OCS Study MMS 2000-046

University of Alaska Coastal Marine Institute

IN COOPERATION

Minerals Management Service

University of Alaska

State of Alaska

Annual Report

Federal Fiscal Year 1999

SUBMITTED BY

Vera Alexander

Director

University of Alaska Coastal Marine Institute

TO

U.S. Department of the Interior

Minerals Management Service

Alaska OCS Region

Anchorage, Alaska

June 2000

Contact information

e-mail: cmi@sfos.uaf.edu
phone: 907.474.7707
fax: 907.474.7204
postal: Coastal Marine Institute
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

Table of Contents

Introduction

The University of Alaska Coastal Marine Institute (CMI) was created by a cooperative agreement between the University of Alaska and the Minerals Management Service (MMS) in June 1993, with the first full funding cycle beginning late in (federal) fiscal year 1994. CMI is pleased to present this 1999 Annual Report, our sixth annual report. Of the nine research projects included in this report, four were scheduled to end this federal fiscal year or in the first quarter of the next one. Only abstracts and study products for those projects are included here because principal investigators are preparing their final reports. Eight additional research projects were begun this year. Abstracts for these projects are included in the section titled New Projects.

The Minerals Management Service administers the outer continental shelf (OCS) natural gas, oil, and marine minerals program in which it oversees the safe and environmentally sound leasing, exploration, and production of these resources within our nation's offshore areas. The Environmental Studies Program (ESP) was formally directed in 1978, under Section 20 of the OCS Lands Act Amendments, to provide information in support of the decisions involved in the planning, leasing, and management of exploration, development, and production activities. The research agenda is driven by the identification of specific issues, concerns, or data gaps by federal decision makers and the state and local governments that participate in the process. ESP research focuses on the following broad issues associated with development of OCS gas, oil, and minerals:

- What are the fates and effects of potential OCS-related pollutants (e.g., oil, noise, drilling muds and cuttings, products of fuel combustion) in the marine and coastal environment and the atmosphere?
- What biological resources (e.g., fish populations) exist and which resources are at risk? What is the nature and extent of the risk? What measures must be taken to allow extraction to take place?
- How do OCS activities affect people in terms of jobs and the economy? What are the direct and indirect effects on local culture? What are the psychological effects of the proposed OCS activities?

Because MMS and individual states have distinct but complementary roles in the decision-making process, reliable scientific information is needed by MMS, the state, and localities potentially affected by OCS operations. In light of this, MMS has developed a locally managed CMI program. Under this program, MMS takes advantage of highly-qualified scientific expertise at local levels in order to:

1) Collect and disseminate environmental information needed for OCS oil & gas and marine minerals decisions;
2) Address local and regional OCS-related environmental and resource issues of mutual interest; and
3) Strengthen the partnership between MMS and the state in addressing OCS oil & gas and marine minerals information needs.

CMI is administered by the University of Alaska Fairbanks School of Fisheries and Ocean Sciences to address some of these mutual concerns and share the cost of research. Alaska was selected as the location for this CMI because it contains some of the major potential offshore oil and gas producing areas in the United States. The University of Alaska Fairbanks is uniquely suited to participate by virtue of its flagship status within the state and its nationally recognized marine and coastal expertise relevant to the broad range of OCS program information needs. In addition, MMS and the University of Alaska have worked cooperatively on ESP studies for many years. Research projects funded by CMI are required to have at least one active University of Alaska investigator. Cooperative research between the University of Alaska and state agency scientists is encouraged.

Framework Issues were developed during the formation of CMI to identify and bracket the concerns to be addressed:

1) Scientific studies to improve understanding of the affected marine, coastal, or human environment;
2) Modeling studies of environmental, social, and economic processes in order to improve predictive capabilities and define information needs;
3) Experimental studies to improve understanding of environmental processes and/or the causes and effects of OCS activities;
4) Projects which design or establish mechanisms or protocols for the sharing of data or information regarding marine or coastal resources or human activities to support prudent management of oil & gas and marine mineral resources; and
5) Synthesis studies of background information.

