they have strongly recommended to NMFS that subsequent to the implementation of these measures, NMFS attempt to evaluate the extent to which these measures, and measures previously adopted by NMFS, have been effective. One such approach, which is the focus of this contract (with Dr. D. Goodman, Montana State University), is to carry out a time-series analysis of existing count data from rookeries and haul-outs. The goal of this study is to test whether existing or future conservation measures have proven effective in promoting the recovery of the western stock of Steller sea lion. Previous attempts to evaluate the efficacy of buffer zones using the count data have focused on using data from a single rookery or haul-out. This approach is confounded by the extreme inter-annual variability in the count data and the lack of replicate count data from most sites. Therefore, the proposed approach is intended to use all of the count data to minimize the degree to which site-specific variability is a problem and use specific covariates related to time of year, location, and fishing practices and regulations to test whether existing or future conservation measures have proven effective in promoting the recovery of the western stock of Steller sea lion. In this analysis, the contractor will test whether certain covariates were significant in explaining the inter annual pattern in sea lion counts. Covariates are to include: 1) time of year, 2) subarea, 3) year, 4) site type (rookery or haul-out), 5) site within no-trawl zone (yes, no), 6) number of years no-trawl zone has existed, and 7) tonnage of groundfish caught in subarea. Additional covariates may be identified by NMFS or the contractor.

Activities in FY02

This is a multi-year project which will form the basis of a Ph.D. dissertation under the guidance of Dr. Goodman. Dr. Goodman and his student met with NMML and AFSC staff on several occasions during the fiscal year to provide summaries of the analysis, request additional data (which was provided), and to provide a draft status report of the project.

Results From FY02 Work

As above, the contractor provided NMML with a draft report and met to discuss the report with NMML staff. Additional analyses were proposed based on data obtained since inception of the project; contractor and student agreed to these suggestions. The project is expected to be completed by the end of the fiscal year with a presentation of status and results at the symposium, *Marine Science in the Northeast Pacific*, held in January 2003 in Anchorage.

Plans for FY03

Work continues on this project in FY03, though under funding provided to Montana State University through funds transferred in FY02 under a cooperative agreement with the United States Geological Survey Cooperative Fisheries Research Unit at MSU.

Estimate Cost of Swimming (02SSL-27)

Principal Investigators: Thomas Loughlin and Michael Castellini (UAF)
Division: NMML
SSL Projects Database #: 2002-06

Project Description
This study will analyze Steller sea lion metabolic balance equations in an attempt to assess the costs of living in the sea with the energy gain obtained through foraging against the costs associated with that foraging. If that balance is seriously impaired such that it costs more to forage than the energy gain, then survival for individuals or for populations is compromised. In essence, this is the most basic element of the Steller sea lion controversy on the "Food and Fisheries" side of the equation: Are the sea lions getting enough food to support their population? There are combined pressures on the animal to balance blubber and lean tissue for fuel utilization, thermoregulation, water balance and hydrodynamics. These forces are not independent of each other and change during development with the animals shape and body condition. The current extensive work on juvenile Steller sea lions by the NMFS and other groups has major components defining condition and health indices. Dr. Castellini will provide the analytical and measurement tools to include the balance of hydrodynamic and condition co-variance.

This work occurred during FY02 and was accomplished through field efforts coordinated by the NMML and the ADF&G. Specifically, the study will provide:

A. Detailed morphometric analyses of juvenile sea lions for measurements of hydrodynamic factors and interactions with condition indices. Calculations of body shape, volume, surface area, and foreflipper area.

B. Analysis of sea lion fur for total density, water flow characteristics, oil levels and developmental changes.

C. Measurement of underwater video of juvenile sea lions for stroke patterns, body shape changes and glide patterns.

D. Calculations of drag and thrust.

E. Correlation of hydrodynamic and condition indices.

Activities in FY02
Analysis of underwater video footage of Steller sea lions was initiated. In late September, Susan Inglis traveled to Vancouver, B.C., to meet with Dr. Blake, Department of Zoology, Biomechanics Laboratory, University of British Columbia, to view and discuss techniques for analyzing underwater video footage of Steller sea lions. Footage currently being analyzed is from underwater captures taken by ADF&G. The University of Alaska also received permission from Shane Moore Films to analyze data from his underwater filming of sea lions. Overhead

and underwater video cameras have been purchased to conduct hydrodynamic drag studies on Steller sea lions at the ASLC. Investigators will also collaborate with Dr. Russ Andrews at the ASLC, who is using accelerometers and other telemetry equipment. A study comparing traditional methods of collecting morphometric measurements for hydrodynamic analysis with photogrammetry technology has been initiated. The NMML collected detailed morphometric measurements from 16 juveniles captured at Kodiak Island during July-August to be incorporated into models of hydrodynamics and body condition.

Non-Consumptive Value of Steller Sea Lion Protective Measures (02SSL-28)

Principal Investigator: Todd Lee
Division: REFM
SSL Projects Database #: 2002-07

Project Description
The economic benefits of providing protection to the endangered Western population of Steller sea lions are primarily the result of the non-consumptive value individuals attribute to such protection. Non-consumptive value is also referred to as non-use, passive use, or existence value. Since these values are not observed in the market, economists have developed specialized techniques to estimate them. The objective of this project is to use survey, sampling, and statistical techniques to estimate the value that people place on providing protection to Steller sea lions. This information is important for the management and monitoring of marine resources but is currently unavailable.

The project is designed to estimate a valuation function that depends on four factors. The first factor is the expected aggregate size of the population. The second is a measure of the expected change in the probability of survival of the western stock of Steller sea lions. These two factors will allow fishery managers or analysts to determine the change in non-consumptive value associated with management measures that vary in the degree of protection. The third factor is a measure of the geographical range of the Steller sea lion population. The study will determine whether and to what extent non-consumptive values depend on the geographical range of the population as opposed to aggregate population numbers and the probability of survival. The fourth factor is the effect of Steller sea lion protection measures on fishery participants and communities. It is likely that stronger protection measures will result in more significant impacts on fishery participants and communities. The project will determine whether and to what extent such impacts affect non-consumptive values.

Activities in FY02
During FY02 three tasks were accomplished.

1) A contract was awarded to the Pacific States Marine Fisheries Commission (PSMFC) to assist the principal investigator in administering, coordinating and contracting the survey research activities. The contract with PSMFC began on 1 October 2002 and will expire 30 September 2005. The contract specifies that PSMFC will coordinate with the principal investigator to complete three tasks: 1) survey design; 2) survey implementation; and, 3) analysis of data and completion of a final report.

2) Development of the survey instrument and protocols began in July 2002. During August and September 2002 the core research team evaluated several different survey design and administration alternatives. Key or important features were highlighted for further research or testing. A survey development plan was developed. The core team is composed of Todd Lee (NMFS), David Layton (UW) and Bob Hicks (College of William and Mary).

3) The principal investigator met with researchers from three different survey and economic research firms to discuss the project. These meetings contributed to the work activity discussed in Task 1 above.

Results From FY02 Work
No data were collected in FY02.

Plans for FY03
Please see attached project timeline for a summary of the milestones through completion of the project. The timeline and milestones may be contingent on the hiring of a non-market valuation economist at AFSC (the current principal investigator left his position at AFSC). The current schedule has not been altered to reflect a transition period between the current and a new principal investigator. It should also be noted that receiving approval from the Office of Management and Budget on the survey may be more lengthy than expected.

Completed in FY03 through 2/15

1) A contract has been signed with Stratus Consulting for Task 1 of the project. The purpose of Task 1 is to develop a detailed work plan for the contractor based on the work completed in FY02.

2) A meeting between the principal investigator, the contractor and two expert consultants was held in January 2003. A work plan for the contractor was outlined. The final work plan for the contractor will be completed by 28 February 2003.

To Be Completed in FY03

1) The primary task for FY03 is to develop and pretest the survey versions. This will require contracting with sub-contractors through PSMFC to administer the pretests and to supply specialized consulting services. To be completed by 30 September 2003.

2) Finalize survey administration protocols and determine the sample frame. To be completed by 30 September 2003.

3) Contract with outside reviewers through PSMFC or the contractor. To be completed by 31 March 2003.

4) Initiate OMB clearance procedures. To take place throughout FY03. Formal clearance cannot be applied for until the final draft of the survey is completed.

5) After the final survey instrument and procedures are developed, it will be necessary to contract through PSMFC to administer the survey. This task will likely begin during FY03, and extend into FY04. The final survey will be administered during FY04.

AFSC Steller Sea Lion

The Non-Consumptive Value of Steller Sea Lion Protection Measures

Project Timeline

Activity	FY02				FY03				FY04				FY05			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Predesign																
Develop study plan			X	X												
Design Contracting																
Write Statements of Work- Expert consulting and review contracts				X	X	X										
Write Statement of Work - Survey design and pretesting				X	X	X										
Award Contracts				X	X	X										
Design																
Final work plan						X										
Develop draft survey and methods					X	X	X									
Pretest survey, and revise survey and methods						X	X	X								
Finalize survey instrument and methods								X								
Survey Contracting																
Write Statements of Work- Expert consulting, review and analysis contracts							X	X								
Write Statement of Work - Survey administration							X	X								
Award Contracts								X	X							
Survey Implementation																
OMB/PRA approval							X	X	X	X						
Administer survey										X	X					
Data entry and formatting											X					
Analysis and Report																
Preliminary statistical Analysis												X				
Finalize statistical analysis													X	X		
Final report & papers														X	X	X

Predation on Steller Sea Lions

In its 2001 appropriation of Steller sea lion research funds, Congress directed the NMFS to investigate the extent to which predation could be contributing to the decline of Steller sea lions. The AFSC responded by funding a series of studies of sleeper shark population abundance, movement and distribution, and diet in the Gulf of Alaska (02PP-02: 2001-127, 2001-128, and 2001-129); and killer whale diets, abundance and distribution in western Alaska (02PP-01; 2001-108). The latter killer whale study was conducted in conjunction with three other studies of killer whales in the North Pacific Ocean, whose principal investigators were Jan Straley of University of Alaska Southeast (2001-04), Lance Barrett-Lennard of the University of British Columbia and the Vancouver Aquarium (2001-07), and Craig Matkin of the North Gulf Oceanic Society (2001-139).

Considerable progress has been made in evaluating the magnitude of predation by sharks and killer whales on the Steller sea lion population. To date, there is no evidence that sleeper sharks eat sea lions, and no evidence that they consume live marine mammals of any kind. Therefore, the magnitude of the threat to sea lions posed by sharks is extremely low. Other than completing reports, the sleeper shark predation project was concluded in FY02.

Killer whales exist as distinct "ecotypes": transients, residents, and offshores. Transients feed exclusively on marine mammals, residents on fish, and there is currently little information on the diets of offshore killer whales. Curiously, transient whales are more numerous within the range of the eastern stock of Steller sea lions, which is increasing slightly, than within the western stock which is decreasing at 4% per year. In addition, transient killer whales comprise a larger percentage of the total killer whale population in the east (possibly as high as 40%) than in the west (7%). While these findings do not support the hypothesis that killer whale predation is responsible for the decline of Steller sea lions in the western stock, it cannot yet be concluded that they are not preventing their recovery. Field work conducted in FY02 under 02PP-01 represented the second of a planned 3-year study of killer whales in western Alaska, which will be completed in FY03.

Pacific Sleeper Shark Predation of Steller Sea Lions (02PP-02)

Principal Investigator: Michael Sigler
Division: ABL, RACE
SSL Projects Database #: 2001-127, 2001-128, 2001-129

Project Description
The objective of this study is to determine whether sleeper sharks prey on Steller sea lions, and if so, estimate the predation rate. Evidence of shark predation on Steller sea lions would identify a source of Steller sea lion mortality.

Activities in FY02
The second and final cruise of the study was completed in May 2002 using the chartered vessel F/V *Norska*. May field operations were scheduled to occur when sea lion pups are weaned (April - May), when pups may be more vulnerable to shark predation. A combined total of 15 longline sets was completed in the central Gulf of Alaska near Steller sea lion rookeries at Marmot Island, Sugarloaf Island, Outer Pye Island, and Seal Rocks. In addition to the 99 sleeper sharks collected for stomach samples, 24 were released with archival satellite tags. Archival satellite tags are being used to collect data on the sharks' geographic and vertical movements, which will be compared to those of Steller sea lions to determine if sleeper shark and sea lion habitats overlap in time and space in the central Gulf of Alaska. Blood samples also were collected from the hepatic portal vein, which collects material absorbed through the gut wall, to determine if diet (fish vs. marine mammal) influences fatty acid composition of the blood. Questionable marine mammal prey are identified by microsatellite DNA methods (G. O'Corry-Crowe, SWFSC). Forensic pathology methods are applied to infer whether marine mammal prey were scavenged or caught live. In these methods, the tissue is examined for injuries and hemorrhage. Hemorrhage into the tissue is evidence that whatever caused the hemorrhage, occurred before death. Samples also are examined microscopically for hemorrhage (Dr. N. Thompson, MD and pathologist).

Lee Hulbert, Michael Sigler, and Chris Lunsford presented results of the August 2001 cruise at the Steller Sea Lion Principal Investigator's meeting in March 2002.

Results From FY02 Work
<u>Sleeper Shark Diet</u>
Analysis of 99 sleeper shark stomach contents collected during the initial cruise in August 2001 indicated no evidence that sleeper sharks actively prey on sea lions. For the May 2002 cruise, 6 contained cetacean tissue and 4 contained unidentified mammal tissue. (The equal sample size from the August and May cruises was coincidental). Species identification of unknown mammal tissue and cetacean tissue by micro- satellite DNA analysis is pending.

The 99 Pacific sleeper shark stomachs were analyzed from sharks sampled during the May 2002 cruise: 83 contained food items, and 16 were empty. Cephalopods (octopus and squid) were the dominant food category on a numerical basis (80.7%), while Osteichthyes (bony fishes) were the dominant food category by weight (41%), frequency of occurrence (76%). Mammal tissue was the second most important diet item by percent weight (34%). Giant Pacific octopus *(Octopus*

dofleini) was the most important identified prey species, representing 25% by weight and 36% by frequency of occurrence. Other non-teleost prey included squid (Teuthoidea), and crabs (Decapoda), while teleost prey included Pacific cod (*Gadus macrocephalus*), Pacific salmon (*Onchorhynchus* spp.), Pacific halibut (*Hippoglossus stenolepis*), arrowtooth flounder (*Atheresthes stomias*), rockfish (*Sebastes* spp.), and sablefish (*Anoplopoma fimbria*).

Sleeper Shark Depth Distribution

Data recovered from popup archival tags show that sleeper sharks sometimes make diel migrations to within 1 m of the surface at night. In May 2002, we released sleeper sharks with tags that also transmit location when the sharks are at the surface. Geographic movements data from the tags will potentially allow us to determine whether sleeper sharks near the surface are located near sea lion haul-outs and rookeries.

Sleeper Shark Stock Assessment

We are estimating sleeper shark population trends using quantitative stock assessment methods. A written report is scheduled to be presented at the November 2002 Gulf of Alaska Plan Team meeting.

Plans for FY03

The popup archival tags are scheduled to release and float to the surface in March 2003. The depth information from the tags will be analyzed and added to a draft manuscript. A final draft is scheduled for review in May 2003. Work will continue on this project in FY03, though without Steller sea lion research funds.

The quantitative analysis of the sleeper shark data will be updated with new data from the 2002 and 2003 halibut and sablefish longline surveys. The report also will be revised based on Plan Team comments. A manuscript for publication may be written depending on the quality of the data for tracking sleeper shark abundance.

Fisheries Interactions Research

Steller sea lion and fishery interaction research at the AFSC is organized primarily around process-oriented field studies that examine potential impacts of commercial groundfish fisheries on prey availability and Steller sea lion foraging success. In addition, models are being developed to predict ecosystem response to fishing and individual sea lion responses to changes in prey fields, and evaluate the effects of fisheries and fishery management on Steller sea lion recovery. Through this combination of field, laboratory, and modeling studies, the AFSC is addressing whether

- Removals of prey by fisheries on ecosystem or local scales have reduced Steller sea lion prey abundance or availability,
- Disturbances of prey by fisheries has changed the distribution, or reduced the density, size or number of prey patches for Steller sea lions, and
- Fishing has altered the composition of the fish community resulting in reduced quality of prey or significantly modified the Steller sea lion food web.

Process-oriented fishery interaction studies were conducted at three locations in the Gulf of Alaska, Eastern Bering Sea, and the Aleutian Islands, and investigated potential effects of the pollock (02FIT-07), Pacific cod (02FIT-06) , and Atka mackerel fisheries (02FIT-04 and 02FIT-05). These studies form one part of a series of integrated research studies at these locations that also includes oceanographic and prey assessment surveys, and investigations of Steller sea lion food habits, foraging behavior and physiology (see further discussion of these integrated studies under Biophysical and Climate Studies). In addition, a fourth study was conducted in the inside waters of Southeast Alaska (02FIT-02) during which prey populations near haul-outs were surveyed in conjunction with a variety of related sea lion tagging, foraging ecology, and fish distribution studies (ADF&G's tagging study 2001-91, UBC's Steller sea lion diet study 2002-40, UAF's Steller sea lion and fish distribution study 2001-28, and AFSC's eulachon project 02FF-10).

Each of these four projects was originally conceived as multi-year efforts to survey prey populations and determine the magnitude of any fishery effects. The pollock fishery experiment off Kodiak has been conducted in the summers of 2000-2002, but is unlikely to be continued in FY03 because of budget shortfalls involving the AFSC's use of the NOAA ship *Miller Freeman* in FY02 and because the pollock fishery quota in 2002 is small (as is the likelihood of detecting any fishery effect). The Atka mackerel tagging study in the Aleutian Islands began in 1999 at Seguam Pass, and was enlarged and improved upon in 2000-2002 at this location. In FY02, tagging also occurred at Tanaga Pass, which has a smaller resident Atka mackerel population as well as a smaller trawl exclusion zone than at Seguam Pass. Therefore, conclusions regarding zone efficacy at Seguam (with a 20 nmi zone, large mackerel populations both inside and outside of the zone, and a relatively small fishery) may not be applicable to other areas in the western and central Aleutians (with smaller buffer zones (10 nmi), smaller resident mackerel populations, and potentially larger fisheries). Work conducted in FY02 on the evaluation of changes in abundance and distribution of Pacific cod near Unimak Island solely involved feasibility and gear trials in anticipation of an early FY03 initial trial. While the Southeast Alaska prey study does not specifically examine a fishery effect, researchers have begun to link

sea lion foraging activities to prey distributions. This information will help us determine if sea lions have threshold prey densities, as well as increase our understanding of sea lion behavior within their marine habitats.

In addition to process-oriented field studies, the AFSC also undertook a series of modeling projects in FY02 to understand individual sea lion behaviors and decision-making in a simulated prey field (02FIT-01), determine how changes in the ecosystem and fisheries could affect sea lions and prey populations (02FIT-10), and evaluate how fisheries management decisions could affect the recovery of sea lions (02FIT-13). The projects to model individual sea lion behavior and fisheries management effects were initiated in FY02, and were projected to be completed in FY04. The Steller sea lion modeling projects undertaken by Drs. Kerim Aydin and Jesus Molina-Cruz in 02FIT-10 were begun several years ago and were supported directly by Steller sea lion funds in FY02.

The AFSC also worked directly with the commercial pollock fleet to install acoustic data loggers on their vessels which enabled the collection of information on changes in prey distribution while the fishery is occurring in the eastern Bering Sea (02FIT-08). A large amount of information was collected in FY02 and is currently under analysis.

Individual-based Modeling of Steller Sea Lion Foraging Behavior and Bioenergetics (02FIT-01)

Principal Investigators: Sarah Hinckley, Martin Dorn, John Horne, Bern Megrey, and Anne York
Division: RACE, REFM, NMML
SSL Projects Database #: 2001-133

Project Description

The objective of this study is to build a simulation modeling tool which will allow examination of the effect of varying prey abundance and distribution on Steller sea lion foraging behavior and bioenergetics. This tool would be useful in investigating hypotheses on how locally and regionally varying prey densities and prey distribution patterns, as affected by fishing activity (e.g., the theory of "localized depletion"), climate change (e.g., regime shifts) or other factors, may affect sea lion condition and growth. This tool may also be useful in determining optimal prey densities within no-trawl zones around rookeries and haul-outs in relation to sea lion condition and growth. Initially, pollock will be the main prey type used in the model, however this may be expanded to other species to allow examination of the effects of climate change.

We propose a multi-disciplinary modeling project. This will include 1) an individual-based model of sea lion foraging and bioenergetics, 2) a fish distribution and movement model, and 3) a model of the distribution and changes in fishing effort. The modeling tool should be general enough to allow us to model different regions, and different prey species, as needed. The model will bring together knowledge gained through process-oriented field and laboratory research, will be useful in integrating and synthesizing existing knowledge about sea lions, and in identifying important processes and parameters which would benefit from further research. It is also anticipated that this modeling work will give rise to new hypotheses, aid in giving direction to future field and laboratory work, and promote integrated ecosystem-oriented management policies.

Activities in FY02

In FY02, one post-doctoral fellow (Carlos Alvarez) was hired. He started on 9 September 2002. Dr. Alvarez will work on development of a new approach to modeling movement and foraging. Money in FY02 was spent on computers and software for several team members, a laser printer, and statistics and modeling reference books. Support for a graduate student (Julian Burgos) working with John Horne was obtained and applied. Burgos is working on fish distribution modeling.

A workshop on modeling sea lion foraging was held 24-25 September 2002 at Aljoya Conference Center in Seattle. Attending were members of the AFSC sea lion modeling team, others from UW and AFSC who are interested in this work, and several members of Ian Boyd's modeling group from St. Andrews, Scotland (SSLRI Project ID 2001-03) who are also working on a model of the effects of varying prey distributions on Steller sea lions. There was a total of ~20 people attending. Presentations were made at this workshop by members of the Steller sea lion Individual-based Modeling team, including Sarah Hinckley ("Steller sea lion individual-based modeling: bioenergetics, movement and diving", Julian Burgos ("Modeling the three-

dimensional distribution of walleye pollock", Martin Dorn ("Preliminary results from a field project to record acoustic backscatter and fine-scale fishing patterns" and "Modeling fishing impacts on pollock prey fields"), Bern Megrey ("Rule-based methods for modeling animal behavior"), and Anne York ("Stable isotopes in the teeth of Steller sea lions: Do they tell us the age at weaning?" and "Using age-structure to detect impacts on threatened populations: a case study using Steller sea lions").