Projects funded through CMI are directed towards providing information which can be used by MMS and the state for management decisions specifically relevant to MMS mission responsibilities. Projects must be pertinent to either the OCS oil and gas program or the marine minerals mining program. They should provide useful information for program management or for the scientific understanding of potential environmental effects of resource development activities in arctic and subarctic environments.

Initial guidelines given to prospective researchers identified Cook Inlet and Shelikof Strait, as well as the Beaufort and Chukchi seas, as areas of chief concern to MMS and the state. Primary emphasis has subsequently shifted to the Beaufort Sea, and to the Chukchi Sea as it relates to the Beaufort Sea. However, a strong interest in Cook Inlet and Shelikof Strait remains.

The proposal process is initiated each summer with a request for letters of intent to address one or more of the Framework Issues. This request is publicized and sent to researchers at the University of Alaska and to various state agencies, and to relevant profit and non-profit corporations. The CMI technical steering committee then decides which of the proposed letters of intent should be developed into proposals for more detailed evaluation and possible funding.

Successful investigators are strongly encouraged to publish their results in peer-reviewed journals as well as to present them at national meetings. In addition, investigators report their findings at the CMI's annual research review, held at UAF in February. Some investigators present information directly to the public and MMS staff in seminars.

Alaskans benefit from the examination and increased understanding of those processes unique to Alaskan OCS and coastal waters because this enhanced understanding can be applied to problemsother than oil, gas, and mineral extraction, such as subsistence fisheries and northern shipping.

Many of the CMI-funded projects address some combination of issues related to fisheries, biomonitoring, physical oceanography, and the fates of oil. The ultimate intent of CMI-related research is to identify the ways in which OCS-related activities may affect our environment, and potential economic and social impacts as well.

Kachemak Bay Experimental and Monitoring Studies

Raymond C. Highsmith <ffrch1@uaf.edu>
Susan M. Saupe[1] <saupe@circac.org>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

[1]Present address: Cook Inlet Regional Citizens' Advisory Council, 910 Highland Avenue, Kenai, AK 99611

Task Order 11982

Abstract

This study in lower Kachemak Bay, Alaska, was designed to obtain baseline data on abundance and distribution of intertidal invertebrates and algae and to gather information throughout the year on community-structuring mechanisms such as recruitment and succession. Specific objectives were 1) to gain an understanding of the seasonal and interannual relationships among intertidal invertebrates and plants, 2) to assess community relationships when recovering from seasonal disturbances in the form of cleared substrate, and 3) to determine the role of wave exposure in differences found in the first two objectives.

Quadrats in rocky intertidal habitat on eight sites were cleared of all invertebrates and algae during four visits in 1994 and 1995. Control, or uncleared, quadrats were also established to provide community assemblages for determining recovery on each site. The dates for creating the quadrats were selected to provide substrate for organisms that recruit in different seasons. The quadrats were subsequently monitored for organism abundance and percent cover. The acorn barnacles, Semibalanus balanoides *and* Balanus glandula *first colonized the quadrats in the high and middle tidal zones, often with > 80% cover.* Fucus gardneri *colonized the plots only after barnacles were established. The recovery rates of quadrats scraped on different dates were driven by the timing of barnacle recruitment relative to the timing of bare substrate availability.*

Recovery of the dominant algae in the low intertidal zone, Alaria flocossa, *was dependent on recruitment of the thatched barnacle,* S. cariosis. *Bray–Curtis dissimilarity matrices were calculated on community level data to compare recovery rates of scraped quadrats among sites, quadrat scrape dates, and data collection dates. Multi-dimensional scaling (MDS) ordination plots of the dissimilarity data show that scraped quadrats had not fully converged with control quadrats by the last sampling date, 30 months after the first set of quadrats were scraped in March 1994.*

Recovery rates varied by the season that quadrats were scraped, with quadrats scraped in July and October 1994 showing slower recovery rates than quadrats scraped in March 1994 or 1995. MDS ordinations indicate that the extent of recovery on disturbed quadrats compared to control quadrats varied among sites. Differences in wave exposures on the sites do not account for the differences found for recovery.

Study Products

Reports

Highsmith, R.C., T.L. Rucker and S.M. Saupe. 1995. Kachemak Bay experimental and monitoring studies, p. 44–54. *In* V. Alexander, University of Alaska Coastal Marine Institute Annual Report No. 2. OCS Study MMS 95-0057, University of Alaska Fairbanks.

Highsmith, R.C. and S.M. Saupe. 1997. Kachemak Bay experimental and monitoring studies, pp. 63–84. *In* V. Alexander, University of Alaska Coastal Marine Institute Annual Report No. 3. OCS Study MMS 97-0001, University of Alaska Fairbanks.

Highsmith, R.C. and S.M. Saupe. 1997. Kachemak Bay experimental and monitoring studies. Draft Final Report for Task Order 11982, University of Alaska Coastal Marine Institute, MMS Cooperative Agreement Number 14-35-0001-30661.

Presentations

Saupe, S.M. 1995. Kachemak Bay experimental and monitoring studies. University of Alaska Coastal Marine Institute Annual Research Review, February 1995, Fairbanks, Alaska.

Saupe, S.M. 1996. Kachemak Bay experimental and monitoring studies. University of Alaska Coastal Marine Institute Annual Research Review, February 1996, Fairbanks, Alaska.

Saupe, S.M. 1997. Kachemak Bay experimental and monitoring studies. University of Alaska Coastal Marine Institute Annual Research Review, February 1997, Fairbanks, Alaska.

Wind Field Representations and Their Effect on Shelf Circulation Models: A Case Study in the Chukchi Sea

Andrey Y. Proshutinsky <prosh@ims.uaf.edu>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

Task Order 14194

Abstract

Arctic pollutant transport models use winds obtained from forecasts of surface atmospheric pressure fields. Uncertainties inherent in these forecast pressure fields lead to errors in the calculation of surface winds, and therefore, to errors in circulation-model results dependent upon them. We have investigated the differences among three nominally identical wind field representations derived from surface atmospheric pressure fields prepared by:

- *The European Center for Medium Weather Range Forecasting (ECMWF),*
- *The U.S. Navy's Fleet Numerical Oceanography Center (FNOC), and*
- *The National Centers for Environmental Predictions and the National Center for Atmospheric Research (NCEP/NCAR).*

We have analyzed:

- *Wind and surface atmospheric pressure data from the National Weather Service offices at Barrow and Kotzebue, Alaska, to examine differences between observed and estimated winds;*
- *Ice-drifting buoy data from the International Arctic Buoy Program (IABP), to examine differences between observed and interpolated surface atmospheric pressures, and to examine differences between observed and simulated ice drift; and*
- *Differences in shelf circulation, as predicted by 2-D and 3-D barotropic shelf circulation models when forced by the three wind field representations.*

This study has demonstrated that ECMWF sea level atmospheric pressure data with a spatial resolution of 1.125° and a temporal resolution of six hours can be recommended as the best source of wind forcing data. The FNOC atmospheric pressure fields with a spatial resolution of 2.5° and a temporal resolution of six hours can be recommended as well, in the absence of ECMWF data. NCAR data with a spatial resolution of about 350 km and a temporal resolution of 12 hours can be used successfully for climatological simulations.

Study Products

Proshutinsky, A. 1998. Wind field representations and their effect on shelf circulation models: A case study in the Chukchi Sea. University of Alaska Coastal Marine Institute Annual Research Review, February 1998, Fairbanks.

Proshutinsky, A.. 1999. Climate states of the Arctic Ocean. MMS Information Transfer Meeting, January 1999, Anchorage.