Results From FY02 Work

Steller Sea Lion Individual-based Model (SSLIBM)

The basic framework of the SSLIBM was coded in C++, with a flexible design so that various subprograms (for example for different ways of modeling foraging movements) may be included. A preliminary movement sub-model, using a very simple algorithm (including a simple random walk) was developed and tested. This algorithm is designed to move the animals around through 2D or 3D space, where they encounter and consume prey. A sea lion diving sub-model was developed. Its purpose is to use the vertical fish distributions derived from the fish dynamics model to calculate the net energy return from each dive, the optimal dive depth, the optimal surface interval and the foraging duration. The consumption derived from this dive model is input to the bioenergetics sub-model (for life stages of sea lions which are actively foraging, pup consumption of milk is predicted by the prey consumption and bioenergetics of its mother). The bioenergetics sub-model, based on one developed at the University of British Columbia, was coded and tested against the few available data. This sub-model consists of an energy balance equation for each life stage of sea lion, and predicts growth and condition as a function of consumption.

Fish Modeling

A preliminary static 3D fish distribution model was developed and distributed to sea lion modelers in both this group and Ian Boyd's group. This model uses Gaussian techniques to generate random 2D fish distributions based on user defined input parameters controlling degree and type of patchiness, and then expands these into the vertical dimension using a beta distribution. Initial analyses of pollock acoustic data were used to develop this model. The main purpose of this initial model is to provide scenarios of fish distributions, with various user-specified characteristics of patchiness and density, with which to test the models of sea lion foraging.

Simple initial plotting routines for animal tracking and fish distributions were developed using the PMEL freeware tool, Ferret. A fully 3D tool for visualizing animal movement through the prey fields is under development as part of a NOAA HPCC (High Performance Computing and Communications) grant. This tool, NCBrowse, a Java-based tool which will be freely distributed to users and useful on any platform, will significantly enhance our ability to explore and communicate our results. Initial work on this project has started in the summer of 2002.

Plans for FY03

In FY03, we intend to further develop the submodels of the SSLIBM and to do sensitivity analyses on them. Further estimation of parameters for all parts of the SSLIBM will be done. By September 2003 we intend to have an preliminary working version of the SSLIBM. This initial version will be capable of utilizing prey distributions from the fish model, and will give

output on sea lion condition and growth. We then intend to do a sensitivity analysis of the full model and begin simulations with different types of prey distributions.

For the fish distribution part of this project, distribution patterns of walleye pollock biomass will be described. The description will include quantification of scale dependent variability, inference and modeling of spatial autocorrelation, and characterization of walleye pollock aggregations. Daily, seasonal and geographical differences in distribution patterns will be quantified. This description will be used to structure a three-dimensional dynamic simulation model of walleye pollock distribution (which will be used as input to the sea lion model).

Inter-project cooperation with Ian Boyd's modeling group will continue and expand through the Steller sea lion Foraging Modeling Working Group created at the September 2002 workshop. This working group (S. Hinckley, coordinator) will produce a report of the September meeting, circulate copies of descriptions of the various models under construction by both groups, will encourage one-on-one and larger discussions among group members (via videoconferencing), and will start and maintain a website for group members to facilitate communication and sharing of materials. A videoconference meeting will be held in ~ 6 months to review the model whitepapers. In ~18 months a comparison plan for model experiments (using the same prey fields from the fish model) will be developed. Before the project end, a results meeting will be held.

Milestones in FY03

Steller Sea Lion Foraging Modeling Working Group web site

At the September 2002 Steller sea lion foraging modeling workshop that was held in Seattle, it was decided that both the AFSC and the SMRU (Sea Mammal Research Unit) groups (and other assorted interested individuals) should form a Foraging Modeling Working Group. For the purposes of coordination, communications, document and model review, etc, we are developing a SharePoint website (which is restricted to group members), which will be fully functioning in the spring of 2003.

Bioenergetics Code

We will be providing this code for use in SMRU (Ian Boyd et al.) foraging modeling work, as well as our own. It was decided at the September 2002 modeling workshop that it would be useful for both groups to use a common bioenergetics model. Code will be posted on the Steller sea lion foraging modeling working group website.

Initial pseudocode or a working version of the integrated bioenergetic/foraging SSLIBM, which will use initial fish distributions produced by the fish distribution modeling subgroup (see below), will be completed by October, 2003.

Fish Distribution Patterns

For the fish distribution part of this project, distribution patterns of walleye pollock biomass will be described. The description will include quantification of scale-dependent variability, inference and modeling of spatial autocorrelation, and characterization of walleye pollock aggregations. Daily, seasonal and geographical differences in distribution patterns will be

quantified. This description will be used to structure a three-dimensional dynamic simulation model of walleye pollock distribution (which will be used as input to the sea lion model).

This project will conclude in September 2004. At that point, we will submit paper(s) to refereed journals on model description and results. This model will also generate scenarios of how changes in pollock prey fields affect Steller sea lion condition and growth, which could be useful to managers.

Southeast Alaska Steller Sea Lion Prey Study (02FIT-02)

Principal Investigator: Michael Sigler
Division: ABL, RACE
SSL Projects Database #: 2001-126

Project Description
The objective of this work is to test the hypothesis that sea lion prey diversity and seasonality are related to Steller sea lion population trends in Southeast Alaska.

Steller sea lion abundance is decreasing in central and western Alaska, but increasing in Southeast Alaska. Hypotheses for the decline include decreased prey availability and lower diet diversity. This study conducts seasonal measurements of prey abundance and nutritional quality in Southeast Alaska. This study is a comparison to similar studies around the Kodiak Archipelago and proposed for the Krenitzin Islands.

The following questions will be addressed:

- Define the characteristics of Steller sea lion foraging habitat (e.g., prey, bathymetry, oceanography) within the study area. This is the **available prey field.**
- Define the characteristics of Steller sea lion foraging habitat (e.g., prey, bathymetry, oceanography) within areas where tagged sea lions are diving. This is the **utilized prey field.** NMML tags animals to identify areas where sea lions forage. The prey abundance and foraging information can be used to answer: Are sea lions diving in areas with high densities of prey within the study area? If not, where are the tagged sea lions diving?
- Which prey field is better represented by sea lion scats collected from haul-outs within the study area, the available or utilized prey field?

Methods employed will include:

- Measure pelagic prey abundance using acoustic and mid-water trawl surveys.
- Measure nearshore prey abundance using remotely-operated vehicle (ROV), gillnet, and beach seine surveys.
- Record observations of sea lion foraging (diving) and measure prey abundance.
- Measure prey energy density and nutritional quality using chemical analyses.
- Infer diet from scat collections (UBC and UA).
- Measure sea lion haul-out attendance using aerial surveys (UA).
- Compare results to sea lion foraging area measurements from satellite tagging (ADF&G, NMML).
- Compare results to Kodiak Archipelago Sea Lion Prey Study (UA; 2001-148) and the Krenitzin Islands Sea Lion Prey Study (AFSC; 02FF-01 and 2002-21)

This project is a cooperative project involving the University of Alaska (sea lion use of eulachon in Berners Bay; sea lion project 2001-28), University of British Columbia (Southeast Alaska sea lion diet studies; 2002-40), the ADF&G (Southeast Alaska sea lion diet and foraging studies;

2001-91 and 2001-96), and other NMFS researchers (eulachon population studies in Berners Bay; 2002-28 and 02FF-10).

Activities in FY02

Four cruises of 14 days each were completed by the FV *Solstice* and FV *Viking Storm* in Frederick Sound and Lynn Canal, December 2001 and March, May, and September 2002. Prey were sampled by acoustics and midwater trawling and scat collected. In each cruise about 200 nmi of acoustic transects and 40 midwater trawls were completed. Twelve trips of one day each were completed by the FV *Williwaw* in Lynn Canal, one trip each month. Prey were sampled by acoustics. Each trip, 20 nmi of acoustic transects were completed. Five trips of one day each were completed by the FV *Williwaw* in Berners Bay during April 2002 to measure the arrival and departure of a pre-spawning aggregation of eulachon. Nearshore surveys from 0-90 m deep by beach seines, jigging, and ROV were conducted near Benjamin and Brothers Islands in southeastern Alaska in February and July 2002. Each season, approximately 15 seine hauls, 15 jig sites, and 7 ROV dives were completed at Benjamin Island, and 14 seine hauls, 15 jig sites, and 10 ROV dives were completed at Brothers Islands. In FY02 more than 500 prey samples were collected for nutritional analysis. The energy content has been estimated for 280 of these samples and another 200 prey samples collected in the last half of FY01. Thirteen aerial surveys were completed in Lynn Canal, Stephens Passage, Icy Strait, Chatham Strait, and Frederick Sound, one survey each month and two during April to monitor Steller sea lion association with herring and eulachon spawning aggregations. The numbers of sea lions at haul-outs were counted.

A manuscript "Availability to Steller sea lions of a seasonal prey resource, a pre-spawning aggregation of eulachon in Southeast Alaska" was prepared by Michael Sigler, Johanna Vollenweider, and Jamie Womble.

Michael Sigler presented results of the 2001 cruises at the Steller Sea Lion Principal Investigator's meeting in March 2002.

Results From FY02 Work

Three preliminary conclusions are:

- Prey abundance is concentrated: 45-75% of prey abundance expressed in kcal km^{-2} was concentrated in 10% of the area of Frederick Sound during May, September, and December 2001.
- Overwintering herring aggregations in Frederick Sound and lower Lynn Canal may be important energy sources for Steller sea lions during winter. Herring were concentrated and found throughout winter 2001-2002 at certain, known locations (e.g., on the east side of Benjamin Island; a seasonal Steller sea lion haul-out is located on the west side) and were at their highest energy density.
- Spawning aggregations of eulachon appear to be important energy sources for Steller sea lions during spring. Peak sea lion abundance at Berners Bay, the site of an eulachon pre-spawning aggregation, was 949 animals. Sea lion abundance increased as eulachon began concentrating in Berners Bay, peaked as eulachon abundance peaked, and

decreased as the eulachon moved upriver. Eulachon energy density was greatest during the period of highest sea lion abundance.

- Total fish caught during nearshore surveys was low in winter at both sites. In February, only 231 fish representing 12 species were captured by seine at Benjamin Island and only 331 fish representing 21 species were captured at Brothers Islands. The most abundant species captured by seining or jigging at both sites included tubesnouts, armorhead sculpins, rock sole, Pacific cod, and yellowfin sole. Total fish catch was much greater in summer than in winter. In July, over 6,200 fish representing18 species were captured by seine at Benjamin Island and over 17,500 fish representing 22 species were captured at Brothers Islands. The most abundant species captured by seining or jigging included sandlance, juvenile walleye pollock, juvenile chum salmon, armorhead sculpins, and dusky rockfish. We rarely observed any species with the ROV that we did not capture by seine or jig.

Plans for FY03

The project is planned to continue as conducted in FY02. The purpose is to collect multiple observations of prey abundance each season (e.g., prey abundance in May in Frederick Sound) and to determine if study results are affected by interannual variation.

Milestones in FY03

- Complete 87 sampling days for prey surveys.

Four cruises of 14 days are planned by the FV *Viking Storm* in Frederick Sound and Lynn Canal for December 2002 and March, May, and September 2003. Prey are sampled by acoustics and midwater trawling and scat are collected. During each cruise about 200 nmi of acoustic transects and 40 midwater trawls are completed. Twelve trips of one day each are planned by the F/V *Williwaw* in Lynn Canal near Benjamin Island, one trip each month. Prey are sampled by acoustics. During each trip, about 20 nmi of acoustic transects are completed. Five trips of one day each are planned for the FV *Williwaw* in Berners Bay during April 2003 to measure the arrival and departure of a pre-spawning aggregation of eulachon. Nearshore surveys from 0-90 m deep by beach seines, jigging, and ROV are planned near Benjamin and Brothers Islands in southeastern Alaska in February and July 2003. Each season, approximately 15 seine hauls, 15 jig sites, and 7 ROV dives are completed at Benjamin Island, and 14 seine hauls, 15 jig sites, and 10 ROV dives are completed at Brothers Islands. In FY03 more than 500 prey samples are planned for collection and nutritional analysis. All planned cruises during FY03 to date have been successfully completed.

- Submit for publication a manuscript "Availability to Steller sea lions of a seasonal prey resource, a pre-spawning aggregation of eulachon in Southeast Alaska".

A manuscript "Availability to Steller sea lions of a seasonal prey resource, a pre-spawning aggregation of eulachon in Southeast Alaska" was prepared by Michael Sigler, Johanna Vollenweider, and Jamie Womble and currently is undergoing editorial review. Publication as a refereed publication is anticipated for FY03. The manuscript provides information on the proportion of the Southeast Alaska sea lion population dependent on the Berners Bay eulachon run, as well as information on the amount of nutritional energy that's sufficient to attract sea

lions. Information on the dependency of sea lions on concentrated sources of nutritional energy will help us understand how much nutritional energy sea lions require.

- Prepare for publication manuscript(s) on the numerical response of Steller sea lions to overwintering herring aggregations.

One or two manuscripts on the numerical response of Steller sea lions to overwintering herring aggregations by Michael Sigler, Johanna Vollenweider, David Csepp, Jamie Womble and Scott Gende are planned for FY03 to be published as refereed publication(s). These manuscript(s) are expected to provide information on how sea lions respond numerically to prey abundance, information that will help us understand how much nutritional energy sea lions require.

- Present results of study at scientific conferences and seminars.

Michael Sigler presented the 2001 and 2002 results at the North Pacific Science Symposium in January 2003, at the University of Alaska in January 2003, and at the Alaska Fisheries Science Center in November 2002.

Archival Tagging of Walleye Pollock with Data-Storage Tags (02FIT-03)

Principal Investigator: Dan Nichol
Division: RACE
SSL Projects Database #: 2001-131, 2002-15

Project Description

Our objective is to determine vertical movement patterns of walleye pollock. Walleye pollock are highly abundant and are viewed as one of the most important food sources for Steller sea lions near Kodiak Island. Seasonal and daily movement patterns of walleye pollock would undoubtedly give us insight as to how available they are to Steller sea lions. Hydroacoustic research has provided valuable information concerning walleye pollock behavior, however, this research can only provide snapshots of behavior within a year. Archival tag data can provide months and potentially years of continuous data concerning the vertical migration of individual fish.

From a resource assessment perspective, knowledge of walleye pollock vertical migration is essential if we intend to use surveys (i.e., bottom trawls) to estimate stock biomass. Seasonal and daily movements of pollock can potentially decrease or even increase the availability of pollock to survey gear. Knowledge of this behavior may allow us to correct for these potential biases.

We have successfully deployed archival tags on both Atka mackerel (in 2000) and Pacific cod (2001). Thirteen Atka mackerel and 12 Pacific cod tags have been returned so far. The Atka mackerel data have been extremely valuable in terms of recognizing their diel movement patterns as well as their seasonal movements. The diel pattern, in particular, has brought attention to a significant flaw in the way we conduct bottom trawl surveys for Atka mackerel. The Pacific cod data is in the process of being evaluated, however, preliminary analysis indicates much more convoluted movements compared with Atka mackerel, although diel patterns have been recognized. We think the experience and success with these tags in terms of attachment, function, and reliability will translate well to walleye pollock.

We propose to tag walleye pollock with archival tags off Kodiak Island, AK. Tags will collect depth and temperature data. Walleye pollock are known to form local concentrations in bays off Kodiak Island. Our tagging effort will target on these local concentrations. We expect a better return rate if we limit tagging to fish that will be available to local Kodiak fisheries where the catch volume is generally not as high. With shoreside processing, tagged fish will likely be easier to recognize compared to offshore processors that target larger volumes of fish. We have consulted with jig fishermen off Kodiak, AK. These fishermen have captured walleye pollock incidentally while fishing for Pacific cod and/or rockfish. They are confident that if they target walleye pollock, fish could be captured in shallow-enough waters and in sufficient numbers for tagging purposes. We anticipate, with approved funding, a charter in September 2002.

Activities in FY02

A 48 ft purse-seiner was chartered for a total of 10 days. Charter time was split between two periods: 6 days from 7-12 May, and 4 days from 21-23 June. The vessel FV *Mythos* was

equipped with a herring purse seine and automatic jigging gear. We searched for pollock in shallow waters off Kodiak Island, where in past years they were commonly captured by salmon seiners. Unfortunately, we found no concentrations of pollock in shallow enough water for tagging purposes. After 4 days of searching for pollock, we decided to concentrate on Pacific cod instead and tagged 105 Pacific cod with archival tags off Ugak and Kiliuda Bays (11-12 May). Tags used on Pacific cod were in excess of the 200 tags planned for pollock. These tags were actually previously used tags, recovered from Pacific cod that were originally released off Kodiak in October-November 2001. The charter was resumed on 21 June with the hope that pollock had entered the bays. Unfortunately, still no concentrations of pollock were found in waters shallow enough for tagging, although we successfully tagged one pollock captured with hook and line.

Results From FY02 Work

Thus far, 5 archival tags with depth and temperature data have been recovered from Pacific cod released off Ugak and Kiliuda Bays. These data will be added to an ongoing project on the vertical movement patterns of Pacific cod, which began in 2001. A total of 329 Pacific cod off Kodiak, and 269 Pacific cod off Unimak Island in the eastern Bering Sea have been released with archival tags since October 2001. To date, 151 tagged Pacific cod have been recovered from off Kodiak Island, and 41 off Unimak Island.

Plans for FY03

Our main goal for 2003 is to tag 200 walleye pollock with the tags purchased in 2002. This requires more charter time. Our plan is to conduct a more "on-the-fly" charter(s) in areas with recent reports of concentrations of walleye pollock in shallow water. We plan to search for a charter(s) off of Sand Point, Alaska, where greater concentrations of pollock were found in 2002. This work may continue in FY03, but without Steller sea lion research funds.

Atka Mackerel Tagging Studies (02FIT-04)

Principal Investigators: Elizabeth Logerwell and Susanne McDermott
Division: REFM
SSL Projects Database #: 2001-118

Project Description

The objective of our ongoing tag release-recovery studies is to determine the efficacy of trawl exclusion zones as a management tool to maintain prey abundance and availability for Steller sea lions at local scales. For 2002, we propose to continue tagging Atka mackerel in Seguam Pass in order to refine model parameters and to continue a time series that will provide insight into interannual variability of Atka mackerel abundance and movement relative to trawl exclusion zones. As Steller sea lion research conducted by NMML is further developed in the Seguam Pass area (02SSL-08), we will be able to coordinate our research to provide an integrated, focused examination of the effects of the fishery on Steller sea lions. We also propose to expand this study geographically by conducting a preliminary tag release-recovery study at Tanaga Pass. This is important because patterns of local abundance and movement of Atka mackerel in other areas might differ from Seguam Pass due to different environmental and biological factors in those areas. A geographical expansion will also contribute to improved stock assessment modeling of Atka mackerel.

The tag releases required for both our ongoing tagging study and the fishery interaction feasibility study will be accomplished during a 28-day research charter in July 2002. Model simulations based on data collected during the 2000 tagging study indicate that a tagging effort in excess of 30,000 fish (15 days of tagging) would result in only a marginal improvement in the coefficient of variation for estimates of movement and abundance inside and outside the exclusion zone. Our objective will be to release 30,000 spaghetti tags in Seguam Pass in areas both open and closed to the fishery. We will release approximately 15,000 tagged fish (8 days of tagging) in the open and closed areas around Tanaga Pass. We will also release 200 archival tags in each pass.

The tag recovery effort will be modified from previous years to accommodate our fishery interaction feasibility study, but will still accomplish the recoveries necessary for our ongoing tagging study. In the context of the fishery interaction feasibility study, the area inside the 20-mile trawl exclusion zones in Seguam Pass will be our control site, the area outside the trawl exclusion zones will be our treatment site. We will charter a vessel to recover tags in the control and treatment areas before and after the fishery. We will compare the population abundance and movement estimates before and after the fishery in our control area to assess whether there is sufficient certainty in our estimates to detect a change. We will do the same comparison in our treatment area. The fishery will provide additional tag recoveries in the treatment area. We will compare these data to our charter recoveries to determine whether recoveries on the first and last days of the fishery can serve as “before” and “after” fishery data in the future. As part of our on-going tagging study we will also examine whether movement rates between the open and closed areas are affected by the fishery.

At present we are requesting funds for two charters in 2002, one for tag release on a catcher vessel and one for tag recovery on a factory trawler. The tag recovery charters are "no cost" because the cost of the charter is offset by the value of the catch. In fact the vessel awarded the contract pays the government. We are investigating the possibility of combining the tag release and recovery charters into one contract so that the cost of the tag release charter would be partially offset by the value of the catch during the tag recovery charter. Because it is not certain that this type of contract could be arranged for 2002, we are requesting the full price of the tag release charter. We would also like to investigate the possibility for a long-term charter for the tag releases and recoveries, separately or combined. Our goal is to continue tagging studies of Atka mackerel through at least 2005.

Activities in FY02

Tagging cruise

The fishing vessel FV *Pacific Explorer* was chartered from 10 June to 9 July 2002 for the purposes of tagging and releasing Atka mackerel inside and outside trawl exclusion zones in the Seguam Pass and Tanaga Pass areas of the Aleutian Islands, Alaska. This cruise represents the third consecutive year of work by AFSC on Atka mackerel in Seguam Pass and the first year of work in Tanaga Pass.

Recovery cruises

The fishing vessel FV *Seafisher* was chartered from 23 to 28 August 2002 for the purposes of recovering tagged Atka mackerel inside and outside the trawl exclusion zone at Seguam Pass. This cruise provided the "before fishery" data for the feasibility study of a fisheries interaction experiment. The FV *Seafisher* was also chartered from 30 September to 12 October 2002 to recover tagged Atka mackerel in both Seguam and Tanaga Passes. This cruise constituted the "after fishery" portion of our Seguam fisheries interaction feasibility study. Both cruises also contributed to the basic tagging model to assess the local abundance and movement rates of Atka mackerel in Seguam and Tanaga Passes.

Staff hired

Sandi Neidetcher was hired as a permanent employee. Kim Rand was hired as a term employee. Ruth Christensen was hired as a summer intern and will continue working with the Fisheries Interaction Team (FIT) as a Research Assistant when she begins her MS program in the School of Marine Affairs, University of Washington, in fall 2002. These staff also assist with FIT's Pacific cod project.