Proshutinsky, A., T. Proshutinsky and J. Maslanik. 1999. Decadal variability of the Beaufort and Chukchi Seas. IUGG99 meeting, 19–30 July 1999, Birmingham, UK, Symposium JSP25, abstracts B.241.

Proshutinsky T. and A. Proshutinsky. 1998. Environmental conditions effecting commercial navigation along the Northern Sea Route. AGU Spring Meeting, 26–30 May 1998, Boston, MA.

Proshutinsky, T. and A. Proshutinsky. 1999. Seasonal variability of the Beaufort and Chukchi Seas. IUGG99 meeting, 19–30 July 1999, Birmingham, UK.

Proshutinsky, T., T. Weingartner and A. Proshutinsky. 1998. Numerical modeling of seasonal and interannual variability of the Chukchi Sea circulation. AGU Spring Meeting, 26–30 May 1998, Boston, MA, AGU, EOS, Transactions, OS51A-4, S183.

Historical Changes in Trace Metals and Hydrocarbons in the Inner Shelf Sediments, Beaufort Sea: Prior and Subsequent to Petroleum-Related Industrial Developments

A. Sathy Naidu <ffsan@uaf.edu>
John J. Goering <goering@ims.uaf.edu>
John J. Kelley <ffjjk@uaf.edu>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

Task Orders 14195 & 15167

Abstract

The project objective is to the assess historical changes in concentrations of selected trace metals (Cu, Cr, Ni, V, Pb, Zn, Cd, Ba, As, and methyl Hg) and normal, branched and cyclic (tricyclic di- and pentacyclic tri-terpenoid) hydrocarbons and polynuclear aromatic hydrocarbons (PAH), in nearshore sediments of the Beaufort Sea extending from Harrison Bay to Canning Delta. The goal is to ascertain if there have been any significant increases in concentrations of the trace metals and the hydrocarbons subsequent to the recent development of petroleum-related activities.

This year (1998–1999, Phase II study) 24 mud fractions (<63 μm size) separated from triplicate surficial sediment samples from eight stations (out of the 61 total samples collected from 21 stations in September 1997) were analyzed for all of the above elements except methyl Hg. The methyl Hg (MeHg) analysis was on the gross sediment samples. Additionally, total Hg (THg) on gross sediments and Fe and Mn in the mud fraction were analyzed on one sediment sample from the total 21 stations occupied in the study area. This year the hydrocarbon analysis on gross sediments consisted of n-alkanes on 18 samples from 13 stations and PAHs, tri-terpenoids and steroids on 39 samples from 20 stations. These analyses on trace elements and hydrocarbons together with those run in 1997–98 complete the project's commitment inasmuch as analysis of samples is concerned. Time-series comparisons among data from 1977, 1986, and 1997, based on the trace metal mean concentrations in muddy sediments of the nearshore Beaufort Sea, show significantly increased concentrations in V in 1986 and 1997, and in Ba from 1986 to 1997. However, these findings are not reflected in the stratigraphic variations of elements on two cores collected at the western and eastern margins of the study area. The stratigraphy demonstrates net significant decrease upcore in MeHg, Zn, Cd, and Pb accompanied by no changes in the concentrations of other metals. The discrepancy between decadal time-series and stratigraphic data may be due to comparision of samples of different lithologies. The specific mechanism and source(s) of the enhanced concentrations of V and Ba, identified on the decadal basis changes, are unknown.

Statistical analyses on the trace elemental data were updated since the last annual report in 1997–98 (Phase I study) as supplemental data were available in 1998–99. The multiple and partial correlation coefficient analyses suggest that V, Cu, Ni, Zn, As and Mn are chelated with OM in sediments, whereas some of the V is adsorbed by clays. Cluster analysis demonstrates the presence of two predominant

station cluster groups. Stepwise multiple discriminant analysis indicates that Station Group I, mostly clustered around Prudhoe Bay, has significantly lower concentrations of THg and MeHg compared to Station Group II located east and west of the bay. The levels of all the metals in the study area are within ranges similar to those in unpolluted marine sediments.