Presentations

A description of this study was presented at the Steller Sea Lion Principal Investigators meeting in March 2002. Susanne McDermott presented results from year 2000 tag release-recovery data at the Western Groundfish Conference, 11-14 February 2002. Results from the 2000 tag release-recovery data were also published in the feature article of the April-June *AFSC Quarterly Report*. Preliminary results from 2002 field work were presented at the symposium on "Marine Science in the Northeast Pacific: Science for Resource Dependent Communities", held in Anchorage, Alaska from 13 to 17 January 2003.

Results From FY02 Work

Tagging Cruise

Approximately 28,000 fish were tagged with plastic T-bar ("spaghetti") tags in the Seguam Pass area – 21,000 were released inside the trawl exclusion zone and 7,000 were released outside. Approximately 14,520 were tagged near Tanaga Pass – 8,520 were released inside the trawl exclusion zone and 6,000 were released outside. Additionally 200 archival tags were released in Seguam Pass and Tanaga Pass, respectively.

Recovery Cruises

A total of 636,501 Atka mackerel were caught and examined for tags in the Seguam Pass area before the fishery, and 608,259 were caught after the fishery. A total of 980,190 were caught in the Tanaga Pass area after the fishery. Summaries of the tag recoveries are shown in Tables 1, 2, and 3. The strata are shown in Figures 1 and 2.

Fishery Recoveries

An estimated total of 2,226,246 Atka mackerel were caught and examined for tags by commercial vessels in Seguam Pass during the B-season (September) 2002 fishery. 429,088 were caught by commercial vessels in Tanaga Pass. Tables 4 and 5 summarize the tag recoveries from the commercial vessels.

Table 1. Tags recovered at Seguam Pass during the before-fishery leg of the recovery charter in 2002. Dark shaded cells indicate tags that were released and recovered in the same strata, indicating no movement between strata.

		Strata Recovered				
		Inside	Inside	Inside	Outside	
		1	**2**	**3**	**4**	*Total*
Strata Released						
Inside	**1**	0	2	0	0	*2*
Inside	**2**	0	0	0	0	*0*
Inside	**3**	2	0	14	2	*18*
Outside	**4**	0	0	7	2	*9*
Total		*2*	*2*	*21*	*4*	*29*

Table 2. Tags recovered at Seguam Pass during the after-fishery leg of the recovery charter in 2002. Dark shaded cells indicate tags that were released and recovered in the same strata, indicating no movement between strata.

		Strata Recovered				
		Inside	Inside	Inside	Outside	
		1	**2**	**3**	**4**	*Total*
Strata Released						
Inside	**1**	2	0	0	0	*2*
Inside	**2**	2	0	0	0	*2*
Inside	**3**	0	0	5	0	*5*
Outside	**4**	0	0	0	0	*0*
Total		*4*	*0*	*5*	*0*	*9*

Table 3. Tags recovered at Tanaga Pass during the after-fishery leg of the recovery charter in 2002. Dark shaded cells indicate tags that were released and recovered in the same strata, indicating no movement between strata.

		Strata Recovered						
		Outside	Inside	Inside	Outside	Outside	Outside	
		1	**2**	**3a**	**3b**	**3c**	**4**	*Total*
Strata Released								
Outside	**1**	5	2	0	0	0	0	*7*
Inside	**2**	0	6	0	0	0	0	*6*
Inside	**3a**	0	0	0	0	0	0	*0*
Outside	**3b**	0	0	3	2	1	0	*6*
Outside	**3c**	0	1	8	3	1	1	*14*
Outside	**4**	0	0	0	0	0	1	*1*
Total		*5*	*9*	*11*	*5*	*2*	*2*	*34*

Table 4. Tags recovered at Seguam Pass during the B-season (September) 2002 fishery. Dark shaded cells indicate tags that were released and recovered in the same strata, indicating no movement between strata. Commercial vessels did not fish within the "inside" strata.

		Strata Recovered				
		Inside	Inside	Inside	Outside	
		1	**2**	**3**	**4**	*Total*
Strata Released						
Inside	**1**				0	
Inside	**2**				0	
Inside	**3**				3	
Outside	**4**				13	
Total						*16*

Table 5. Tags recovered at Tanaga Pass during the B-season (September) 2002 fishery. Dark shaded cells indicate tags that were released and recovered in the same strata, indicating no movement between strata. Commerical vessels only fished in "outside" Stratum 1 during this fishery.

		Strata Recovered						
		Outside	Inside	Inside	Outside	Outside	Outside	
		1	**2**	**3a**	**3b**	**3c**	**4**	*Total*
Strata Released								
Outside	**1**	13						
Inside	**2**	0						
Inside	**3a**	0						
Outside	**3b**	0						
Outside	**3c**	0						
Outside	**4**	0						
Total								*13*

Movement of fish seemed to be restricted between the strata inside the actual Seguam Pass area, (strata 1 and 2) and between the strata southwest of the actual pass (strata 3 and 4). It seems that both of these localized pockets of abundance don't mix. However recoveries from the charter vessel indicate considerable amount of movement of fish between area 3 and 4 (Fig. 1). Since area 3 is inside the trawl exclusion zone and area 4 is outside the trawl exclusion zone it appears as if inside to outside movement is quite large when in fact the actual distance moved by the fish may be small (less than 5 nmi). The line dividing inside and outside trawl exclusion zones bisects one sub-population that seems to move frequently back and forth across this 'artificial' border. Movement of fish between strata was similarly low in the Tanaga Pass study area. What movement did occur was between adjacent strata 3a, 3b and 3c (Fig. 2). As was observed in Seguam Pass, these strata borders may bisect one sub-population.

Population estimates in the Seguam Pass area from the analysis of year 2000 tag release-recovery data ranged from 117,900 mt inside the trawl exclusion zone to 82,057 mt outside the trawl exclusion zone (details in the April-May-June 2002 *AFSC Quarterly Report*). Very few tags were released in 2001, due to the truncation of the tagging cruise, so abundance estimates were not made for 2001. Our tag release-recovery data also allows for estimates of movement rates into and out of trawl exclusion zones, information that will help evaluate the probability of fish moving outside the trawl exclusion zone where they may be removed by the fishery. Estimated movement rate from inside to outside the trawl exclusion zone in Seguam Pass in 2000 was less than 1% of the population (after 59 days, the time of the recovery charter). Estimated movement rate was much larger for fish moving from the open area to the closed area at 60% of the population. However, the recovery effort inside the closed area was much smaller so there is a high degree of uncertainty around the estimate of movement rate into the closed area – the 95% confidence bounds included zero and 100% probability of movement. In an effort to reduce these confidence bounds, the number of tags released was greatly increased in 2002. The year 2000 results suggest that there is relatively little movement of Atka mackerel from inside to outside the trawl exclusion zone, indicating that trawl exclusion zones are effective at protecting Atka mackerel near Steller sea lion rookeries around Seguam Pass. Caution should be used in applying these results to other areas, each with resident Atka mackerel populations and fisheries of different size and distribution. To examine geographic variability in movement behavior we released tags in Seguam Pass and in a new study site in 2002, Tanaga Pass.

In addition to T-bar tags, several Atka mackerel were tagged with electronic archival tags which record depth and time continuously. The data can be downloaded from tags recovered from fish caught by commercial vessels or AFSC charters. A total of 200 Atka mackerel were tagged with archival tags in the Seguam Pass area – 60 inside and 140 outside the trawl exclusion zone. A total of 200 fish were tagged with archival tags in the Tanaga Pass area – 120 inside and 80 outside the trawl exclusion zone.

A random selection of tagged fish were placed into tanks to assess mortality rate following capture, handling and tagging. Experiments were conducted over two different durations, 48 hours and 4 days (96 hours). Sixteen experiments were conducted over the course of the cruise. Of the 315 fish participating in the experiments, a total of 13 died, for a mortality rate of 4%.

In addition to tagging and releasing Atka mackerel, AFSC scientists collected length-frequency data and took biological samples that will provide information on age, growth, reproductive condition and diet. Otoliths, gonads and stomachs were collected from 10 males and 10 females from every successful haul for a total of 210 fish of each sex. In addition to these samples, approximately 30 whole fish of each sex were frozen for future proximate analysis (fat, protein, water, and ash content). These data provide information on the caloric value of Atka mackerel as prey for Steller sea lions.

AFSC scientists also collected physical oceanographic data with the goal of examining the water column characteristics of Atka mackerel habitat. Continuous temperature and salinity data were collected with a sensor plumbed to receive water from near the surface. Temperature-depth data were also collected with a microbathythermograph (MBT) mounted on the net used to catch fish for tagging.

Plans for FY03

The objective of our ongoing tag release-recovery studies is to determine the efficacy of trawl exclusion zones as a management tool to maintain prey abundance/availability for Steller sea lions at local scales. For 2003 we propose to expand Atka mackerel tagging into the western Aleutian Islands where Steller sea lion declines are the most pronounced. This is important because patterns of local abundance and movement of Atka mackerel in other areas might differ from Seguam Pass where the majority of our tagging efforts have taken place. For example, bathymetric contours and data from the foreign fishery (1984-1989) suggest that trawl exclusion zones around Amchitka Islands rookeries may be less effective at containing Atka mackerel prey than the zones around Seguam and Tanaga. The Amchitka trawl exclusion zones cut across what appears to be Atka mackerel habitat such that movements of fish from inside to outside the exclusion zone would not be unexpected. In contrast, the Seguam and Tanaga Pass exclusion zone boundaries appear to coincide with natural habitat boundaries, so it is perhaps not surprising that we have observed little movement of fish from inside to outside these trawl exclusion zones. Another reason to expand tagging efforts to another area is that comparison of local Atka mackerel abundance among sites with different sea lion population trends may help illustrate whether variability in local prey abundance influences sea lion abundance and what are the threshold levels of prey. Finally, a geographical expansion will contribute to improved stock assessment modeling of Atka mackerel.

The tag releases required can be accomplished during a 15-day research charter in July 2003. Our objective will be to release a minimum of 12,000 spaghetti tags in the western Aleutians in areas both open and closed to the fishery. Depending on the conditions, we may release as many as 20,000. This release effort is similar to what we accomplished in Tanaga Pass in 2002. Because we have released a large number of tagged fish in Seguam Pass since the project began in 1999, the charter recovery cruise will take place in both Seguam Pass and the tagging site in the western Aleutians (such as Amchitka). Tagged fish will also be recovered by the commercial fishing industry.

Our long-term goal is to continue tagging studies of Atka mackerel through at least 2005. Although we are not requesting funds to continue tagging at Seguam Pass in 2003, we hope to establish a time series (perhaps biannually) that will provide insight into interannual variability

of Atka mackerel abundance and movement relative to trawl exclusion zones. The budget projected for FY04 includes vessel time to tag at Seguam Pass. We will also propose to expand our tag recoveries to include multiple seasons. Fishery data from the fall, and our November 2001 tag recovery survey suggests substantial movement of fish between summer and fall/winter. Assessment of these seasonal movements will contribute to our understanding of how fisheries interact with sea lion prey throughout the year. FY04 plans will also depend on whether analysis of the tagging data from the new site in the western Aleutians indicates that the site is suitable to conduct an explicit fishery effect study. If so, then we will propose a preliminary before-after fishery experiment for that site.

Milestones in FY03

Tag release cruise	July 2003
Tag recovery cruise	October 2003
Presentation of preliminary tagging model results (symposium)	January 2004
Submission of manuscript (*NOAA Technical Memorandum* or or refereed journal)	March 2004

The tagging model results in estimates of local abundance and movement rates of Atka mackerel. These results thus will help assess the efficacy of trawl exclusion zones at containing prey for Steller sea lions. In addition, the comparison of local Atka mackerel abundance across space and time may indicate whether prey variability influences Steller sea lion abundance and what are the threshold values of prey required.

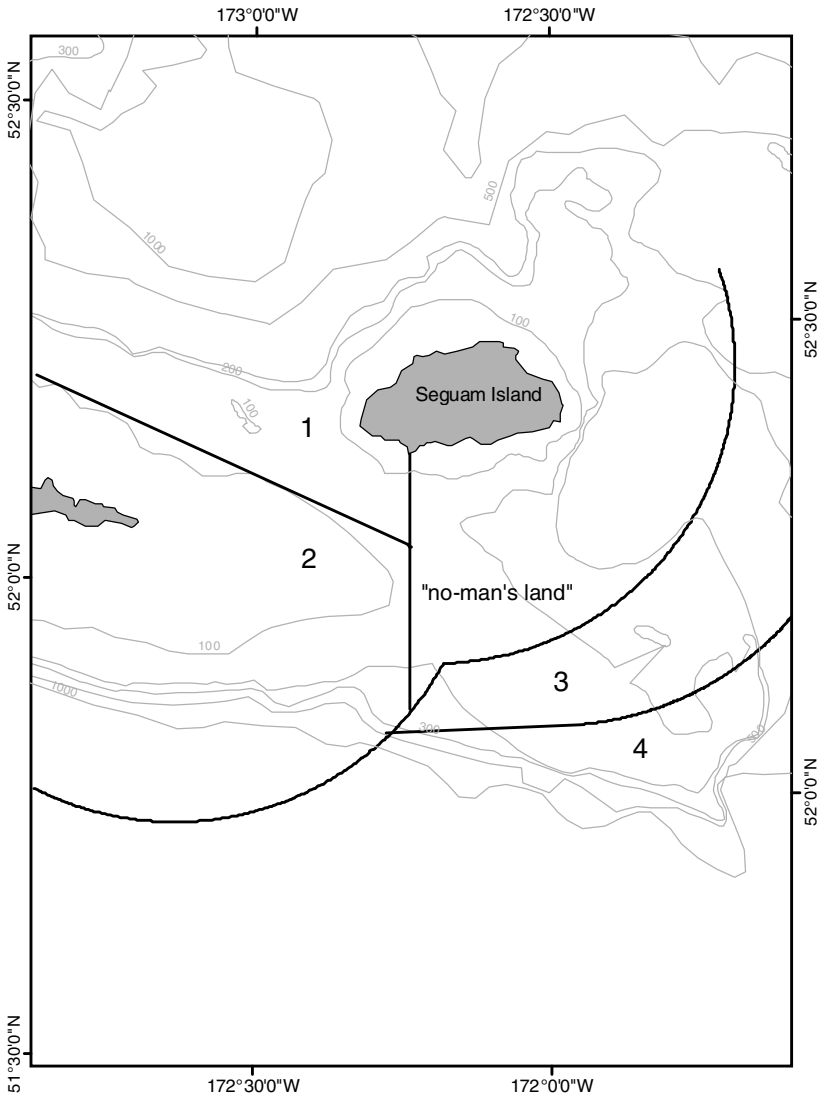

Figure 1. Strata in the Seguam Pass area that were used during the Atka mackerel tag release and recovery cruises. Areas 1-3 are inside the trawl exclusion zone, and Area 4 is outside the trawl exclusion zone.

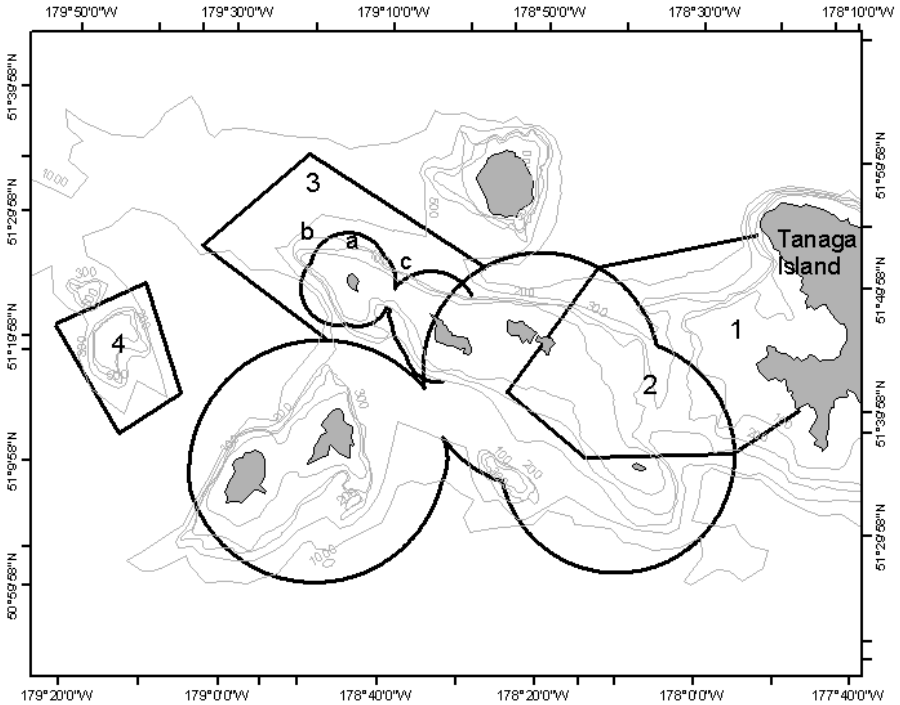

Figure 2. Strata in the Tanaga Pass area that were used during the Atka mackerel tag release and recovery cruises. Areas 2 and 3a are inside the trawl exclusion zone, and Areas 1, 3b, 3c and 4 are outside the trawl exclusion zone.

Improved Sampling Methodologies for Atka Mackerel (02FIT-05)

Principal Investigators:	Elizabeth Conners, Sandra Lowe, Elizabeth Logerwell, Peter Munro and William Karp
Division:	REFM, RACE
SSL Projects Database #:	2002-16

Project Description

Our objective is to begin a feasibility study of the use of multi-frequency acoustics to assess Atka mackerel distribution and abundance. Although Atka mackerel do not have swim bladders there is qualitative evidence from commercial fishermen and from FIT tagging studies that they may be detectible with acoustic systems. Multi-frequency systems have shown promise in distinguishing acoustic sign from different species. Similar to the trawl gear proposed above, applications of acoustic methods for Atka mackerel include improved stock assessment and studies of the linkages between Atka mackerel distribution, biophysical processes, Steller sea lions and the fishery. An additional benefit of collecting acoustic data in Atka mackerel habitat is that bottom types can be classified statistically after the survey. These data could be used to design more detailed studies of Atka mackerel bottom habitat in the future.

Activities in FY02

The Atka mackerel acoustics feasibility study will take place on the 2002 tag recovery charter (see 02FIT-04). This is an ideal platform to test acoustic methods because the species composition of the catch is determined as part of the usual tag recovery protocols. We propose to purchase a multi-frequency acoustic system that could either be installed on a vessel selected for a long-term charter or that could work with commercial-grade sounders already installed on many fishing vessels. Our goal for the first year of feasibility work is to assess whether Atka mackerel are detectible with acoustics and if so, at what frequencies.

Results From FY02 Work

Acoustic data loggers were deployed on the vessel participating in the fall Atka mackerel tag recovery cruises (October 2002). No results are available at this time.

Plans for FY03

Funds to analyze these data were rolled over to 2003 as the timing of data collection did not justify a grant for graduate student assistance before the data was obtained. Additional savings were gained because the vessel chartered for the Atka mackerel project was already equipped with some of the technology needed to collect data.

Pacific Cod Pot Fishing and Tagging Studies (02FIT-06)

Principal Investigators: Elizabeth Conners, Peter Munro and Grant Thompson
Division: REFM
SSL Projects Database #: 2002-16

Project Description

Pot Fishing Before-After Impact Control Study

This project is designed to examine the effect of commercial fishing activity on the distribution and abundance of Pacific cod. Pacific cod are an important prey to Steller sea lions during the winter months. The study follows a Before-After Impact Control design where a comparison will be made between fished and unfished sites.

A three-phase research plan, spanning as many as 7 years, is proposed. The first phase, which is well on its way to completion, is the design and testing of a research pot, a gear for which many of the parameters that affect fishing efficiency are held fixed. The second phase, to be conducted during FY02, consists primarily of a pilot study, in the neighborhood of the commercial trawling grounds known as "cod alley," just north of Unimak Pass. The third phase consists of experimentation to assess the potential effects of a cod fishery. An experimental design, based on changes in ratios of cod pot catches (not changes in the catches themselves), has been developed and awaits verification of the sampling instrument. These experiments are to occur annually for five years, beginning in winter of 2003. Annual replication will directly measure repeatability. However, variation in experimental results may also serve as an indicator of effects of varying harvest strategies or different levels of harvest. (Note, the third phase of this plan will not be pursued if the variance structures revealed by the pilot study indicate that sampling strategies are unfeasible).

In FY02, we propose four main areas of work: 1) complete the development and fabrication of research pot gear; 2) procure oceanographic sensors (current sensors were already procured under the budget for FY01) and design and fabricate the sensor pots; 3) charter a commercial pot fishing vessel as a platform from which to conduct gear trials and the pilot study (cruise to occur in March or April 2002); 4) charter a commercial pot fishing vessel and conduct follow-up gear trials in September 2002.

Cod Tagging Studies

This project proposes two types of tags: archival and traditional. The tags will be deployed by extending the duration of the cod pot studies. The objectives of each study differ; however, there is a significant cost savings in utilizing the ship time for both projects. For this reason, the projects have been bundled.

The primary objective of the archival tag study is to infer vertical movement of Pacific cod, especially in the times leading up to aggregation for spawning through dispersal afterwards. Vertical movements of Pacific cod are not well understood and could influence the effectiveness of a given cod pot study design. Depending on the bathymetry in the region where fish are tagged, inferences could also be made on cod horizontal movements (e.g., swimming to deeper waters off a shelf).

The goals of traditional tagging studies in FY02 are to evaluate a tagging program for estimating movement of Pacific cod. Evaluation of feasibility entails determining costs of tagging and releasing fish and determining the cost of establishing a recovery program. A model for cod population biology is already being developed by Dr. Grant Thompson (REFM). Dr. Thompson has expressed strong interest in incorporating tagging data into this model and would be working in partnership with the FIT to develop this essential element of mark-recapture research. The long-term goal of this study is to estimate the migratory movements of Pacific cod in the region of the before-after fishery interaction study. If this region is "cod alley" (north of Unimak Pass) then fish will be tagged and recovered in both the Bering Sea and Gulf of Alaska sides of the pass in order to determine whether there is movement between the two areas. Estimation of this movement will be critical to understanding the results of tag recoveries in cod alley.