The concentrations of n-alkanes in sediments of this study are generally comparable to values reported by earlier workers from the nearshore Beaufort Sea in 1982 and 1992. The n-alkanes generally show a bimodal distribution typical of a mixture of marine autochthonous and terrestrial allochthonous inputs. Statistical analysis on the hydrocarbon data is in progress.

Study Products

Naidu, A.S. 1998. Historical changes in trace metal and hydrocarbon contaminants on the inner shelf, Beaufort Sea: Prior and subsequent to petroleum-related industrial activities. University of Alaska Coastal Marine Institute Annual Research Review, February 1998, Fairbanks.

Naidu, A.S. 1998. Historical changes in trace metal and hydrocarbon contaminants on the inner shelf, Beaufort Sea: Prior and subsequent to petroleum-related industrial activities. MMS Information Transfer Meeting, May 1998, Anchorage.

Naidu, A.S., J.J.Goering and J.J. Kelley. 1998. Time-series monitoring of trace elements in nearshore sediments of the Alaskan Beaufort Sea. Proc.1998 ASLO/ESA Annual Meeting, St. Louis. p. A-63.

Naidu, A.S., J.J. Goering and J.J. Kelley. 1999. Three-decadal time-series monitoring of trace elements in nearshore sediments, Alaskan Beaufort Sea. MMS Information Transfer Meeting, January 1999, Anchorage.

Naidu, A.S., J.J. Kelley and J.J. Goering. 1999. Historial changes in trace metals and hydrocarbon contaminants on the inner shelf, Beaufort Sea: prior and subsequent to the petroleum-related industrial development. University of Alaska Coastal Marine Institute Annual Research Review, February 1999, Fairbanks.

An Economic Assessment of the Marine Sport Fisheries for Halibut, and Chinook and Coho Salmon in Lower Cook Inlet

Mark Herrmann[1] <ffmlh@uaf.edu>
S. Todd Lee[2] <stoddlee@aol.com>
Charles Hamel[3] <chuck.hamel@noaa.gov>
Keith R. Criddle[4] <kcriddle@b202.usu.edu>
Hans T. Geier[5] <ffhtg@uaf.edu>
Joshua A. Greenberg[5] <ffjag@uaf.edu>
Carol E. Lewis[5] <ffcel@uaf.edu>

[1]Department of Economics, School of Management, University of Alaska Fairbanks, Fairbanks, AK 99775-6080
[2]Alaska Fisheries Science Center, National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle, WA 98115-0070
[3]North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, AK 99501
[4]Department of Economics, Utah State University, Logan, UT 84322-3530
[5]Department of Resources Management, School of Agriculture and Land Resources Management, University of Alaska Fairbanks, Fairbanks, AK 99775-7140

Task Order 14196

Abstract

Cook Inlet Planning Area Oil and Gas Lease Sale 173 includes and abuts productive commercial, subsistence, and sportfishing grounds. OCS exploration, development and production activities could affect the productivity of these fisheries, the quality of recreation opportunities, and the demand for tourism-related services. The marine sport fisheries of lower Cook Inlet are the focus of a large and growing recreation-based economic sector. Sport fisheries provide non-monetary benefits to participants and monetary benefits to tourism-related businesses. This study develops a predictive model of participation rate changes that can be used in conjunction with a regional input–output model to measure the impact of marine sport fisheries on the Kenai Peninsula economy and to predict how those impacts will vary as variations in trip characteristics influence participation. In addition to a baseline corresponding to an average trip in 1997, the final report will describe the results of six simulations that will provide for increased (or decreased) angler success that could arise from changes in stock abundance or from changes in bag limits.

Introduction

The sport fisheries of lower Cook Inlet (Figure 1) contribute to the economic well-being of residents of the Kenai Peninsula, Alaska, and the nation. In this analysis, we focus primarily on the marine sport fishery for Pacific halibut (*Hippoglossus stenolepis*). However, because the marine salmon sport fishery is both a substitute and a complement for the sport halibut fishery, the analysis also addresses the marine sport fisheries for chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), and other salmon.