Activities and Results in FY02

FIT scientists Elizabeth Conners and Peter Munro conducted preliminary gear trials in June 2002 from Kodiak, and a pilot study in Unimak Pass was performed in April 2002. The preliminary studies indicate that the experimental pot gear works well for this species, and that field operations of the scope needed for the study are feasible. The pilot study fished more than 700 pot-sets over 3-6 hour soaks; catches ranged from 0 to 103 cod/pot, with an average catch of 29 cod/pot. The consistency of catches in the pilot study suggests that good precision may be attained in the full experiment. Analysis of the pilot study data and final design for the experiment were conducted during summer 2002. A full experiment, consisting of before/after surveys of both trawled and untrawled areas of the pass, is planned for winter 2003. In order to successfully infer presence or absence of a fishing effect, the study needs to determine differences between the fished and unfished areas that are separate from changes in cod abundance due to seasonal migration, local habitat variability, and short-term movement of cod. Tagging studies are being conducted concurrently with the FIT study in order to learn more about local and seasonal cod movement rates.

Publications

Environmental Assessment / Regulatory Impact Review Initial Regulatory Flexibility Analysis for Regulatory Amendment to Provide a Short-term Trawl Closure to Facilitate and Experiment Investigating the Effects of Commercial Fishing on Local Abundance of Pacific Cod.

Presentations

- E. Conners. Forage fish research development meeting, 29-30 January 2002
- E. Conners. March 2002, Steller Sea Lion Principal Investigators Orientation and Coordination Meeting. Presentation of NMFS Fishery Interaction Studies.
- E. Conners. 18 March 2002. Cod spawning biology research meeting.
- E. Conners. September 2002. Krenitzin Island studies coordination meeting.
- E. Conners. October 2002. NPFMC Council Meeting.
- S. Neidetcher. January 2003. Marine Science in the Northeast Pacific: Science for Resource Dependent Communities

Plans for FY03

Funds are requested in FY03 to support field operations conducted during 2003 and to secure vessel charter for winter 2004. Budget amounts for overtime, travel, transportation, and supplies

are primarily expenses already incurred during fall and winter 2003 cruises. Rents in the budget are vessel charter fees for a 7-day cruise to complete research on fishing methodology and oceanographic instruments, and for "before" and "after" legs of the local abundance experiment in winter 2004. Although the January 2003 cruise was hampered by bad weather and equipment failures, we anticipate that the combination of January, February, and March 2003 data will provide both useful preliminary information fishery effects and sufficient data to fully test and validate the experimental design. A report on results of the project in 2003 will be prepared for the June 2003 Council meetings, and scientific publications based on the pilot and 2003 studies will be prepared. The March 2003 cruise is also scheduled to provide a platform for collection of over 1,000 fish tissue samples for genetic analysis of Pacific cod stock structure. Biological specimens collected will be used both for Pacific cod fecundity studies and to verify the length at 50% maturity parameter that is used in the Pacific cod stock assessment. Fish tagged during the winter 2003 cruises will continue to provide information on local, depth-based, and seasonal movement of Pacific cod as tags are returned by the fishery and NMFS observers. Work planned for the summer-fall 2003 includes continued development of instrumentation for research pots and pot-mounted oceanographic sensor arrays.

Projected Work for FY04 and Beyond

A repeat of the before-after local abundance experiment is planned for winter 2004, 2005, and 2006. These repetitions of the experiment are needed to determine if study results are consistent over the substantial year-to-year variation that can occur in Bering Sea fisheries. The estimated budgets for these years also include the addition of a "during" cruise to better understand the seasonal dynamics of Pacific cod movements and local abundance. Incorporation of oceanographic instruments in future studies is planned to assess how physical and chemical factors affect the efficiency of pot gear and contribute to variability in pot catch. These budgets also include continued support of the tagging program and continuing analysis of tag return data. these cruises. This item also includes 7 charter days for the "methodology" cruise, to complete the development of oceanographic instrument arrays and trigger sensors for use with pot studies. This item also includes some minor expenditures for storage and handling of research pots and rental of a deck module used to house and download instruments.

Milestones

3 April 2003 - Completion of 2003 local abundance experiment.
June 2003 - Summary Report of project for NPFMC, including preliminary data analyses.
July-August 2003 - Award of contract for charter vessel for 2004 cruises.
August-September 2003 - "Methodology" cruise to test instrument cages and trigger timers.
November-December 2003 - Shipping and setup of vessel for 2004 cruises.
Summer-Fall 2003 - Submission of manuscript on study design and 2002-2003 data.
November 2003 - Presentation of pot design and instrumentation data at ICES symposium.
Summer-Fall 2003 - Preparation of presentation/ manuscript on biological data.
Summer-Fall 2003 - Preparation of manuscript on experimental design and pilot study results.
Fall-Winter 2003-04 - Preparation of manuscripts on tagging data.

Kodiak Island Walleye Pollock Fishery Interactions (02FIT-07)

Principal Investigators: Chris Wilson, Anne Hollowed, Michiyo Shima, Paul Walline, Elizabeth Logerwell, Phyllis Stabeno and Sigrid Salo
Division: RACE, REFM, PMEL
SSL Projects Database #: 2001-125

Project Description

The primary objective of this project is to evaluate the hypothesis that commercial fisheries compete with Steller sea lions (*Eumetopias jubatus*) for walleye pollock (*Theragra chalcogramma*) in localized regions by reducing the abundance/availability of prey at local scales and/or disturbing prey fields (reduction in patch densities and redistribution of prey patches). This study serves as a means to evaluate whether the proposed RPAs are achieving their stated objectives, and provides an evaluation of methods for conducting experiments to determine what levels of fishing are required to induce a measurable change in the forage base of Steller sea lions. Secondary objectives of the proposal include collection and evaluation of the role of oceanographic features in determining the spatial distribution of forage fish and walleye pollock in localized regions of the GOA and providing key information needed to develop realistic models of Steller sea lion foraging behavior. Information on the spatial distribution of forage fish and pollock relative to oceanographic features will be provided by this study. PMEL has proposed funds to process ADCP and nutrient data collected during this study. The survey will also provide a platform for gear trials of multiple opening and closing nets.

We request funds for the third year of a multi-year study to quantify the effects of commercial fishing on prey concentrations in Barnabas and Chiniak troughs. Scientists will conduct an echo integration-trawl (EIT) survey on the east side of Kodiak Island. The work will be conducted aboard the NOAA ship *Miller Freeman* from approximately 10 August to 3 September 2002. The survey will assess changes in fish biomass, abundance, and distribution before and during commercial fishing. The work is planned for several years to assess inter-annual variation in the response of pollock to fishing due to changes in natural oceanic conditions and pollock year-class strength.

One possible outcome may be that commercial fishing practices do not produce a measurable change in pollock distributions on the eastside of Kodiak Island given the small size of the current (ca. 2001-2002) fishery. This information would be used to demonstrate that the fishery management regulations passed in 2002 are achieving their stated objective. Evaluation of the degree of correlation between treatment and control sites, together with data on measurement error and temporal variability, can be used to assess the power of our ability to discern natural variability from fishery induced change. The study will provide a measure of the efficacy of the fishery management regulations in a single location. It will not be possible to extrapolate the results from a single year to other areas or seasons. Depending on the success of this proposed work, however, this type of approach may be used in other areas and during other seasons to better understand the relationships among commercial fishing practices, walleye pollock, and Steller sea lions.

Collaborations

An objective of this work is to relate observed changes in prey fields to the foraging behavior of Steller sea lions. Studies of sea lion foraging are being conducted in the Kodiak area by NMML (2001-104 and 02SSL-08), ADF&G (2001-91) and the University of Alaska (2001-02, 2001-149 and 2001-150). In addition, assessments of prey fields in the Kodiak area are also being conducted by the researchers at the University of Alaska (2001-14, 2001-21, and 2001-148) and Prince William Sound Science Center (2001-44).

Fisheries oceanographic studies are facilitated by collaborations with investigators at the PMEL (2001-48). PMEL will provide analytical support for processing most of the oceanographic data including the shipboard ADCP data. Likewise PMEL will deploy eight current meter moorings, satellite track drifters, and expendable CTDs in the study region.

The results from this study will also supply critical information for ecosystem modeling and individual based modeling projects being conducted at the AFSC by Dr. Sarah Hinckley (2001-133 and 02FIT-01) and Patricia Livingston (2002-19 and 02FIT-10).

Activities and Results in FY02

Scientists from the Alaska Fisheries Science Center's (AFSC), Resource Assessment and Conservation Ecology (RACE) and Resource Ecology and Fisheries Management (REFM) Divisions and NOAA's PMEL conducted an acoustic trawl survey on the east side of Kodiak Island from 14 August to 5 September 2002. The primary objective of the survey was to evaluate the effects of fishing on the distribution and abundance of sea lion prey before and during a commercial fishing operation. During the course of acoustic operations, a considerable amount of oceanographic information was collected through collaboration with PMEL. This provided an opportunity to evaluate the effect of ocean conditions on the distribution of sea lion prey during the survey. Understanding the role of ocean forcing on the distribution and abundance of sea lion prey is a necessary element of this study as investigators are striving to distinguish changes due to fishing from natural events.

Publications

Hollowed, A. B., C. D. Wilson, P. Stabeno, and S. Salo. Submitted. Effect of ocean conditions on the cross-shelf distribution of walleye pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*). Fisheries Oceanography.

Logerwell, E., L. Fritz, A. B. Hollowed, S. McDermott, P. Stabeno, and C. Wilson. 2002. The fishery interaction team: investigating the potential impacts of commercial fishing on the foraging success of endangered Steller sea lions. April-May-June 2002 *AFSC Quarterly Report*.

Logerwell, E., and C. Wilson. In Prep. Interpretation of acoustic data at two frequencies to discriminate between fish aggregations of different species composition.

Shima, M., A. B. Hollowed, G. R. VanBlaricom. 2001. Changes over time in the spatial distribution of walleye pollock (*Theragra chacogramma*) in the Gulf of Alaska,1984-1996. Fishery Bulletin, U.S. 100: 307-323.

Wilson, C., A. B. Hollowed, M. Shima, P. Walline, and S. Stienessen, In Review. Interactions between commercial fishing and walleye pollock. Alaska Fisheries Research Bulletin.

Wilson, C., A. B. Hollowed, M. Shima, P. Walline, and S. Steinessen. 2002. Interactions between commercial fishing and walleye pollock. January-February-March 2002 AFSC *Quarterly Report*.

Presentations

February 2002. North Pacific Fishery Management Council Presentation. Interactions between commercial fishing and walleye pollock. C. Wilson, A. Hollowed, M. Shima, P. Walline, and S. Stienessen.

February 2002. Ocean Sciences Meeting. Effect of ocean conditions on the cross-shelf distribution of walleye pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*). A. B. Hollowed.

March 2002. Steller Sea Lion Principal Investigators Orientation and Coordination Meeting. Presentation of NMFS Fishery Interaction Studies. A. B. Hollowed, C. Wilson, P. Stabeno, and S. Salo.

June 2002. ICES Symposium on Acoustics in Fisheries and Aquatic Studies. Interactions between commercial fishing and walleye pollock. C. Wilson, A. Hollowed, M. Shima, P. Walline, and S. Stienessen.

June 2002. ICES Symposium on Acoustics in Fisheries and Aquatic Studies. Interpretation of acoustic data at two frequencies to discriminate between fish aggregations of different species composition. E. Logerwell and C. Wilson.

September 2002. Steller Sea Lion Modeling Workshop. Diving to depths: optimizing efficiency for Steller sea lions. M. Shima, A B. Hollowed, and J. Sterling.

January 2003. Marine Science for the Northeast Pacific: Science for resource-dependent communities. Effect of ocean conditions on the cross-shelf distribution of walleye pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*). A. B. Hollowed, C. Wilson, P. Stabeno, and S. Salo.

January 2003. Marine Science for the Northeast Pacific: Science for resource-dependent communities. Discrimination of Steller sea lion prey fish using frequency-dependent acoustic backscatter. E. Logerwell and C. Wilson.

January 2003. Marine Science for the Northeast Pacific: Science for resource-dependent communities. Fishery interaction study: Interactions between commercial fishing and walleye pollock. C. Wilson, A. B. Hollowed, M. Shima, P. Walline, and S. Stienessen.

Plans for FY03

Because of FY03 budget cut-backs and uncertainties in GOA pollock fishery distributions in August 2003, field operations on this project have been suspended. During 2003, data collected during 2000-2002 will be analyzed and the project will be proposed again for field operations in 2004.

Deployment of an Acoustic Data Logger on Commercial Fishing Vessels to Evaluate the Potential of Fishing-induced Declines in Local Pollock Abundance (02FIT-08)

Principal Investigators: Jim Ianelli, Martin Dorn, William Karp, Vidar Wespestad and Terrance J. Quinn
Division: REFM, RACE
SSL Projects Database #: 2002-17

Project Description

Concerns over potential biological interactions between Steller sea lions and commercial fishing have escalated due to the reclassification of the western population of sea lions as endangered under terms of the Endangered Species Act (ESA) in 1997. Competition for walleye pollock, an important sea lion prey and the target of major fisheries in the Gulf of Alaska and the Eastern Bering Sea, is a major focus of attention. Biological Opinions required by the ESA have concluded that the overall harvest rate of pollock is not likely to jeopardize sea lion recovery or adversely modify their critical habit. Instead, the potential for "localized depletion" of pollock by fishing has been a primary consideration in designing measures to reduce extinction risk and promote recovery of sea lions.

Evaluation of the effects of "localized depletion" has been hampered by extreme scientific uncertainty on several fronts. First, the foraging behavior of sea lions is poorly known, so that the effects of changes in pollock abundance at small spatial scales on sea lion fitness cannot be determined. Second, how fisheries affect the distribution of pollock is likewise poorly known. Fortunately, pollock can be surveyed using acoustic methods, which because of their high sampling rates can be used to study fish distribution patterns over a range of spatial scales down to tens of meters (the resolution of individual pings). Temporal persistence of fishery effects can be studied using replicated scientific surveys at study and control. However, there are logistical constraints to scientific surveys, such as the difficulty of securing sufficient ship time to conduct replicate surveys, the lack of appropriate study and control sites in the eastern Bering Sea, and the legal obstacles of implementing an adequate survey design under ESA restrictions.

We propose a novel approach to the study of "localized depletion" of pollock by deploying acoustic data loggers on catcher/processors participating in the eastern Bering Sea pollock fishery. Since acoustic imaging is an important source of information on pollock aggregations, all catcher/processors in the pollock fishery are equipped with state-of-the-art echosounders. The basic premise is that by "looking over the shoulder" of the fishing master we will be able to obtain random samples of acoustic data during the exploration/searching process that all fishing vessels engage in before making decisions about where to fish.

Activities in FY02

Our objective was to develop a logging system that would 1) require minimal attention, 2) could log raw acoustic data for entire fishing trips, 3) would be fully spatially and temporally referenced, and 4) would not interfere with the primary use of the echosounder as a fish-finding tool. A prototype data logger was deployed on three factory trawlers during January 2002. Acoustic data were successfully logged during 2002 winter and summer pollock fisheries in the

eastern Bering Sea, and during the Pacific whiting fishery off the West Coast. Preliminary processing of the 2002 A season pollock fishery data was done using Echoview, a SonarData software product.

Results From FY02 Work

Preliminary results were presented at the ICES Symposium on Acoustics in Fisheries and Aquatic Ecology in a poster "Using fishing vessels to collect acoustic data for scientific purposes: preliminary results from midwater trawlers in the eastern Bering Sea walleye pollock fishery" by Martin W. Dorn, William A. Karp, Vidar G. Wespestad, James Ianelli, and Terrance J. Quinn.

Plans for FY03

Funding requirements for this project in FY03 are being met from other sources, so no FY03 funds are being requested for this project. Additional funding may be sought in the future.

Proximate Analysis of Steller Sea Lion Prey (02FIT-09)

Principal Investigator: Elizabeth Logerwell
Division: REFM
SSL Projects Database #: 2002-18

Project Description
The purpose of these analyses is to determine the caloric content of selected fish species from the Aleutian Islands (AI), Gulf of Alaska (GOA) and Bering Sea (BS). The data will be used to construct bioenergetic models that will help assess the impact of changes in prey abundance or distribution on the ability of Steller sea lions to meet their energetic needs. The data will also be used to construct trophic models of the AI, GOA and BS, models which contribute to multispecies management of these systems. A review of current literature indicates that data on caloric content are missing for several important Steller sea lion prey species. Thus, the requested analyses provide an opportunity to fill these data gaps for AFSC projects and for the scientific community at large.

Funds are requested to process samples to be collected during the AI trawl survey in 2002. In 2001 samples were collected during the GOA and BS trawl surveys and during the Fishery Interaction Team's (FIT) at-sea studies. These samples are being processed at a contracted laboratory with money awarded in 2001. Analysis of samples from the AI will provide a geographically complete data set of the caloric content of Steller sea lion prey species throughout the range of the western population. If the Nutritional Ecology Laboratory proposal is granted full funding then samples from the AI survey will be processed there and additional funds will not be required.

Activities and Results in FY02
Samples of a variety of fish species were collected during the AI trawl survey. In addition, sufficient funds may be available from a contract with a private laboratory initiated in FY01.

Preliminary results were presented at the symposium on "Marine Science for the Northeast Pacific: Science for resource-dependent communities." by Elizabeth A. Logerwell and Ruth Christiansen. The title of the poster presentation was "Energy density of Steller sea lion prey in western Alaska: Species, regional, and seasonal differences."

Plans for FY03
Because the Nutritional Ecology Laboratory (02SSL-02) proposal was granted full funding, no funds for analyses of these samples are requested in FY03.

Predator-Prey Modeling: Updates, Expansion and Validation (02FIT-10)

Principal Investigator: Patricia Livingston
Division: REFM
SSL Projects Database #: 2002-19

Project Description

REFM has developed a suite of single-species models with predators, multispecies models, and ecosystem models in eastern Bering Sea (EBS) and Gulf of Alaska (GOA) regions inhabited by Steller sea lions and including key prey of Steller sea lions. The models all require periodic updates, improvement and continuing hypothesis generation and testing. Furthermore, the predator-prey relationships in the Aleutian Islands (AI) have not yet been modeled. A global predator-prey model of the EBS has been developed for the 1980s period. This model needs to be updated to the late 1990s period and compared with the newly developed global model of the GOA. A global model of the AI needs to be developed for the corresponding time period along with an AI stock assessment model of Atka mackerel that contains predators. These models will allow us to perform hypothesis testing about factors influencing changes in predator and prey abundance, the role of fishing in influencing these dynamics in a global sense, and the influence of bottom-up (climate and lower trophic level) and predation-related factors in ecosystem dynamics. When the AI global predator-prey model is completed, we will develop ecosystem-level change indicators for cross-ecosystem comparisons.

Several years from now when sufficient data are available from field studies, particularly Krenitzen Islands, community models of the EBS will be constructed at several spatial scales and designed to interact with each other and other modeling and data gathering efforts currently proposed or underway. A specific aim would be to provide a strong complement for the individual-based foraging and bioenergetics approaches currently under development for Steller sea lions and their immediate predators and/or prey. We will perform statistical hypothesis testing at the ecosystem level regarding the likelihood of factors influencing ecosystem change and we will establish "biological boundary conditions" for the extent and strength of species interactions.

The multispecies virtual population analysis model (MSVPA) of the eastern Bering Sea is a seasonally explicit predator-prey model. This model and the forecasting that can be done using model estimates allows the evaluation of various fishing strategies and climate-driven recruitment assumptions on age-structured multispecies groundfish dynamics. Update of the model will allow further assessment of the role of seasonal predation by groundfish and other predators on key species dynamics such as walleye pollock and Pacific cod. Simulations of various fishing strategies can be performed to examine hypotheses of effects of fishing on multispecies dynamics. Initial simulations have shown that fishing may affect the frequency and amplitude of population fluctuations in key species such as walleye pollock. Model results also indicate that the largest differences between single-species and multi-species model predictions have been those relating to species that are prey, particularly walleye pollock, Pacific herring, and rock sole. Understanding the direct and indirect impacts of fishing on the age-structured groundfish complex and the associated food web and particularly on sea lion prey in the EBS is the primary purpose of this type of model. We are working on developing a statistically based

multispecies assessment model (MSSAM) for the EBS that can take into consideration uncertainty in input data. In the future, MSSAM of GOA groundfish complex might be performed if sufficient seasonal diet samples are obtained.

Activities and Results in FY02

The primary activity in FY02 was to amend the JISAO project "Marine Biological Interactions in the North Pacific" to include the funding to accomplish the proposed modeling work. The project modification to include the new funding was completed in September 2002. Despite the lag in obtaining funding and amending the JISAO cooperative agreement, the EBS multispecies virtual population analysis model was updated to reflect the 2001 groundfish stock assessment results. The update to include recent groundfish diet information and revise the way northern fur seals are modeled will be accomplished early in FY03, using the FY02 funding put into the JISAO project.

A UW doctoral graduate student, Ivonne Ortiz, is now employed under the JISAO project to begin the Aleutian Islands ecosystem and predator-prey work. An ECOPATH model of the Aleutians is presently under development and ecosystem characteristics of the Aleutians are being researched to aid in establishing ecosystem boundaries and components and model construction.

Milestones in FY03

Initial Aleutian Islands ECOPATH model will be completed along with a general description of the model and parameter sources. The model will be described initially in an *AFSC Processed Report*. Once the model gets fully balanced, a more detailed paper showing results from various model runs will be produced in a later year. This model will help us understand food web dynamics and controls in the Aleutian Islands, where Steller sea lions are still showing declines, and may help explain changes in ecosystem production that affects Steller sea lions.

<u>Other ECOPATH products anticipated for FY03</u>

- Draft of paper "Resonant Trophic Control in Pacific Ecosystems" (interaction between climate and life history in food webs)
- Submission to a peer-reviewed journal of a paper on uncertainty in management of trophic cascades (applies to levels or possibilities of failure when, for example, advising on management strategies of marine mammals).
- Publication (as lead author) of PICES Scientific Report "Report of the BASS/MODEL Workshop On Trophic Models of the Subarctic Pacific Basin Ecosystems" which includes the first publication of new sensitivity routines and Bayesian fitting routines for food-web models (EcoSense). These routines will be incorporated into a later, stand-alone paper for peer-review.
- Submission to a peer-reviewed journal of a paper comparing MSVPA and Ecosim-style results for practical multispecies management uses.
- Draft update (process report format) on EBS Ecopath model (perhaps in combination with Aleutians/Gulf model updates).
- Work to incorporate above results into using Ecosim for developing sections of the Ecosystem Assessment chapter.

These efforts will help us evaluate this model and its usefulness as a tool for advising fishery management on the food web implications of various fishing strategies, including those involving Steller sea lions.

MSVPA work for FY03

This model will be updated to add several years of groundfish diet information acquired since the model was last updated. We will also examine the availability of data necessary to add Steller sea lions as a predator in the model. Work will continue to turn this model into a multispecies statistical age-structured model that is more in line with the models presently used in single-species assessment. A manuscript on the methodology involved in turning the model into a multispecies statistical age-structured model will be submitted to a peer-reviewed journal. The model will also be used in assessing long term implications of fishery management strategies in an Ecosystem Assessment chapter of the annual Stock Assessment and Fishery Evaluation document. This model and its results can help us understand multispecies factors controlling the dominant groundfish in the eastern Bering Sea. These groundfish, particularly pollock and cod, are important prey of Steller sea lions and their dynamics may be important in understanding Steller sea lion production patterns.

Fisheries Interactions Studies (02FIT-11)

Principal Investigators: Anne Hollowed, Elizabeth Logerwell, Elizabeth Conners, Peter Munro, Sandi Neidetcher, Susanne McDermott, Steven Barbeaux and Kimberly Rand
Division: REFM

Project Description
This proposal calls for a continuation of funding for a core research team whose primary responsibility will be to investigate fisheries interactions. Members of this team will conduct studies to determine whether commercial fishing operations are capable of impacting the foraging success of sea lions either through disturbance of prey schools or through direct competition for a common prey. To accomplish this objective, the team will conduct process oriented studies to examine potential commercial fishery impacts including reduction in the abundance or availability of prey at local scales and disturbance of prey fields (reduction in patch densities and/or redistribution of prey patches). In addition, the team will develop and parameterize models to investigate how locally varying prey densities and prey distribution patterns, as affected by fishing activity, may influence sea lion condition, reproduction and survival. The research team will play an integral role in the design and evaluation of current and proposed management of commercial fisheries in Federal waters. It is anticipated that members of this research team will provide information that is directly relevant to the development of biological opinions as well as stock assessment advice.

In the next 5 years the FIT team will work in concert with NMML to conduct research to evaluate the following questions:

1) At what level are commercial fishing operations capable of eliciting a measurable impact on Steller sea lion foraging success? What is the functional relationship between commercial fishing effort and foraging success of Steller sea lions? This research element will evaluate relationship between the level of commercial harvest and the intensity and duration of the fishery response.

2) What natural factors influence the functional relationship between commercial fishing and foraging success of Steller sea lions? This research element will evaluate differences in fish response in different regions, seasons, and population structure (e.g., the role of age composition, fisheries oceanography).

3) What human factors influence the functional relationship between commercial fishing and foraging success of Steller sea lions? This research element will examine how alternative methods of harvest influence the relationship between the commercial harvest and foraging success of Steller sea lions. Alternative methods will include, but will not be limited to, studies of the influence of daily amount of fish removed from localized regions, the gear used to remove the fish, and the number of vessels participating in removing the fish.

4) These projects will be used to evaluate whether proposed or current fishery management regulations are achieving their stated goals. Specifically, is there a measurable impact of

commercial fishing under proposed or current RPAs? If so, are these impacts sufficiently small that they do not cause a change in the foraging success of a Steller sea lion that is large enough to adversely impact the habitat of Steller sea lions?

The research activities of FIT currently focus on impacts of three commercial fisheries: Atka mackerel, Pacific cod and walleye pollock.

Activities and Results in FY02

Vacant positions were filled. These individuals allowed REFM to meet the objectives of several FIT projects.

Expanded Pollock Fisheries Interaction Team Staff (02FIT-12)

Principal Investigators: Anne Hollowed, Chris Wilson and Elizabeth Logerwell
Division: RACE, REFM

Project Description

This proposal calls for augmentation of existing staff to support additional echo integration trawl surveys to measure the effect of commercial fishing on prey distributions of Steller sea lions. New scientists take a minimum of 1 year of training to become fully capable of leading a field program. Thus, the projections include hiring additional personnel in FY02 with the expectation that the first field year would occur in FY03.

Echo integration-trawl surveys will be designed in 2002 and feasibility surveys will be implemented in 2003. New staff will allow the agency to expand seasonal coverage in the Kodiak region and will facilitate a new project north of Unimak Island during the walleye pollock A season. Expanded studies in the Kodiak region would build on the background work already accumulated by Wilson/Hollowed and Wynne/Foy surveys. Development of a Fishery Interaction program in the Eastern Aleutians will utilize the RACE winter acoustic survey data coupled with new information from commercial fishing vessels. The large trawling capability of the fleet coupled with the higher abundance of fish would allow for an interesting comparison to the Kodiak regional studies.

Implementing a two new studies of impacts of fishing on walleye pollock distribution and abundance will require two GS-12 fishery biologists and two GS-9/11 support staff. In 2003 and beyond, charter costs for a vessel will be anticipated.

Activities and Results in FY02

The position openings were announced. However, no additional staff were hired in 2002 because of the uncertainty in future budget projections.

Plans for FY03

There are no plans for expanding the Fisheries Interaction Team staff in FY03 with Steller sea lion research funds.

Evaluating the Effects of Fisheries on the Recovery of Steller Sea Lion Populations in the North Pacific (02FIT-13)

Principal Investigators: Graeme Parks and Marc Mangel, MRAG
Division: SD
AFSC Contact: Lowell Fritz
SSL Projects Database #: 2002-20

Project Description

Under the Endangered Species Act, Steller sea lion west of Cape Suckling, Alaska, are listed as endangered; east of Cape Suckling they are listed as threatened. In the core region from the Kenai Peninsula to Kiska Island, counts of adult and juvenile Steller sea lions have declined by about 80% since the population size was estimated in the late 1950s. Despite a considerable research effort, much of it still on-going, there remains substantial controversy over the cause of the decline, the role played by human activities, and the potential for human intervention to reverse the decline and promote recovery. There are a large number of hypotheses concerning the causes of the decline, ranging from the effects of a major oceanographic regime shift in the north Pacific in the mid- to late 1970s, to the ongoing localized depletion of prey species, most notably pollock, as a result of commercial fisheries. With the control of the latter generally considered to be playing an important role in the recovery of the Steller sea lion, management interventions are already underway, including modification of fishing activities in specific areas and fisheries, such as closed areas around rookeries and haul-outs, closed seasons and catch allocations (NMFS 2001).

In this research effort we are proposing to develop quantitative options for discriminating between the range of hypotheses for the continued decline in the Steller sea lion population. In this regard, we note the following key issues:

- The effect of past fishing may, or may not be substantial by itself, but when considered cumulatively with other effects, such as the regime shift, may be enough to have caused the Steller sea lion population to decline;
- Modification of human activities, including modification of current and future fishing, may or may not be sufficient to arrest the decline in Steller sea lion and cause the population numbers to recover;
- A methodology is needed that permits prospective and ongoing evaluation of the consequences of alternative management measures of the rate of recovery of the Steller sea lion, such that the recovery is not compromised by an unacceptable amount.

This research effort will therefore develop models designed to provide advice on experimental and monitoring procedures that will support the quantitative evaluation of the benefits of alternative management interventions.

Activities in FY02

During FY02, a statement of work was prepared and a request for proposals was released. Two proposals were received and reviewed, and the contract was awarded to MRAG Americas, Inc. (Tampa, FL) on 5 September 2002.

Results From FY02 Work
None to date; contract awarded on 5 September 2002.

Plans for FY03
This work will be conducted in 2003 using FY02 funds. No FY03 funds are required for this project and none are proposed. Continuation of this work beyond 2003 will depend on the results of this project, which is scheduled for completion in December 2003.

Biophysical and Climate Studies

The biophysical/climate component of the Steller sea lion-funded research addresses specific hypotheses adopted by the Science Plan of the Alaska Fisheries Science Center to determine the cause of the decline of the western population of Steller sea lions. The hypotheses and funded research projects spanned the spatial range of acute local impact to chronic regional effects and the temporal range of paleo-oceanography and the recent past, to the present. A key component of the biophysical-climate investigations was the collaboration between the AFSC and NOAA/OAR PMEL in multi-disciplinary studies of atmospheric climate, physical oceanography, lower trophic level production, fish abundance and distribution, and Steller sea lion ecology at focal study sites in western Alaska. PMEL's efforts in FY02 included studies of climate-ocean-biological coupling in process-oriented experiments conducted at three key sites near Steller sea lion rookeries:

- Near Kodiak Island in conjunction with AFSC Projects 02FF-03, 02FF-04, 02SSL-08, 02PP-02, and 02FIT-07; University of Alaska's Gulf Apex Predator Projects 2001-149 through 2001-153; and SSLRI-funded fish assessment Projects 2001-14 and 2001-21;
- Near Unimak Island in conjunction with AFSC Projects 02FF-01, 02FIT-06, 02PP-01, and 02SSL-08; and
- In the Aleutian Islands in conjunction with AFSC Projects 02FIT-04, 02FIT-05, 02PP-01 and 02SSL-08; and the CIFAR Aleutian Passes Projects 2001-46 and 2001-47.

In addition, PMEL addressed regional issues of ecosystem change through modeling and retrospective studies of the coupling between the atmosphere and upper ocean.

To address critical biological aspects of the climate research, and to complement the work of PMEL, the AFSC funded an additional seven in-house biophysical-climate projects. The purposes of these studies were to:

- Examine whether past changes in climate or the ocean environment have either directly or indirectly affected availability of Steller sea lion prey (Projects 02BP-01, 02BP-02, 02BP-03, 02BP-04, 02BP-05);
- Develop indices of ecosystem status and trends that are directly or indirectly related to Steller sea lion population health, and improve forecast methods used by AFSC scientists to predict future ecosystem changes (Projects 02BP-01, 02BP-02, 02BP-07);
- Construct new modeling tools to help in the understanding of how fluctuations in climate could affect the dynamics of Steller sea lion prey populations (Project 02BP-03), and
- Purchase new upper ocean survey and assessment tools (Project 02BP-06) to conduct future Steller sea lion predator-prey studies at selected study sites.

In FY02, work began on each of the metrics development studies (02BP-01 and 02BP-02) and two of the three modeling projects (02BP-03 and 02BP-07; 02BP-05 did not commence in FY02 due to difficulties hiring suitable staff). Most of these projects were planned as multi-year efforts. With hiring of staff not finalized until well into the fiscal year, work was begun in FY02 but will not be completed until late 2004. The retrospective, paleoecological investigation of forage fish communities (Project 02BP-04) was funded and completed in FY02 and most of the equipment for upper ocean survey and assessment was purchased under Project 02BP-06 at the end of the fiscal year. Delivery is expected in early 2003.

Several projects were quick to produce results. Complex systems modeling (Project 02BP-03) began in May 2002 as soon as the funds were made available. Investigators have made a number of presentations of their results and have submitted results for publication. The Metrics Projects (02BP-01 and 02BP-02) will present preliminary results at the marine science symposium (Marine Science in the northeast Pacific) in Anchorage (January 2003). The major portion of tools needed for predator-prey process studies around Steller sea lion rookeries and haul-outs were purchased; target studies conducted in collaboration with the Fisheries Interaction Team will be conducted in the future as funding permits.

New Metrics for Ecosystem Change: Bio-diversity and Dynamics of Ichthyoplankton Assemblages (02BP-01)

Principal Investigators: Janet Duffy-Anderson, Kevin Bailey, Jeff Napp, Anne Matarese, Susan Picquelle and Bern Megrey
Division: RACE
SSL Projects Database #: 2002-08

Project Description

We are analyzing our 20+ years of ichthyoplankton, and 10+ years of zooplankton and physical data for use as metrics to evaluate long-term ecosystem change in the North Pacific ecosystem. The ichthyoplankton data set includes larvae of important Steller sea lion prey species. This will directly address hypotheses E1, E4, E5, and S1 of the Steller Sea Lion Research Plan. Plankton biomass and ichthyoplankton abundances/assemblages may be useful indicators of ecosystem change since perturbations are likely to be felt at lower trophic levels before effects are reflected at the top of the food chain (i.e., Steller sea lions). The metrics developed (Pelagic Ecosystem Metrics, PEM) will be new and innovative investigational tools, thus developing them will be an exploratory and multi-year process. Year 1 is dedicated to development of metrics using our ichthyoplankton time series. Additional years of support will be required as we implement metrics and add new variables (e.g., zooplankton displacement volume, zooplankton species information, information on chlorophyll levels, nutrients, climate, and abiotic data). The PEM are largely being developed and tested in the GOA because of our long time series there, but we intend to expand to the Bering Sea. Accordingly, we also requested support to develop and conduct a long-term investigation of ichthyoplankton and zooplankton assemblages in the Bering Sea. The site selected for this is near Unimak Island, south-west of the Sea Lion Rock rookery. This will assist us in establishing a baseline for evaluating the effects of future changes in that system.

Activities and Results FY02

Personnel

We hired a postdoctoral associate, Dr. Wiebke Boeing, who began work on 1 October 2002. Dr. Boeing has begun to examine the ichthyoplankton time series for geographic trends (abundance, assemblage structure, size information). She will then begin work on the development of quantitative indices based on these analyses which can be used to evaluate ecosystem shifts in the North Pacific.

We hired a Fisheries Biologist, Jennifer Lanksbury, who began work on 1 June 2002. Ms. Lanksbury is coordinating the recovery of zooplankton displacement volume data from 1985 to the present. This work involves overseeing the data entry process and error-checking all data. She will be coordinating getting the data entered in the appropriate databases (Ichbase, Biological Oceanographic Database) for use in the development of ecosystem indices.

Fisheries Biologist Christina Deliyanides has been working to retrieve and synthesize available historical ichthyoplankton data. To date, she has developed a compendium of ichthyoplankton cruises in the Bering Sea and will be retrieving similar data from the Gulf of Alaska and the west coast.

Field Work

We conducted an ichthyoplankton survey in the Bering Sea in the vicinity of Unimak Island, Alaska (12-21 May 2002), southwest of the Sea Lion Rock rookery. Unimak Island is a major spawning site for pollock on the eastern Bering Sea shelf placing large prey in the vicinity of the rookery. This work was needed to describe larval fish assemblages in the Bering Sea (slope, outer shelf, and middle shelf) in spring, and to establish a time series of ichthyoplankton data in the region. Ichthyoplankton data were collected with 60 cm bongo and neuston nets, and zooplankton data were collected with 20 cm bongo and CalVET nets. Seacat and CTD data on physical characteristics of the water column were also collected.

Purchases/Expenses

An Optical Plankton Counter was purchased for rapid analysis for zooplankton samples. The plumbing system required to do the analyses must be designed and built in FY03.

Computer has been purchased.

Ichthyoplankton and zooplankton samples from Bering Sea 2002 survey cruise have been sent to Poland for sorting and identification.

Statistician (S. Picquelle) participated in a workshop (Analysis of Marine Biodiversity and Assemblage Data for Environmental Assessment) in New Brunswick, Canada. Brought back new techniques for examining time-series data for use in ecological assessments.

Presentations

We presented a summary of our project at the Principal Investigators meeting of the Steller Sea Lion Coordinated Research Program held in Anchorage, Alaska, March 2002.

Participation in research supported by non-SSLRI funding resulted in a presentation at the 26th Annual Larval Fish Conference, Bergen, Norway. This research examines interannual variations in Bering Sea ichthyoplankton assemblages from cruises conducted east of the Pribilof Islands, and begins to analyze existing ichthyoplankton data from the Bering Sea for future use in the development of ichthyoplankton metrics for the region.

Plans for FY03

- Continue investigation into gradients in ichthyoplankton abundance/composition in the GOA. Relate observed patterns to other biotic and abiotic variables (gradients in zooplankton data, temperature).
- Use data generated from above investigation to develop ichthyoplankton metrics which which will incorporate ichthyoplankton species dynamics, bio-diversity, and species dominance. We will be examining adult spawning biomass data to examine feedbacks of ichthyoplankton and adult community dynamics and associated lags.
- Contribute to the investigation of interannual variation in composition and distribution of spring ichthyoplankton assemblages in the Gulf of Alaska in collaboration with other members of the FOCI group.

- Proceed with zooplankton displacement volume data recovery. Coordinate making data available in the appropriate databases (Ichbase, Biological Oceanographic Database) for use in the development of ecosystem indices.
- Proceed with developing a compendium of ichthyoplankton data/cruises in the Gulf of Alaska and the west coast.
- Conduct a cruise (May 2003) in the vicinity of Unimak Island in the Bering Sea to continue a time series of ichthyoplankton/zooplankton data collection in that region.

Anticipated Presentations

- Present preliminary results from the examination of geographic trends in GOA ichthyoplankton abundance, assemblage structure, and size data will be presented at Marine Sciences in the Northeast Pacific Symposium, Anchorage, Alaska, 13-17 January 2003. Plans for development of ichthyoplankton/zooplankton metrics based on these results will also be presented.
- Present final results of geographic trends analyses and associated metrics in GOA ichthyoplankton data at the 27th Annual Larval Fish Conference, Santa Cruz, CA, 20-23 August 2003.

Milestones in FY03

February 2003	Literature research, exploration and organization of ichthyoplankton data, classification of fish into guilds (feeding habits, habitat, physiology), gathering of historical environmental data (temperature, Pacific decadal oscillation, freshwater discharge, coastal upwelling index, wind mixing).
April 2003	Statistical exploration of ichthyoplankton data and relation to environmental variables (canonical correlation analysis, canonical correspondence analysis).
July 2003	Prepare manuscript and presentation of results
August 2003	Presentation of results at Larval Fish Conference.
September 2003	Start to apply dynamic linear modeling approach to data.

Feasibility of Using Ecosystem Metrics to Characterize the Status of the North Pacific Ecosystem and Detect Climate Change Signals (02BP-02)

Principal Investigators: Bernard Megrey
Division: RACE
SSL Projects Database #: 2002-09

Project Description
The objective of this project is to establish an in-house ecosystem status working group within the AFSC to assist with the identification of potential data sets, to assemble a suite of metrics for the North Pacific continental shelf ecosystem at aggregate, community, food web, single species, and system levels, to apply multi-variate and descriptive statistical techniques to communicate trends, magnitudes and relationships among key species and processes, and to investigate whether any of the metrics could be useful for the characterizing the status of the North Pacific ecosystem and detecting climate change signals. This directly addresses hypotheses E1, E2, E4, E5, and S1 of the Steller Sea Lion Research Plan.

Activities in FY02
Progress on the project was delayed due to funding uncertainty caused by the very late approval of the Science Plan and actual transfer of funds. Nonetheless, some progress was made. We were able to

- acquire computer and software;
- attend the meeting, International Congress on Aquatic Protected Areas in Cairns, Australia. Chaired session on How Good are Aquatic Protected Areas - Measuring Their Performance;
- advertise post-doctoral position;
- interview potential candidates; and
- hire JISAO Post-Doc, Dr. Franz Meuter.

Results From FY02 Work
During FY02, we completed position documentation, job advertising and hiring of a post-doctoral scientist who will be the chief researcher for this project. Dr. Franz Meuter will begin work during the first quarter of FY03.

Milestones in FY03

- Develop species richness, species diversity indices and multi-variate indices of species composition and apply it to the Bering Sea data sets.
- Update Meuter's 1999 GOA analysis by adding 3 new years of data.
- Take the biotic and abiotic indices and the newly formed indices and add human metrics (landings by species, revenues by species, number of trawls, trawl income, fishery restrictions and fishery area closures).
- Continue assembling data and information products.
- Perform statistical analysis of assembled data.
- Examine the feasibility of applying the Signal Detection Theory model to the Bering Sea and Gulf of Alaska data sets as a candidate ecosystem metrics analysis method.
- Present paper/poster at Annual PICES meeting

Complex System Dynamics and Climate Change (02BP-03)

Principal Investigator: Kevin Bailey
Division: RACE
SSL Projects Database #: 2002-10

Project Description

The pattern of dynamics of marine fishes and their response to climate change is influenced by complex processes occurring at different scales. The dynamics of fish populations may be a complex process within a larger complex adaptive system (a system that is to some degree self-organizing). Complex adaptive systems can be pushed into near-chaos and re-organization by perturbations such as climate change. Significant ecosystem changes and apparent reorganization of community structure have been associated with climate regime shifts in the Gulf of Alaska (GOA), and may have impacted Steller sea lions. These observations suggest behavior similar to complex adaptive systems. Our research on reorganization of community structure addresses hypotheses E1, E4, E6, and S1 of the Steller Sea Lion Research Program.

This proposal develops a collaboration between scientists at Alaska Fisheries Science Center (AFSC) and a world-renown ecology group at the University of Oslo, Norway, who specialize in the analysis of ecological processes to examine underlying causes of changes in dynamics and community structure, as well as the Complexity Group at the University of New Mexico. The principal collaborators in Norway are Drs. Nils Chr. Stenseth and Geir Ottersen. The principal collaborator at the University of New Mexico is Dr. Andrea Belgrano in the laboratory of Prof. James Brown. The research is facilitated by exchanges of scientists and by a postdoctoral scientist (Dr. Lorenzo Ciannelli). This collaboration has two main research components. The first is to be a comparison study of the response of Barents Sea cod to climate change with that of GOA and Bering Sea pollock and cod. We are particularly interested in exploring, for example, why is the importance of the cod/capelin linkage so strong in the Barents Sea and tied with climate change when it is virtually unknown in the Bering Sea and GOA? We expect that this will result in a major synthesis and a better understanding of marine fisheries community structure. Comparisons of the GOA and Bering Sea ecosystems with the Barents Sea ecosystem, where time series are much longer, could prove useful in determining the future of GOA and Bering ecosystems under the stress of climate change. The second phase of the collaboration is an exploration of the dynamics of key groundfish species, especially walleye pollock in the GOA and Bering Sea as a complex process and development of models to better understand factors underlying changes in abundance. Walleye pollock is an important item in the diets of Steller sea lions.

Activities in FY02

Personnel

Staff hired: Dr. Lorenzo Ciannelli, Postdoctoral Research Associate, JISAO, University of Washington.

Collaborations Established

- In February 2002 Dr. Andrea Belgrano from the Complexity Group at the University of New Mexico visited AFSC to discuss the project planning. Several cooperative projects were detailed.
- In May 2002 Dr. Lorenzo Ciannelli traveled to New Mexico to meet with Drs. James Brown and Andrea Belgrano to discuss future collaborations. Dr. Ciannelli presented two talks at the University of New Mexico.
- In August 2002 Dr. Bailey visited the laboratory of Dr. Nils Chr. Stenseth of the University of Oslo and Dr. Geir Ottersen of the Institute of Marine Research. Drs. Bailey, Ottersen and Stenseth discussed research plans and established a future collaboration.
- In September 2002 Dr. Ciannelli traveled to Oslo Norway where he stayed for 3 weeks doing collaborative research with Drs. Stenseth and Ottersen.

Presentations

Bailey, K.M., Ciannelli, L., and Agostini, V.N. Complexity and constraints combined in hybrid models of recruitment. 26th Annual Larval Fish Conference, Bergen, Norway, July 2002.

Ciannelli, L, Duffy-Anderson, J.T., Honkalehto, T., Bailey, K., Sogard, S., Springer, A., and Buckley, T. Distribution of age-1 and age-2 walleye pollock in the North Pacific: sources of variation, implications for higher trophic levels and climate change. 26th Annual Larval Fish Conference, Bergen Norway, July 2002.

Bailey, K.M., Ciannelli, L., Bond, N.A, Belgrano, A and Stenseth, N.C. (Invited) Recruitment of walleye pollock in a complex physical and biological ecosystem. 40th Anniversary of the Japanese Society of Fisheries Oceanography, Tokyo Japan, December 2002.

Ciannelli, L. Processes and scales affecting walleye pollock (*Theragra chalcogramma*) recruitment, in a complex physical and biological ecosystem. Presentation given to the Complexity Group, University of New Mexico, May 2002.

Ciannelli, L. Ecosystem Boundary of the Pribilof Archipelago: an application of Central Place Foraging Theory. Presentation given to the Complexity Group, University of New Mexico, May 2002.

Ciannelli, L. Processes and scales affecting walleye pollock (*Theragra chalcogramma*) recruitment, in a complex physical and biological ecosystem. Presentation given at the Zoology Dept., University of Oslo, Norway. August 2002.

Ciannelli, L., Belgrano, A., Bailey, K. and Stenseth, N.C. (Invited) Patterns and mechanisms of walleye pollock (*Theragra chalcogramma*) recruitment in the Gulf of Alaska. Ocean Sciences Meeting, Salt Lake City, February 2003.

Results From FY02 Work

Publications Prepared

Bailey, K.M., Ciannelli, L., and Agostini, V.N. (submitted) Complexity and constraints combined in hybrid models of recruitment. The Big Fish Bang: Proceedings of the 26th Annual Larval Fish Conference.

Duffy-Anderson, J.T., Ciannelli, L., Honkalehto, T., Bailey, K., Sogard, S., Springer, A., and Buckley, T. (submitted) Distribution of age-1 and age-2 walleye pollock in the North Pacific: sources of variation, implications for higher trophic levels and climate change. The Big Fish Bang: Proceedings of the 26th Annual Larval Fish Conference.

Bailey, K.M., Ciannelli, L., Bond, N.A., Belgrano, A., and Stenseth, N.C. (in review). Recruitment of walleye pollock in a complex physical and biological ecosystem.

Bailey, K.M., Hollowed, A.B., and Wooster, W.S. (submitted) Complexity in marine fisheries dynamics and climate interactions in the Northeast Pacific Ocean. Book chapter. Oxford Press.

Bailey, K.M. (In press). Complex processes in the survival of walleye pollock larvae and forecasting implications. Journal of Fisheries Science.

Publications Planned and In Progress

Bailey, K.M., Ottersen, G., Ciannelli, L. and Stenseth, N.C. A comparison of cod-capelin interactions in the Bering and Barents Seas: influence of landscape ecology and climate change on marine food webs.

Ciannelli, L., Chan, K.S. and Stenseth, N.C. Density-dependence and climate interactions in a marine fish, walleye pollock (*Theragra chalcogramma*) in the Gulf of Alaska.

Belgrano, A., and K. M. Bailey. Recruitment and complexity of marine fishes.

Ciannelli, L., Belgrano, A., Bailey, K. and Stenseth, N.C. (Invited) Patterns and mechanisms of walleye pollock (*Theragra chalcogramma*) recruitment in the Gulf of Alaska.

Discussion of results

We have outlined a new way of viewing recruitment of marine fishes in terms of complex interactions with climate, high frequency activating factors and low frequency constraining and dampening factors. Simple models using these concepts have successfully described the patterns and trends in recruitment of walleye pollock in the Gulf of Alaska. We also have produced novel model results showing the interaction of density dependence with climate change (SSLRP Hypothesis E1).

With regards to the other component of this study, which is comparing ecosystem interactions in the Barents Sea versus the Bering Sea and Gulf of Alaska, we have compiled data and proposed several strawman hypotheses for differences, especially with regards to cod-capelin interactions. We believe that sea lion declines are not simply explained by climate change. However, species interactions greatly accentuate the effects of climate change and differences in landscape ecology

also play a role in how different communities respond (Hypothesis E6). This research attempts to clarify these complex interactions.

Partly as a result of our discussions on complexity in marine ecosystems, one of our collaborators, A. Belgrano, is sponsoring a symposium on emergent factors in aquatic communities at the 2003 Ocean Sciences meeting.

FY02 Budget
All funds for travel and salary were committed to JISAO to support L. Ciannelli and travel for himself and collaborators. The contract to K. S. Chan at the University of Iowa is in place.

Plans for FY03
Excellent progress has been made on this project and international relationships with two world-renowned laboratories working in ecology, climate change and complex systems have been forged. This work will continue in FY03, but without Steller sea lion funding.

Biophysical Models of Pollock Recruitment Processes in the Western Gulf of Alaska (02BP-05)

Principal Investigators: Sarah Hinckley, Bern Megrey and Albert Hermann
Division: RACE, PMEL
SSL Projects Database #: 2002-12

Project Description

The objective of this study is to update an existing individual-based model (IBM) for the early life stages of walleye pollock in the western Gulf of Alaska (Hinckley, 1999), along with a Nutrient-Phytoplankton-Zooplankton (NPZ) model (designed to provide a dynamic food source for young pollock), and use these in (1) model experiments designed to examine recruitment processes in the western Gulf of Alaska pollock stock, and (2) to run the coupled IBM-NPZ model with a 20 year time series of physical model (SPEM). The research addresses Sea Lion Research Program hypotheses E1 and E4 which focus on walleye pollock, an important prey species. This suite of coupled biophysical models has the potential to enhance our understanding of recruitment for this stock of pollock by examining the effects of climate/physical factors, regime shifts and food resources on recruitment, both through designed model experiments and via a time series of model runs. This should be useful in managing this stock of pollock, both for the fisheries, and for the endangered Steller sea lion whose diet in the Kodiak area is dominated by pollock.

Activities in FY02

A post-doc was recruited for this project, but decided not to accept the offer once he arrived in Seattle. A computer and reference books were purchased.

Results From FY02 Work

Due to delays in receiving funding and consequent delayed hiring process, work has not started yet on this project. The post-doc to be hired will be responsible for the majority of the work done on this project.

Plans for FY03

In FY03, the new post-doc will arrive and begin the task of recoding the pollock individual-based model. Some recoding work may have to be done on the NPZ model as well. Research into new additions to the suite of models, to reflect current theories about control of recruitment in western Gulf of Alaska pollock will begin in FY03, as will incorporation of these new additions into the models. These may include the addition of prey of juvenile pollock and extension of the time period modeled for the NPZ model, and expansion of the juvenile stage component and the mortality component of the pollock IBM. By September 2003 we will have a completely rewritten version of the pollock individual-based model which has been recoded for efficiency, and will be in the process of making additions and updates to the model in preparation for producing a series of simulations of recruitment dynamics in the next year. No direct Steller sea lion funding is provided to this project in FY03.

Acquiring Modern Sampling Technology for
Site-Specific Steller Sea Lion Studies (02BP-06)

Principal Investigators: Jeff Napp, William Karp and Phyllis Stabeno
Division: RACE, PMEL
SSL Projects Database #: 2002-13

Project Description
An old and frustrating problem in conducting biophysical research in the oceans is our inability to sample the physics and biology on the same space and time scales. Study of sea lion prey and their food around structural fronts requires continuous sampling of the spatial distributions of temperature, salinity, fluorescence, zooplankton (small copepods up to euphausiids), juvenile and adult fishes. While fisheries acoustics can sufficiently quantitatively map the spatial distribution of acoustic backscatter while underway, obtaining continuous spatial distributions of the other variables during transects is not possible with the suite of instruments presently owned by the AFSC. Such a suite of instruments is needed to address SSLRP hypotheses: E2 and E3.

We propose to acquire and configure commercially available samplers and an undulating towed vehicle to make simultaneous, continuous underway quantitative measurements of physics, chemistry and plankton. This new tool would be paired with presently owned, ship-mounted, hydroacoustics technology for Steller Sea Lion site-specific studies (e.g., 02FIT-07 or 02FF-04). PMEL (P. Stabeno) will purchase the towed undulating vehicle (ScanFish or Nu-shuttle), complete with a basic set of sensors (temperature, salinity, and fluorescence), computer controller, cable fairing and software. We will contribute three additional sensors: Laser Optical Plankton Counter (OPC), Continuous Plankton Recorder (CPR), and a Tracor Acoustic Profiling Systems (TAPS; purchased by GLOBEC).

Activities in FY02
Purchases of most major systems were made in FY02 despite the late acceptance of the Science Plan. Bid solicitation for the towed vehicle occurred during the last quarter of the fiscal year, and a contract was signed with MECCO, Inc. to provide a WS EnviroTech U-Tow Mark III. Unfortunately due to the late determination of the tow vehicle we (PMEL and AFSC) were not able to separately purchase the tow winch and cable. Delivery of the vehicle will occur around the first of the calendar year. Sea trials are included in the price of the contract, but ship costs must be paid for by NOAA. The contract includes integration of the following biological sensors: PAR, fluorometer, TAPS, and LOPC. It was decided during the process not to purchase a Continuous Plankton Recorder at this time as the priority for this instrument was much lower than the others. The APS (purchased by GLOBEC) was delivered in September and delivery of the LOPC is expected in late February 2003.

Results From FY02 Work
None at this time as the system has not yet been delivered.

Plans for FY03
We are currently working with vendors to get specifications for a matched set of winch and cable. Purchase of these is dependent on the length of the FY03 Continuing Resolution and other budget

factors. Sea trials for the towed body and integrated sensors will likely take place in the second or third quarter of FY03. If there are no major problems we will examine the feasibility of doing a pilot study in late summer or early fall. No Steller sea lion funding for this project was awarded in FY03.

Ecological Forecasting of Walleye Pollock Recruitment in the Gulf of Alaska and Bering Sea Based on Ecosystem Status and Climate Change Trends (02BP-07)

Principal Investigators: Bernard Megrey and S. Allen Macklin
Division: RACE, PMEL
SSL Projects Database #: 2002-14

Project Description
The objective of this project is to examine the adequacy of an existing recruitment prediction scheme, implement improvements, extend the prediction scheme into the Bering Sea, incorporate more ecosystem and climate change data into the analysis, and move the forecast activity forward with the aim of improving stock assessments, building sustainable fisheries, advancing our knowledge of forage fishes, and protecting endangered species. This work addresses Steller Sea Lion Research Plan hypotheses E1 and E4.

Activities in FY02
Progress on the project was delayed due to funding uncertainty caused by the very late approval of the Science Plan and actual transfer of funds. Nonetheless, some progress was made. We were able to

- acquire a computer and software for the project,
- advertise the post-doctoral position,
- interview potential candidates, and
- hire JISAO post-doctoral fellow, Dr. Yong-Woo Lee.

Results From FY02 Work
During FY 2002, we completed position documentation, job advertising and hiring of a post-doctoral scientist who will be the chief researcher for this project. Dr. Yong-Woo Lee will begin work during the first quarter of FY03.

Plans for FY03

- Assess accuracy of current forecasting technique.
- Assemble biophysical data sets.
- Examine alternative forecasting methods.
- Apply statistical procedures to collected data sets.
- Present paper at annual PICES meeting in Seoul, Korea.

Forage Fish Studies

The AFSC Forage Fish research program addresses concerns regarding availability of forage species to sea lions. It is also designed to improve our understanding of the biology, ecology, and population dynamics of forage fish. A suite of nine Steller sea lion-related forage fish studies was conducted by AFSC scientists in FY02*. Some of these studies were continuations and expansions of ongoing work, others were retrospective analyses of previously-collected data, and several new studies were initiated.

Planning and equipment purchases for a comprehensive study (02FF-01) of seasonal patterns in Steller sea lion prey abundance and nutritional quality near the Krenitzen Islands (part of the eastern Aleutian Islands in western Alaska) was begun in FY02. It was anticipated that field work to determine the vertical and horizontal distribution of sea lion nutritional energy would commence in FY03. However, due to budget constraints in FY03, this project was put on hold and will be re-initiated if and when resources for it are made available. This project was designed to be one component of a coordinated, multi-disciplinary study of sea lions, fishery interactions, and hydrography of the eastern Aleutian Islands, which complemented similar efforts occurring near Kodiak and Seguam Islands.

Steller sea lion research funds supported the expansion or initiation of three forage fish survey efforts in FY02. The first (02FF-03) was a small mesh index survey of nearshore areas in the Gulf of Alaska, a time series which has been useful in tracking temporal and spatial changes in the abundance of key forage species. The second (02FF-04) was an examination of the distribution and productivity of pollock and smelts in the vicinity of seven sea lion haul-outs and rookeries in the western Gulf of Alaska in relation to zooplankton abundance and physical/hydrographic features. In addition, an investigation of the early life history of eulachon and the development of spawning stock abundance estimation techniques were initiated in an area (Berner's Bay in Southeast Alaska) utilized by sea lions for foraging (02FF-10). This study was done in conjunction with the U.S. Forest Service and with researchers at the University of Alaska Fairbanks in Juneau (Jamie Womble and Mary Willson, SSLRI project 2001-28).

To complement the field studies of forage fish, FY02 Steller sea lion funds also supported:

- analyses of ichthyoplankton collections from the Gulf of Alaska (02FF-06) and logbook observations of salmon foraging behavior from Alaska salmon troll fisheries (02FF-05), which provided valuable insights on early life history and distribution of forage species as well as the possible effects of climate change on North Pacific fish community structure,
- enhanced training for observers to improve forage fish bycatch mortality estimates and further advance our knowledge of their temporal and spatial distribution (02FF-07), and
- analysis of previously-collected groundfish (02FF-02) stomach samples to provide information on groundfish utilization of forage fish, indices of forage fish abundance and predation mortality.

*The study, Age and Growth of Forage Fish (02FF-09), was not commenced in FY02 and was not re-initiated.

Information obtained as a result of the research initiated or augmented in FY02 will be synthesized by a forage fish stock assessment scientist (02FF-08). Mark Nelson will be responsible for characterizing small and large scale aspects of the population dynamics of capelin, eulachon, and other species, which will provide important insights into their availability to sea lions, and seasonal and interannual changes in abundance.

Krenitzen Predator-Prey Study (02FF-01)

Principal Investigator: Michael Sigler
Division: Auke Bay Laboratory, RACE
SSL Projects Database #: 2002-21

Project Description
The objective of this work is to test the hypothesis that sea lion prey diversity and seasonality are related to Steller sea lion population trends in the vicinity of the Krenitzin Islands.

Steller sea lion abundance is decreasing in central and western Alaska, but increasing in Southeast Alaska. Hypotheses for the decline include decreased prey availability and lower diet diversity. This study proposes to conduct seasonal measurements of prey abundance and nutritional quality near the Krenitzin Islands in western Alaska. This study is a comparison to similar studies around the Kodiak Archipelago and in Southeast Alaska.

The following questions will be addressed:

- What is the vertical and horizontal distribution of nutritional energy?
- Is sea lion foraging influenced by prey density and spatial pattern?
- Is sea lion foraging influenced by diel changes in prey availability?
- Is sea lion foraging influenced by seasonally available prey?

Methods employed will include the following:

- Measure pelagic prey abundance using acoustic and mid-water trawl surveys.
- Measure epipelagic prey (e.g., salmon) abundance using surface trawl surveys.
- Measure demersal prey (e.g., cod) abundance using bottom trawl surveys.
- Measure nearshore prey (e.g., sand lance) abundance using beach seine and ROV surveys.
- Record observations of sea lion foraging (diving) and measure prey abundance.
- Measure prey nutritional quality using chemical analyses.
- Infer diet from scat collections (NMML).
- Measure sea lion haul-out attendance using aerial surveys (NMML).
- Compare results to sea lion foraging area measurements from satellite tagging (ADF&G, NMML).
- Compare results to Kodiak Archipelago Sea Lion Prey Study (UA) and Southeast Alaska Sea Lion Prey Study (ABL).

Activities in FY02
Equipment was purchased (e.g., hydroacoustic survey equipment; midwater, surface and bottom trawls). Vacancies were advertised and applications received, with new hires originally scheduled to start employment by 10/1/2002. However no hires have been completed as of 9/17/2002 because of uncertainty about future funding. A study plan was prepared. A major planning meeting occurred on 9/24/2002. The purpose of the meeting was to bring together researchers with field experience in the study area to finalize timing and boundaries of the study area. These field scientists include sea lion biologists, a pollock acoustician, a groundfish a survey biologist, and a salmon survey biologist.

Results From FY02 Work
The purpose of FY02 activities was to purchase equipment and hire and train personnel. No field activities were planned for FY02.

Plans for FY03
Because of reductions in Steller sea lion funding in FY03, this project was suspended and will be resumed in FY04 contingent on funding.

Seasonal Food Habits of Forage and Predators (02FF-02)

Principal Investigator: Patricia Livingston
Division: REFM
SSL Projects Database #: 2002-22

Project Description

Forage fish stock assessments require information on life history parameters such as growth and natural mortality. Stomach sampling and analysis of groundfish and forage fish will provide: 1) information on groundfish utilization of forage fish, which can also provide indices of forage fish abundance and predation mortality, especially in the GOA where capelin is a prey of several groundfish species, and 2) information on the prey and stomach fullness of forage fish, how those might vary by area, and the relationship between those and forage species distribution and growth. These activities require additional stomach lab personnel to analyze groundfish and forage fish stomach contents obtained from large-scale EBS, AI, and GOA summer surveys that cover the entire shelf, winter surveys, and the newly developing site specific studies in Kodiak and other sites. Samples from the 2000 EBS and 2001 GOA summer surveys and site specific studies will be analyzed and an historical index of capelin consumption by groundfish species will be developed. Further forage fish food habits collections will be initiated and once sufficient samples have been obtained, diet in a variety of habitats will be described and the relationship to forage fish local abundance and condition factor, oceanographic parameters and prey abundance will be investigated when information on those parameters are known. The forage fish food habits studies here are complementary to the forage fish studies proposed by FOCI, which will be looking at retrospective analysis of forage fish diet in a sampled area between the Shumagins and Shelikof Strait, and the proposed forage studies in the EBS by the Ocean Carrying Capacity program at the AFSC's Auke Bay Laboratory. We will focus on the Kodiak site specific area and broad shelf survey results from the GOA. The proposed FOCI zooplankton sampling at the Kodiak site will be a necessary addition to the site specific samples at that site to understand forage fish distribution and diet relative to biophysical factors. The groundfish and forage fish sampling and lab analysis activities are also essential for supporting multispecies and ecosystem modeling efforts of NMML, RACE, and REFM.

Activities in FY02

The primary activity in FY02 was to amend the JISAO project "Marine Biological Interactions in the North Pacific" to include the funding to accomplish the proposed stomach analysis. Stomach analysis of the 2000 EBS and 2001 GOA summer surveys and the 2002 Kodiak FIT study will be accomplished once the funding is available to JISAO researchers.

Sampling instructions were amended for the Kodiak FIT study to include sampling of capelin in addition to walleye pollock for stomach analysis purposes. A total of 434 pollock and over 274 capelin were collected during this study in 2002 for stomach analysis.

Results From FY02 Work

Results are pending completion of stomach analysis that will be performed in FY03.

Plans for FY03

Stomach analysis of groundfish and capelin samples collected during the 2000 EBS and 2001 GOA summer surveys and the 2002 Kodiak FIT study will be completed. An historical index of capelin consumption by groundfish predators will be derived once these samples are analyzed and a draft report summarizing the results will be produced. Stomach collections of predators will be made during the 2003 GOA and EBS summer shelf surveys and of pollock and capelin during the 2003 Kodiak FIT study. Work on this project continues, though without direct FY03 Steller sea lion funding.

Small Mesh Surveys (02FF-03)

Principal Investigator: Paul Anderson
Division: RACE
SSL Projects Database #: 2002-23

Project Description

This project supplies information integral to testing the environmental change hypothesis as one of the possible contributors to Steller sea lion population decline in the Gulf of Alaska (GOA). Climate patterns in the GOA changed abruptly near the end of the decade of the 1970s and is perhaps reverting again, and possible impacts on the trophic structure and marine species assemblages need to be studied. Small mesh trawl survey data collected from fishery surveys, conducted near continuously in the GOA since 1953, provides the only long-term data set that describes the benthic and epi-benthic community structure over a large portion of the GOA from Kachemak Bay to the eastern Aleutian Islands. It has been well documented that environmental change in the GOA drives changes in the composition and relative abundance of marine species. This project provides data that may lead to understanding driving mechanisms and development of prediction models of species composition change and its impact on Steller sea lion production in the GOA.

The objective of this work is to moderately expand ongoing small-mesh trawl survey sampling of the central and western GOA. Current effort averages between 22 to 80 tows per year for the entire survey area shown in the attached map. We propose to initiate annual sampling at the rate of 80 to 120 tows. Sampling will be conducted with a 61 foot high opening shrimp trawl which has been used by ADF&G and NMFS since 1972. We will collect: number, weight, condition, maturity, life history stage of species data of all species sampled; samples for determining diet of targeted species diets; water column temperatures. Sampling will occur late summer to fall sampling in keeping with the historical database. Products will deal primarily with the long-term changes, if any, in the species community structure of the GOA, background for observed dietary changes, and provision of an ecosystem considerations report to the NPFMC periodically as data and analysis are available.

Activities and Results From FY02 Work

A contract for conducting an expanded survey in the bays around Kodiak Island and along the south side of the Alaska peninsula was developed. A work plan was produced for the contract and deliverables were determined. Standard sampling protocols and data management for the project will be followed as they have been since 1972 in the survey series. Additional sampling for capelin was added to satisfy needs of other projects. The sampling plan was designed with consultation of the ADF&G personnel from the Kodiak office, after review of past survey results. The plan calls for re-sampling some of the same strata that were sampled in 2001 and expanding coverage westward to Morzhovoi Bay on the Alaska peninsula. The spatial expansion of the survey is needed to better understand the spatial significance of recently observed species changes. No new personnel were added as a result of budget limitations. This severely limited the scope and intensity of analysis of the data and the results.

Preliminary Analysis of 2001 Data

A major part of this project was to analyze past data to detect trends, if any, in the composition of the benthic and epi-benthic community structure as measured by this survey series. Data from surveys conducted in 2000 and 2001 were added to the historical database after careful checking and editing. The entire updated and corrected database for this project is available on CD-ROM upon request from the project's principal investigator.

On the surface, it seems that the central GOA is in the early stage of a significant shift in the marine community structure. However, it would be misleading to characterize this preliminary data analysis in this way. The reason for this are complex and requires more analysis of spatial species distribution patterns and expanded survey sampling. Most of the data which have recently been added to the database came from the 2001 ADF&G small mesh survey (96 tows). This survey was concentrated mostly around Kodiak Island and the adjacent Alaska Peninsula area. Survey results from this area did show changes occurring in the species community structure. However another survey conducted by NMFS to the west along the Alaska Peninsula (Pavlof Bay, 23 tows) showed none of the changes evident in the Kodiak area. This spatial partition in changing community structure needs to be investigated and better understood. Fortunately, funding has been obtained through Steller sea lion research funds this year to resurvey areas in the Kodiak Island region and to expand the survey effort westward along the Alaska Peninsula this fall (September through October).

Furthermore, in depth analysis of the data at hand will be needed to discern any possible spatial patterns amoung species groups that may exist. Complementary surveys sampling the same locations in the same manner will be conducted again this fall to help us understand the recent results and any possible restructuring in the species community that may currently be underway.

Pandalid Shrimp

Pandalid shrimp increased notably during the 2001 survey. Average catch per tow for all pandalids combined increased to over 75 kg/km. Relative pandalid shrimp abundance at this level last occurred in survey results twenty years ago in 1981. The years 1995 and 1998 (the most comparable sampling effort to the 2001 survey) indicated only 20 and 13 kg/km, respectively.

Of all the pandalid species the most significant recovery has occurred with *Pandalus goniurus*. This species which has a comparatively shallow depth distribution and had became almost functionally extinct in this region of the GOA increased in certain shallow bays. Overall abundance was 7.9 kg/km the highest CPUE recorded for this species since 1984 (10.3 kg/km). Other pandalids showed high relative abundance in 2001; *P. borealis* (61.2 kg/km), *P. hypsinotus* (1.3 kg/km), and *Pandalopsis dispar* (3.5 kg/km). All of these values for the respective species approach the abundance found in the early 1980s for the survey series. Therefore survey results support the notion that pandalid shrimp, as a group, are showing signs of regaining importance in the community structure of the GOA. Additionally, a recent publication points to pandalid species as a prime indicator in identifying changes in the larger benthic and epi-benthic GOA community structure. Pandalid shrimp through their diel vertical migration habits integrate water column properties from surface to bottom and recruitment appears to have a close linkage to changes in this integrated environment. Recovery of pandalid shrimp populations and concomitant changes

in the community structure should be closely monitored in the GOA with appropriate sampling methodologies.

Gadids

In 2001 the relative abundance of all gadids (codes 21700 through 21749) declined to 111.8 kg/km the lowest abundance in this survey series since 1990 when gadid abundance was at 42.9 kg/km. In contrast, juvenile walleye pollock (code 21741), fish less than 20 cm in length, are at there highest relative abundance 11.4 kg/km in 2001 since 1983 when they registered 10.2 kg/km. Walleye pollock both adults and juveniles combined showed their lowest abundance since 1990. Pacific cod also reached their lowest abundance since 1990 (4.2 kg/km) falling to 12.3 kg/km in 2001.

Pleuronectids

Flatfish as a group averaged 121.2 kg/km during the 2001 survey. This result did not vary significantly from the 1999-2001 average of 125.7 kg/km for the species group. Individual species like arrowtooth did show moderate increases in abundance increasing to 44.8 kg/km, the highest CPUE recorded for this species in the last thirty years. Flathead sole and yellowfin sole showed no significant change.

Osmerids

Osmerids as a group (species codes 23000 through 23099) increased to 2 kg/km in 2001. This is the highest relative level of abundance measured since 1992 when 2.2 kg/km was caught. Eulachon was found at an average 1.9 kg/km during the 2001 survey. This is the highest level observed since 1992 when they had an average catch of 2.1 kg/km. Capelin remained at relatively low levels of just 0.1 kg/km, yet this was the highest relative abundance measured since 1989 when they were caught at an average of 0.12 kg/km. Capelin still remain well below their historic peak abundance in 1980 in the GOA when a peak abundance in the survey series was noted of 16.8 kg/km.

Conclusion

Species changes observed in the Kodiak area were striking, and certainly argue that the system oscillates between two general community structures: one dominated by cod and some flatfish species and another dominated by shrimp, forage fish, and possibly over time with other crustaceans (crab). There appears to be only two community structures that have evolved to take best advantage of the alternating oceanographic conditions in this large region. There is no evidence that changes will revert to yet some unknown or new community structure. This finding, if validated by additional work, will be critical in developing synthesis models to aid in predicting changes in the GOA marine ecosystem over a large area.

There appears to be a significant change, at least in the Kodiak Island region, of community dynamics in the GOA. The persistence of these observed data can only be judged after continuing the survey series for many years. There are no instant answers with the collection of a long-term data series. Only hints of driving mechanisms and the development of usable hypothesis will be the real payoff of this project in the future and for monitoring the current state of the marine ecosystem. This data series may well prove useful in exploring simulation modeling to help explain changes in the observed trophic structure. Unfortunately there is no long-term

commitment to continuing the data collection by the resource agencies currently engaged in this survey series. Historical project data has proved useful in developing a conceptual framework for exploring plausible explanation of species change at many trophic levels in the GOA. If this is deemed useful, than long-term funding must accompany the sampling scheme to be of any useful long lasting value for advancing the state of understanding the of GOA ecosystem.

Plans for FY03

Changes in the temporal and spatial aspects of the GOA species community structure as described in this preliminary analysis needs to be better understood. Hypothesis regarding the apparent rebuilding of pandalid shrimp and osmerid stocks mainly relate to changing conditions in the water column. There appears to be a close linkage of these animal groups to changes in water column temperature. Additionally measurement of water column properties in the bays where these animal groups appear in their greatest abundance appears to warranted. The deployment of oceanographic collecting moorings in prime areas should be considered for possible future funding. Spatial and temporal modeling of data from the project database and relevant oceanographic data will be needed to further develop hypothesis of the mechanisms that control these broad changes in the GOA. Work on this project continues, though without direct FY03 Steller sea lion funding.

Climate Variability, Hydrography, and Zooplankton Availability: What Determines Forage Fish Abundance Near Sea Lion Rookeries and Haul-outs? (02FF-04)

Principal Investigators: Matthew Wilson, Janet Duffy-Anderson, Kevin Bailey and Jeff Napp
Division: RACE
SSL Projects Database #: 2001-121

Project Description

Steller sea lions are in decline and evidence indicates a link between their nutrition and survival. Pollock and smelts are important in sea lion diets due to their abundance, availability, and/or energy content. Sea lion diets exhibit considerable spatial and temporal variation, which likely reflects variation in prey production and availability. However, production and availability of these fishes is not well understood. Our research will contribute information on the distribution and productivity of these fishes within the main pollock nursery amidst seven sea lion haul-outs and rookeries in the western Gulf of Alaska. Specifically, we will: 1) analyze fish distributions and diets in relation to zooplankton abundance and physical/hydrographic features, and 2) model spatial-specific bioenergetic food consumption of dominant fish relative to hydrography and plankton abundance. We will also examine over-winter changes in the caloric content of juvenile pollock. Winter conditions increase the nutrient demand of juvenile and adult female sea lions with possible deleterious effects on survival and the ability of females to nurture dependants.

Activities in FY02

Two analytical activities were completed:

- Retrospective analysis of geographic variation in the ecology of age-0 walleye pollock (*Theragra chalcogramma*) off east Kodiak Island, Alaska during 1993. Methods developed in this analysis are relevant to future analysis of data collected with partial support from Steller Sea Lion research funds.
- Preliminary analysis of distribution, size, and diet data of age-0 pollock and capelin from the September 2000 and 2001 sampling. Although preliminary, the results were presented at the FOCI seminar series, January 2002 (oral presentation), and at the Western Groundfish Conference, February 2002 (oral presentation).

Three cooperative research activities were completed or initiated:

- Dissections of capelin collected during September 2001, to excise the stomach and otoliths, involved cooperative work with Dr. Anne Hollowed (NMFS) and Ms. Jessica Taylor (NOAA-Student Intern).
- Several meetings were held with Dr. Dave Beauchamp (UW School of Aquatic and Fisheries Sciences/Faculty) as part of the post-doctoral selection process, and to discuss our plans for the bioenergetic aspects of the present grant.
- Participation in research supported by non-Steller sea lion funds resulted in two co-authored manuscripts submitted or in-press at peer-reviewed journals. This other research focuses on the relationship between juvenile pollock and hydrographic fronts; as such, it directly relates to our Steller sea lion-funded research. Cooperative research projects greatly facilitate the exchange of ideas with other laboratories.

We presented a summary of our planned research and its relevance to Steller sea lion nutrition during a two-day workshop convened by Dr. William Karp, Seattle, Washington, January 2002, and again at the Principal Investigators meeting of the Steller Sea Lion Coordinated Research Program held in Anchorage, Alaska, March 2002.

Two staff were hired:

- Andre Buchheister (NOAA/NMFS) recently completed his Bachelor of Science, Duke University, North Carolina, USA. His responsibilities include assisting with trophic studies of forage fishes, overwintering study of juvenile pollock, data management, and field sampling. Andre started work at the AFSC on 26 August 2002.
- Jari Pääkkönen (UW School of Aquatic and Fisheries Sciences/JISAO) recently completed post-doctoral work at the University of Jyväskylä, Finland, where he received his Ph.D. His responsibility is to develop and apply bioenergetic models as a means to better understand the flow of trophic energy through the coastal pelagic fish community. Jari also started at the AFSC on 26 August 2002.

Additions to existing facilities were necessary to accommodate the new hires. This included the purchase of dissecting tools, software (Fish Bioenergetics 3.0), a microbalance, and disposables (e.g., centrifuge tubes, preservatives, etc.).

Sample processing and data preparation comprised a large part of the FY02 activities:

- For the 2000 collections, 90% of the age-0 pollock stomach content examinations were completed during this fiscal year. Data from these examinations will enable determination of geographic variation in feeding intensity and diet composition which, in turn, required for subsequent development of geographically explicit bioenergetic models, energy budgets, and trophic vectors.
- For the 2001 collections, all age-0 pollock and capelin stomachs and otoliths were excised, and individual fish length and weight data were measured.
- Editing and standardization of the trawl data is 80% complete.
- For the overwintering study, all age-1 pollock stomachs and otoliths were excised, and individual fish length and weight data were measured.

In addition, the following contributions or manuscripts were produced:

- Manuscript entitled, "Population condition of juvenile walleye pollock (*Theragra chalcogramma*) near Kodiak Island, Alaska: geographic variation in nursery suitability" is currently underdoing peer review and will be submitted to the journal *Marine Ecology Progress Series*.
- Contributed to the Ecosystem Chapter of the Stock Assessment and Fishery Evaluation document, 2002.
- Contributed to the Alaska Fishery Science Center Quarterly Report. (http://www.afsc.noaa.gov/Quarterly/quarterl.htm), July-August-September 2002.
- Contributed to the manuscript entitled, "Interannual and regional variability in distribution and ecology of juvenile pollock and their prey in frontal structures of the Bering Sea" (In Press, *Deep-Sea Research*, Part II).

- Contributed to the manuscript entitled, "Size dependent, spatial and temporal variability of juvenile walleye pollock (*Theragra chalcogramma*) feeding at a frontal region in the southeast Bering Sea" (submitted, *Marine Ecology*).

Results From FY02 Work

Results of the retrospective analysis are summarized in a manuscript entitled "Population condition of juvenile walleye pollock (*Theragra chalcogramma*) near Kodiak Island, Alaska: geographic variation in nursery suitability", which is currently undergoing peer review. This study is relevant to our on-going study of sea-lion prey production for several reasons: 1) the analytical methods that were developed and applied to the data will be used in analyzing the September 2000 and 2001 data due to similarity in structure and content, 2) the results indicate that meso-scale geographic variability among age-0 pollock relates to zooplankton density, which in turn reflects topographic influences on hydrography, this pertains to questions about geographic variation in the production of sea lion prey, and 3) similarity between these studies will enable comparison of ecological features of the Gulf ecosystem between two different geographic areas thought important in the production of sea lion prey. We recognize the importance of geography in understanding not only climate effects on the marine ecosystem, but also as a factor in determining the scale of influence.

Analysis of distribution, size, and diet data of age-0 pollock and capelin revealed high potential for competitive interaction between these fishes. Both of these fishes are important sea lion prey, but they greatly differ in energy content. Because competition can result in disjunct distributions of abundance and alterations in the flow of trophic energy, these results contribute to our understanding of how competition among prey species affect their availability to sea lions. Prey availability and quality are of particular concern because the decline in sea lion populations is hypothetically due to nutrient deficiency.

Plans for FY03

The following research projects will be continued with FY03 Steller sea lion funds.

- Community analysis of the plankton and micro-nektonic fish community in the western Gulf of Alaska
- Age-0 walleye pollock and capelin in the western Gulf of Alaska: potential competitive interaction?
- Seasonal changes in whole body energy content and condition of juvenile walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska.
- Bioenergetic budgets and trophic vectors of coastal, micro-nektonic fishes in the western Gulf of Alaska.

Results from these projects will be published in peer-reviewed journals. In addition, results will be presented at the EVOS-GEMS/GLOBEC/NMFS Steller Sea Lion Symposium, Anchorage, AK, 13-17 January 2003, and at the 27th Annual Larval Fish Conference, Santa Cruz, CA, 20-23 August 2003.

Field sampling will be conducted during a 3-week period in September 2003. The sampling strategy will be similar to that previously employed. The purpose of the sampling includes, but is not limited to, the collection of data for testing hypotheses and models that result from the first two years of field work.

Milestones in FY03

- Age-0 pollock and capelin gut content analysis from 2001 will be completed and ready for input to bioenergetic models, and presentation in a manuscript on potential competitive interaction.
- A manuscript, "Area and site-specific variation among pelagic juvenile walleye pollock (*Theragra chalcogramma*): multivariate evidence of geographic variation in habitat suitability" will be submitted for publication.
- A manuscript of the "Diet and feeding biology of juvenile walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska and the effect of geographic variation on growth" will be finished by August 2003. This manuscript will be submitted to a peer reviewed journal. A bioenergetics approach is used to estimate the effect of geographic variations in diet on the growth rates and food consumption of juvenile walleye pollock. Results will also be presented in the 27th Annual Larval Fish Conference at Santa Cruz, CA, 20-23 August 2003.
- Juvenile pollock energy density estimation will be complete, and preparation of a manuscript on seasonal variation in pollock condition and energy density will begin.
- The final season of field operations will be conducted, data to be used in model verification.

March 2003	Literature search (diet energy contents), data analysis (fish size effect and daily variation in diet), determination of geographic areas, model development, abstract to 27th Annual Larval Fish Conference
April 2003	Model development & testing, statistical analyses
June-July 2003	Preparation of the manuscript "Diet and feeding biology of juvenile walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska and the effect of geographic variation on growth
August 2003	Presentation in Larval Fish Conference

Our study will provide a better understanding of oceanographic effects on the abundance, composition, and production of pelagic fish species eaten by sea lions. The study directly relates to sea lion foraging because 1) nutritional stress is a suspected major contributor to Steller sea lion population declines, 2) the study area encompasses many sea lion rookeries and haul-outs, and 3) our target fish species dominate regional sea lion diets and are important in sea lion energetics.

Retrospective Analysis of Ichthyoplankton Data from the Gulf of Alaska: Understanding Ecosystem Dynamics in Relation to Steller Sea Lion Decline (02FF-06)

Principal Investigators: Janet Duffy-Anderson, Miriam Doyle, Anne Matarese, Morgan Busby, Kathy Mier and Susan Picquelle
Division: RACE
SSL Projects Database #: 2001-120

Project Description

The Recruitment Processes Program has compiled an extensive (25 year) ichthyoplankton, zooplankton and oceanographic data set that provides a unique opportunity for integrated examinations of spatial and temporal trends in the pelagic ecosystem of this region. Examining the relationship between observed patterns in ichthyoplankton abundance and the oceanographic environment in the Gulf of Alaska (GOA) can help us to identify potential sources of fluctuations in fish populations that may relate to the survival of Steller sea lions. Of particular interest are species of forage fish and groundfish that are an important source of food for top predators such as Steller sea lions in the GOA ecosystem. We are using this data set to examine early life history dynamics of individual forage and ground fish species including capelin, Atka mackerel, Pacific sand lance, Pacific cod and several flatfish species. In addition, interannual trends in springtime abundance and distribution of the dominant ichthyoplankton taxa are being investigated in relation to trends in adult biomass and the oceanographic environment.

The Steller Sea Lion Research Program hypothesis being explored is E4: Have environmental changes altered the composition of the fish community, reducing the abundance, availability, or quality of prey resulting in decreased survival or births of sea lions through nutritional stress?

Activities and Results in FY02

Seasonal and interannual variation in occurrence, abundance and distribution patterns of individual, numerically dominant species of fish eggs and larvae in the plankton of the Gulf of Alaska continue to be investigated. Interannual and decadal trends in abundance and distribution patterns are being related to temporal variation in the oceanographic environment of this region, including atmospheric/oceanographic regime shifts that tend to occur on a decadal scale. The hypothesis being addressed is that environmentally induced fluctuations in Gulf of Alaska fish populations (some of which are sources of food for Steller sea lions) may be modulated through the early life history dynamics of these fish and reflected in temporal trends in abundance and distribution of ichthyoplankton species. The investigation of interannual variation in Gulf of Alaska ichthyoplankton is divided into three components: 1) interannual trends in springtime abundance, 2) interannual trends in timing of spring production, 3) interannual trends in springtime spatial patterns. Each component is ongoing and being developed into a manuscript for publication.

A retrospective study of the early life history of capelin in the northeast Gulf of Alaska, based on the above ichthyoplankton data time series, has been completed and is published in the ICES Journal of Marine Science, autumn 2002 (see below). A review study is underway of the early life history of the forage fish species Pacific sand lance (*Ammodytes hexapterus*) in the Gulf of Alaska, also based on our ichthyoplankton data time-series. In collaboration with Rebecca Reuter

and Sandra Lowe of the Resource Ecology and Fisheries Management Division at AFSC, a manuscript on the early life history of Atka mackerel in the Gulf of Alaska is being prepared for submission to the journal *Fishery Bulletin*.

Articles published

Doyle, M.J., Mier, K.L., Busby, M.S., and Brodeur, R.D. 2002. Regional variation in springtime ichthyoplankton assemblages in the northeast Pacific Ocean. Progress in Oceanography 53: 247-281.

Doyle, M. J., Busby, M. S., Duffy-Anderson, J. T., Picquelle, S. J., and Matarese, A. C. 2002. Early life history of capelin (*Mallotus villosus*) in the northwest Gulf of Alaska: a historical perspective based on larval collections, October 1977 – March 1979. ICES Journal of Marine Science 59(5): 997-1005.

Non-refereed articles in press

Doyle, M. J., Busby, M. S., Duffy-Anderson, J. T., Picquelle, S. J., and Matarese, A. C. (in press). Aspects of the early life history of capelin (*Mallotus villosus*) in the northwest Gulf of Alaska based on larval collections, October 1977 – March 1979. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS.

Conference/meeting presentations

Early life history of capelin (*Mallotus villosus*) in the northwest Gulf of Alaska – A historical perspective based on larval collections, 1977-79. Paper presented at the International Symposium on Capelin, "Capelin, what are they good for?", organized by ICES (International Council for the Exploration of the Sea), in Reykjavik, Iceland, 24-30 July 2001.

Retrospective analysis of ichthyoplankton data from the Gulf of Alaska – Understanding ecosystem dynamics in relation to Steller sea lion decline. Overview presented at the NMFS Steller Sea Lion Principal Investigators Meeting in Anchorage, Alaska, 19-21 March 2002.

Plans for FY03

Work on this project will continue, though without direct FY03 Steller sea lion funding.

- Present first component of Interannual Trends (Gulf of Alaska Ichthyoplankton) study at the GLOBEC Open Science Meeting/PICES XIth Annual Meeting in Qingdao, China, October 15th – 26th, 2002. Title of abstract accepted: Interannual Trends in Abundance of Ichthyoplankton Species in the Gulf of Alaska During Spring, 1978 Through 2000: Exploring Linkages Between Pelagic Ecosystem Dynamics and the Early Life History of Fish.
- Continue with the second and third components (interannual trends in ichthyoplankton production and spatial patterns, respectively) of this study. Prepare manuscripts (one for each component of the study) for submission to *Marine Ecology Progress Series* or *Fisheries Oceanography*.
- Continue with investigation of early life history dynamics of individual forage and ground fish species that are sources of food for Steller Sea Lions in the Gulf of Alaska. Complete study on Pacific sand lance and prepare manuscript for submission to a fisheries science

journal.

- Present results from the Interannual Trends study and/or the early life history dynamics of Pacific sand lance study at the EVOS-GEMS/GLOBEC/NMFS Steller Sea Lion Symposium, Anchorage, Alaska, 13-17 January 2003
- Continue investigation of interannual variation in composition and distribution of ichthyoplankton assemblages in the Gulf of Alaska in collaboration with other members of the FOCI group. Contribute to the development of an ecosystem metric for monitoring ecosystem change in the Gulf of Alaska.

Observer Training for Forage Fish Identification (02FF-07)

Principal Investigators: Daniel Ito and Anne Hollowed
Division: REFM
SSL Projects Database #: 2002-25

Project Description
An important element of the stock assessment activity will be to improve forage fish bycatch monitoring. Collection of catch and biological data by observers on the forage fish complex contributes substantially to the accuracy of the catch statistics and their scientific assessment. The Observer Program will modify existing training protocols to facilitate species identification of the forage fish complex. This will require additional annual operational costs to the program.

Activities in FY02
Two contracts were established with the FY02 Steller sea lion funds. A two-year, $65K contract with the University of Washington was established to assist with training and briefing of groundfish observers on fish identification, which includes the forage fish and other species complexes. This contract was set up to provide a qualified person to train fish identification through lectures and laboratory; to assist in inventory and maintenance of the teaching collection; and to provide curation of preserved specimens.

The remaining $10K was used to modify an existing contract with MRAG Americas Inc. (Title: Evaluation and Analysis of Current Field Sampling in North Pacific Groundfish Fisheries). This contract has conducted an analysis of observer time budgets to investigate the implications of tasking observers with additional biological sampling of non-target species in the catch. The analysis to date has focused particularly on longline fisheries, with less attention paid to trawl fisheries. Since the majority of forage fish is caught by trawlers, this additional funding will allow the contractors to specifically investigate the time and task prioritization implications for observers on trawlers of requirements to identify, sample and analyze forage fish species bycatch.

In addition to the two contracts cited above, Observer Program base funds were used to establish a joint fishery research biologist/ichthyologist position with the RACE division. This position was filled by Dr. Duane Stevenson. During FY02, Dr. Stevenson worked closely with the Observer Program to explore avenues for increasing the level of resolution associated with species identification of select species groupings. As such, a special project was initiated 1) to assess the adequacy of the tools provided for identifying skates, smelts (capelin, eulachon, rainbow smelt, and surf smelt), and selected sculpins to genus, and 2) to quantify the amount of additional time observers would need to complete these identifications. This project is currently ongoing. Dr. Stevenson has also traveled to Anchorage to provide the Observer Training Center and NMFS field staff with a briefing of the special project and its progress to date.

Due to a variety of budgeting (timing and availability) and other logistic issues beyond our control, the Observer Program was not able to fund Dr. Stevenson's position with the FY02 Steller sea lion funds as originally proposed. However, recognizing the importance and need for this research position, the Observer Program drew from its own programmatic base funds to

support this position in FY02. FY03 funding will be needed to continue the support for Dr. Stevenson's position and provide the necessary resources to expand on his work.

Plans for FY03

In addition to the activities associated with the University of Washington and the MRAG contracts cited above, observers are currently in the field conducting Dr. Stevenson's special project -- there are now over 35 observers participating in this project. It is anticipated that the data will be available for analysis by late fall 2002. Dr. Stevenson will analyze these data in FY03 1) to assess the adequacy of the tools provided for identifying skates, smelts (capelin, eulachon, rainbow smelt, and surf smelt), and selected sculpins to genus, and 2) to quantify the amount of additional time observers would need to complete these identifications. Depending on the result of this research, changes may be needed to the observers' sampling manual, data forms, fish identification keys, training protocols, etc. It is important to recognize that these changes may not be trivial, requiring concomitant changes to Observer Program priorities and processes. Work on this project continues in FY03, though not with direct FY03 Steller sea lion research funds.

Forage Fish Stock Assessment (02FF-08)

Principal Investigators: Anne Hollowed and Mark Nelson
Division: REFM
SSL Projects Database #: 2002-26

Project Description
REFM will hire a stock assessment scientist to be housed at the Kodiak facility. This individual will compile historical information to develop quantitative assessments and management advice for forage species in the Gulf of Alaska and Bering Sea. The successful candidate will serve the Stock Assessment and Multispecies Assessment Program (SSMA). SSMA is responsible for conducting annual assessments of groundfish species. Members of the SSMA program compile information on forage species for the other species SAFE chapters for the GOA and BSAI. This scientist will enhance these assessments with a goal of developing age or size based models in future years. This staff member will also advise the regional office on potential impacts of fishing on selected forage species as required to fulfill the agencies requirements under the National Environmental Policy Act.

Activities and Results in FY02
Funds received in FY02 were used to establish a contract with Pacific States Marine Fisheries Commission for the period 23 September 2002 to 15 February 2004. PSMFC hired Mark Nelson to compile information on forage species for use in other species SAFE chapters. Nelson plans to complete his Masters of Science degree at the University of Washington, School of Fisheries an Aquatic Sciences in the fall of 2002. He has experience in using mathematical models to assess fish populations and he is familiar with common models used in stock assessment. He has worked the AFSC's Resource Ecology and Ecosystem Modeling program for the last 4 years. During this time he participated in the collection and processing of groundfish catches. Nelson's experience with age-structured modeling techniques coupled with his familiarity with AFSCs sampling strategy and databases will allow him to perform the task required in an expeditious manner.

In addition to the activities cited above, REFM staff worked with Jessica Taylor, a student intern from Hampton University. Taylor participated in a program sponsored by NOAA's Entrepreneurship grant to encourage involvement of Minority Serving Institutions. Taylor assisted in taking length and weight measurements of capelin collected in the Gulf of Alaska. She also extracted otoliths for use in age determinations planned by the age and growth program. Otoliths were removed from 177 fish collected in 2001 from the Shumagin region and 160 fish collected in 2000 from the Kodiak region. Taylor performed an analysis of regional growth patterns of capelin. She used growth patterns as an indicator of differences in population structure that may be related to stock separation. The length - weight measurements used for this analysis were not collected in a standardized manner. Different vessels and nets were used to capture capelin, and samples were obtained at different times throughout the growing season (April - October, Table 1). The precision of the length measurements varied between cruises. Samples taken during the 1996 GOA groundfish trawl survey and the 2002 Southeast Alaska survey were measured to the nearest centimeter while samples taken from the Shumagin region and the east side of Kodiak Island were measured to the nearest millimeter.

Maximum likelihood estimator was used to fit the length weight relationship $W = aL^{b.}$ Regional effects were measured by comparing the relative fits of three models:

Model 1 was a combination all of the data, with two parameters
Model 2 arranged the data into the three regional groups
Model 3 separated each data set

A chi-squared test was done to evaluate regional differences in growth.

Plots of growth curves based on maximum likelihood fits to the data revealed that there appeared to be very little difference in the growth rate between the data sets from the Central Gulf of Alaska (Table 2). The growth rate of capelin seems to be the fastest in Western GOA, while the Eastern GOA has the slowest growth rate for the early stages of life. Due to the large sample size, the chi-squared test determined that there is no substantial difference in the growth trajectories between the regions (Table 3). Separating the stocks into three regional groups produced a marked improvement in fit (Table 3). Separating the data into individual data sets produced a marginal improvement to the fit. This suggests that year effects and gear effects in the Kodiak region were minor relative to regional effects.

This analysis represents a very preliminary evaluation of stock structure of capelin in the GOA. Additional work is needed to evaluate gear, vessel and temporal effects. Despite these problems, and the results of the chi-squared tests, there appears to be an apparent trend indicative of regionally specific growth pattern. The growth patterns do not necessarily imply stock separation but may only be indicative of the differences in the feeding conditions for each region. The results of this preliminary study suggest that stock assessment analysts might consider developing an assessment model that is partitioned into three large regions: western GOA, central GOA, and eastern GOA.

Plans for FY03

Work on this project continues, though without direct FY03 Steller sea lion research funds.

Nelson will initially focus his energy on capelin stock assessment. Potential sources of data that he will use in this project include:

1) Historical small mesh surveys from coastal regions in the Central Gulf of Alaska.
2) ADF&G aerial surveys of selected spawning locations around Kodiak Island.
3) Larval fish abundance indices from ichthyoplankton surveys.
4) Age-length-weight data from ADF&G, University of Alaska, and NMFS.
5) Catch statistics from observer data.
6) CPUE indices from groundfish trawl surveys.
7) Acoustic and trawl data from USFWS in Cook Inlet and AFSC in regions around Kodiak Island and Southeast Alaska.
8) Ocean Carrying Capacity high speed surface trawl survey data.

Nelson will be responsible for assimilating data from these sources. Information on capelin abundance and distribution is available from surveys that were designed for assessment of another species. Under these circumstances, he may treat the data as an index of abundance. It is possible that more than one assessment method may be used for development of a capelin assessment.

Table 1. Comparison of gear, cod-end liner, and type of trawls used to collect samples.

Cruise	Region	Month Year	Gear	Cod-end Liner	Type
RACE groundfish trawl survey	Central GOA	July 1996	Poly Noreastern high opening-bottom trawl	32mm	Demersal
RACE/REFM fishery interaction study	East side Kodiak Island	August 2000	Aleutian Wing Trawl	32 mm	Pelagic
RACE/REFM fishery interaction study	East side Kodiak Island	August 2001	Aleutian Wing Trawl	9.5mm	Pelagic
Auke Bay Steller sea lion study	Southeast Alaska	May 2002			Pelagic
FOCI Juvenile pollock survey	Shumagin Islands	September 2001	Anchovy net	3 mm	Pelagic

Table 2. Growth coefficients for length weight relationships for capelin from different regions of the Gulf of Alaska

Region	Year	a	b
Southeast Alaska	2002	7.27E-10	4.96
Kodiak	2000	1.47E-06	3.35
Kodiak	2001	5.86E-07	3.52
Central GOA	1996	6.62E-08	3.96
Shumagin	2001	5.49E-07	3.59
All data		5.16E-07	3.55
Central GOA Combined		1.76E-06	3.30

Table 3. Analysis of the change in negative log likelihood between different regional growth models.

Model	Description	Negative Log Like.	No. of Parameters	Accept or Reject Model 1
1	All combined	-54.77	2	
2	3 Area	-418.70	6	Accept w/99.9%
3	Separate Data	-478.28	10	Accept w/99.9%

Age and Growth (02FF-09)

Principal Investigator: Daniel Kimura
Division: REFM
SSL Projects Database #: 2002-27

Project Description
Stage based stock assessments require knowledge of key life history parameters including: growth rate, maturity schedules, and natural mortality estimates. Estimates of growth will require evaluation of age determination criteria. Once a ageing method is tested and surveys are implemented, production ageing of key forage species would be encouraged.

Historical studies examined the feasibility of ageing capelin from Alaskan waters. These studies revealed that otoliths were an accurate method for ageing capelin. In addition, some ageing studies on forage species are currently being conducted by sea bird biologists and the U.S.Forest Service. Validation work has not been conducted but the otoliths look pretty clear and appear to be almost all age 3, with a handful of age 4. The scales appear to be unsuitable for age determinations.

This proposal calls for funds to support three primary tasks: a) production ageing of capelin, b) support for age validation studies for capelin and sandlance and c) development of ageing criteria for additional forage fish species. Production ageing of capelin would be accomplished by providing one permanent employee within the REFM Age and Growth Program. This individual would process capelin otoliths collected during aerial survey feasibility surveys, ABL Ocean Carrying Capacity forage fish feasibility surveys, MACE gulfwide feasibility surveys and observer collections.

Activities/Results in FY02
Because of uncertainty in funding, nothing was done in FY02**.**

Plans for FY03
We have no plans for activities in FY03.

Index of Abundance and Spawning Habitat Requirements of Eulachon, a Key Forage Fish for Steller Sea Lions (02FF-10)

Principal Investigator: K Koski
Division: Auke Bay Laboratory, RACE
SSL Projects Database #: 2002-28

Project Description

Eulachon (*Thaleichthys pacificus*) is an important food fish for indigenous peoples in Alaska and the Pacific Northwest as well as an important prey species for Steller sea lions. Information is scarce on larval or juvenile life stages and only a small number of streams along the entire west coast of North America support spawning populations of eulachon. Most of these streams are confined to mainland glacier-fed systems and there are no established spawning populations on any of the coastal islands. In Southeast Alaska they are reported to occur in the Unuk, Smeaton Bay, Bradfield, Stikine, Taku, Mendenhall, Berners Bay, Chilkat, and Situk Rivers. Eulachon appear to be abundant in the southern Bering Sea, the northern extent of their range and they also occur in Cook Inlet drainages and Kenai River. This study will establish an index stream in Berners Bay and, if successful, in other streams in Southeast Alaska, for developing a baseline of annual abundance of eulachon. Sea lions gather in large numbers in Berners Bay in spring to feed on eulachon. Specific objectives include 1) determine run timing, location and timing of spawning, 2) conduct sea lion index counts in the Antler River and compare with eulachon abundance 3) describe size, fecundity, and age composition of eulachon, 4) determine nutritional composition, including fatty acids, 5) describe habitat, incubation period, and environmental conditions (e.g., substrate, temperature, flow, salinity); and 6) estimate adult biomass based on spawning population or larval abundance. Adult spawning abundance will be estimated by mark recapture techniques. Larval abundance in the river will be evaluated as a method to back calculate spawner biomass and population size. Establishing a baseline on one or more spawning streams in Southeast Alaska will provide a long-term trend in abundance for comparison with Sea Lion trends in abundance. An index stream(s) should also be established in the southern Bering Sea to develop a baseline for comparison with southeast. Because spawning populations of eulachon can be impacted by river pollution and watershed disturbances, these baselines may help to understand factors causing variability in eulachon abundance.

FY02 Activities and Methods

- Run timing, location and timing of spawning in the Antler River.

Both seine and dip nets were used to capture fish for life history samples and to develop run timing and duration using catch per unit effort (CPUE). We began the sampling season on 18 April 2002, using dip nets. However, due to low capture rates, we switched to seine nets beginning on 26 April and used this method until the end of the run (21 May). We then continued both methods simultaneously for a period of twelve days to develop a correction factor to expand the early dip net CPUE. However, there were too many zero counts using dip nets to make valid comparisons. We used radio telemetry to learn more about the spawning migration behaviors of eulachon and to locate spawning areas in the Antler and Lace Rivers implementing procedures recently developed.

- Conduct sea lion index counts in the Antler River and compare with eulachon abundance.

Index counts of sea lions were conducted daily from 19 April to 21 May 2002, in a 400 m section of the Antler River approximately 1 km upstream of the confluence of the Antler and Lace Rivers. Counts were not conducted from 1 to 3 May and from 9 to 14 May. Counts were made at day and night at slack high tide when animals entered the system.

- Describe size, fecundity, and age composition of eulachon in the Antler River.

Fish in pre-spawning condition were collected throughout the entire run to determine these life history characteristics. Samples were analyzed in a U.S. Forest Service lab in Anchorage.

- Determine nutritional composition, including fatty acids.

Fish were collected at the Antler River, approximately 1 km upstream from the confluence of the Antler and Lace Rivers. Samples of eulachon males and females in prespawning and postspawning condition were collected and frozen in liquid nitrogen on site and transported to Ron Heinz at ABL for nutritional analyses. Opportunistic samples of capelin were also obtained from a spawning population adjacent to the Antler River and analyzed for nutritional status. Results of nutrition analyses are being reported by Ron Heinz.

- Describe habitat, incubation period, and environmental conditions (e.g., substrate, temperature, flow, salinity).

Radio telemetry was used to determine key holding and spawning areas. Other observations included temperature, relation of tide water limits to spawning areas, and substrate types.

- Estimate adult biomass based on spawning population or larval abundance.

Preliminary work was necessary prior to conducting population estimates. This work consisted of determining the run timing and duration of adult eulachon, the relative distributions of adult eulachon, their retention time in freshwater during the spawning run, and determining methods for capture. The stream channel was surveyed at a range of flow rates to determine the best location for adult and larval sampling. The U.S. Geological Survey was contracted to install stream gauging stations in the Antler and Lace Rivers in 2003 to develop discharge estimates for larval productivity calculations. Different sampling methods and locations were tested for a mark-recapture study.

FY02 Results

- Run timing, location and timing of spawning in the Antler River.

Fish were detected from 19 April to 21 May 2002 with a total of 1,071 fish caught using both sampling methods. The maximum CPUE occurred on 22 April using dip nets and on 3 May for seine nets. Preliminary analyses of pre spawn and post spawn CPUE indicate short freshwater retention or residency time of approximately 1-3 days.

A total of 88 pre-spawning eulachon were implanted with coded microprocessor radio tags and were released in the Antler River. Manual tracking was conducted with the aid of jet and airboats and occurred every day from 27 April to 19 May. A fixed station was also set up to record data continuously just above the upper extent of the high tide mark. Radio telemetry data is still under analysis; however, in the Antler River, a plot of all manual tracking locations clearly identifies the upper limits of migration and clusters of points along the river indicate possible spawning areas. The maximum migration up the Antler River was approximately 4 km and 99% of all observations were found in the lower 2 km section of river.

- Conduct sea lion index counts in the Antler River and compare with eulachon abundance.

Generally, sea lions were observed at night, which coincided with higher CPUE of eulachon. Although, counting at night was difficult and we are uncertain of the accuracy of these counts, we feel that the results may be used to describe relative change in abundance over time. Although retention time of sea lions in the system was not recorded, generally they spent between one and three hours in the index site. Sea lions were detected in the river from 22 April to 1 May, with one counted on 7 May. The peak count of 120 animals occurred on 27 April. This corresponds with high CPUE of eulachon in the Antler River. At this time sea lions were actively pursuing fish, pushing schools of eulachon up onto gravel and sand bars. Weekly counts of sea lions in Berners Bay were made from a vessel by Mike Sigler and aerial surveys were made by Jamie Womble, UAF. These observations will be compared to the CPUE in the Antler River.

- Size, fecundity, and age composition of eulachon in the Antler River.

Life history characteristics (length, weight and fecundity, and age) data were determined for adult fish in the Antler River. Males were on average longer and heavier than females (Table 1). Fecundity of females averaged 29,242 eggs/female (SE=1960). Most males (n=177) were age 3 (57.6%) followed by age 2 (26.6%), age 4 (10.2%), age 5 (5.1%), and age 6 (0.6%). Although females (n=42) were somewhat younger they followed a similar trend, with most being age 3 (52.4%) followed by age 2 (28.6%), age 4 (14.3%), age 5 (2.4%), and age 1 (2.4%).

Table 1. Mean fork length and weight for male and female eulachon in 2002 on the Antler River, Berners Bay

Sex	n	Mean Fork Length (mm) (SE)	Mean Weight (g) (SE)
Male	202	189.0 (0.7)	46.2 (0.6)
Female	59	176.8 (1.3)	39.4 (1.0)

- Determine nutritional composition, including fatty acids.

Results of the nutritional analyses were prepared by Ron Heintz, ABL

- Describe habitat, incubation period, and environmental conditions (e.g., substrate, temperature, flow, salinity).

Spawning habitat in the lower 2 km of river was initially identified using the upper limits of migration from fish tagged with radio transmitters. Therefore, with the exceptions noted below, determinations of spawning areas were made through association of tagged fish and not direct observation of spawning behavior. Spawning behavior was observed during the day on two occasions (25 April, mean temperature 3.88˚C and 26 April, mean temperature 4.30˚C) before water became too turbid to permit direct observations. This area was just above the influence of salt water. Mean daily temperatures during the spawning run varied from 3.03˚ to 5.45˚C with a mean of 4.16˚C for the entire time period. Spawning areas were characterized by gravel substrates (2-25 mm) and in areas of moderate velocities (0.2-0.6 m/s).

- Estimate adult biomass based on spawning population or larval abundance.

Preliminary work was necessary in 2002 before conducting future adult population estimates and developing a larval index. Also initial startup time in spring 2002 did not allow for use of trapping methods to obtain mark-unmarked ratios for calculating population estimates. Knowledge of the run timing and duration, migration behavior, and river retention time will aid in the development of the monitoring program in 2003. The sample design can be refined further utilizing results from comparisons between CPUE and other environmental factors, such as light intensity, tide height, and water discharge. An understanding of spawning locations and flow characteristics will aid in the development of a larval index study. Results of river channel surveys indicate the best location for sampling for adults and larvae is located approximately 1 km upstream of the confluence of the Antler and Lace Rivers. Flood channels were also monitored during high flow to develop methods to account for river braiding during the larval sampling season.

FY03 Methods and Activities

- Determine run timing and life history characteristics for the Antler River.

We will continue to use seine nets to determine run timing and intensity and to collect life history information. The run timing information will be used to determine the timing of mark recapture studies and for larval sampling as previous work using accumulated thermal units will dictate sampling times. Over time, life history information may be used to help develop stock B recruitment relationships for eulachon.

- Conduct sea lion index counts in the Antler River and compare with eulachon abundance.

These index counts and those in Berners Bay by vessel and aircraft will be conducted using the same methods as in 2002 in an effort to further describe the association between sea lions and eulachon.

- Calculate adult population estimate using mark recapture.

The feasibility of using Floy dart tags in a mark-recapture study will be assessed for estimating population size. A combination of rotary screw traps, seines, and possibly small fish wheels will be used to capture, mark, and recapture adult fish on the Antler River.

- Conduct larval sampling as an index of adult abundance.

Larval sampling will be conducted with standard methods and those developed during this project. Additionally, we will investigate the variability in larval downstream drift to increase the effectiveness and efficiency of larval monitoring surveys. Initial work conducted in the Twenty-mile River system near Anchorage for the past couple of years indicates that larval sampling results are robust enough to use as an index of adult population strength; therefore, we are optimistic about applying these results to the Antler River. Back-calculations from larval productivity to adult biomass using fecundity and sex ratio will also be investigated and compared with adult mark-recapture population estimates.

Work on this project continues, though without direct FY03 Steller sea lion research funding.

Conclusions

In the first year, 2002, we were able to determine the adult spawning movements, retention time in the river, and other aspects of their life history that will greatly aid in the development of a monitoring and index program. In 2003, stream gauging stations will be operational and larval sampling can begin to develop a larval index as well. Both methods offer considerable promise for monitoring and indexing populations of eulachon.

Linkages

This is a cooperative study between NMFS, the U.S. Forest Service, the U.S. Geological Survey, the USFWS, and the ADF&G. Within the National Marine Fisheries Service, work is being conducted in cooperation with the Southeast Alaska Predator Study (Sigler) and the Nutritional Ecology Lab (Heintz). The U.S. Forest Service has previously conducted research on eulachon in the Berners Bay area from 1995-1999 and there is new interest in learning more about their ecology due to a proposed mining project in the immediate area. As a result of concerns in the Federal Subsistence Fisheries Program with regard to eulachon on the Unuk, Copper, and Twentymile Rivers, other research is being conducted on developing methods for population monitoring. These methods were derived from studies by the Department of Fisheries and Oceans and Canada, and the USFS. Other supporters of developing methods for monitoring eulachon populations include the Southeast and Southcentral Regional Advisory Councils (Alaska Federal Subsistence Program). We are also cooperating with the Alaska Department of Fish and Game conducting studies on the Copper River. Other efforts to monitor eulachon include work by the Department of Fisheries and Oceans in Canada, and the Washington Department of Fish and Wildlife. This next year (2003), cooperative studies are planned for the Unuk, Stikine, Situk, Copper, and Twentymile Rivers in addition to the continuation of this work in Berners Bay.