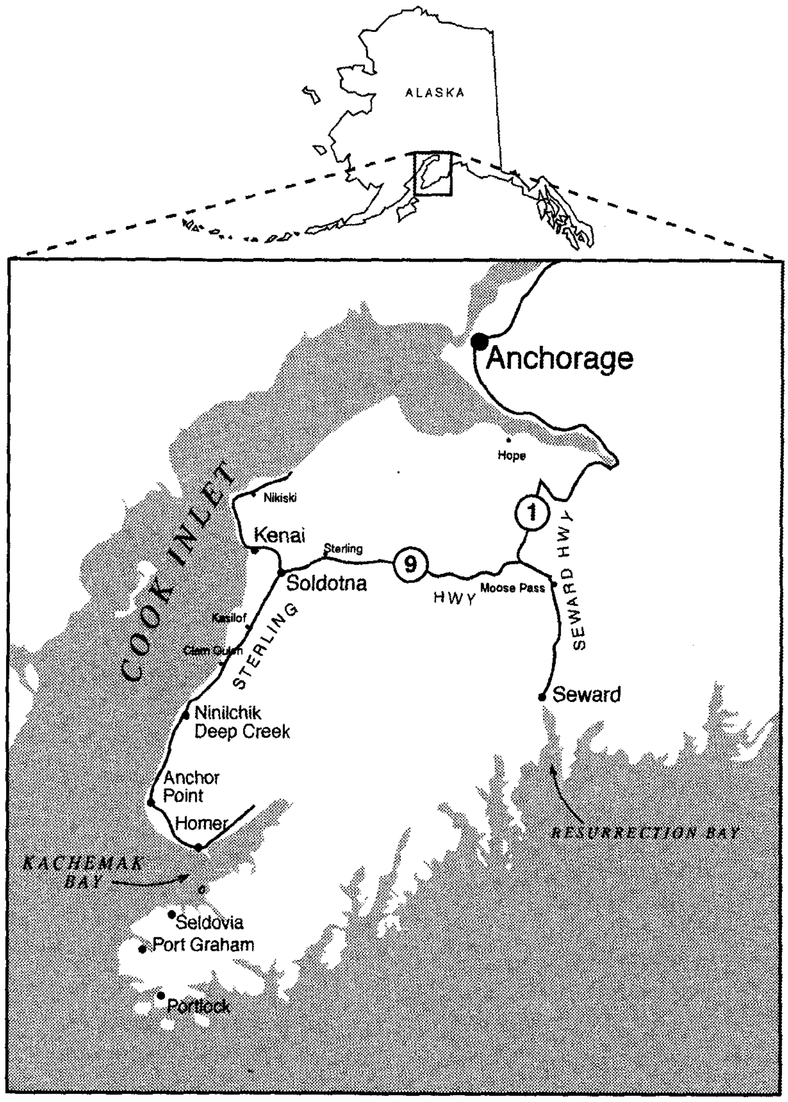

Figure 1. Location of the study area.

Pacific halibut are managed by an international agreement between the U.S. and Canada. Under the auspices of this agreement, the International Pacific Halibut Commission [IPHC] establishes overall harvest limits in ten management zones (2A-C, 3A,B, 4A-E) in the North Pacific, Gulf of Alaska, and eastern Bering Sea (Figure 2) while authority to allocate catches among competing interests is delegated to the individual nations. With passage of the Fishery Conservation and Management Act of 1976 (MSFCMA), the North Pacific Fishery Management Council (Council) was given responsibility for allocating halibut catches off Alaska. While the Council has exercised direct management of the commercial catch and bycatch of halibut, it has relied on the Alaska Department of Fish and Game (ADF&G) to manage the sport fishery under bag and possession limits established by the Alaska Board of Fisheries. Current regulations stipulate a 1 February—31 December open season with a two fish daily bag limit and a four fish possession limit.

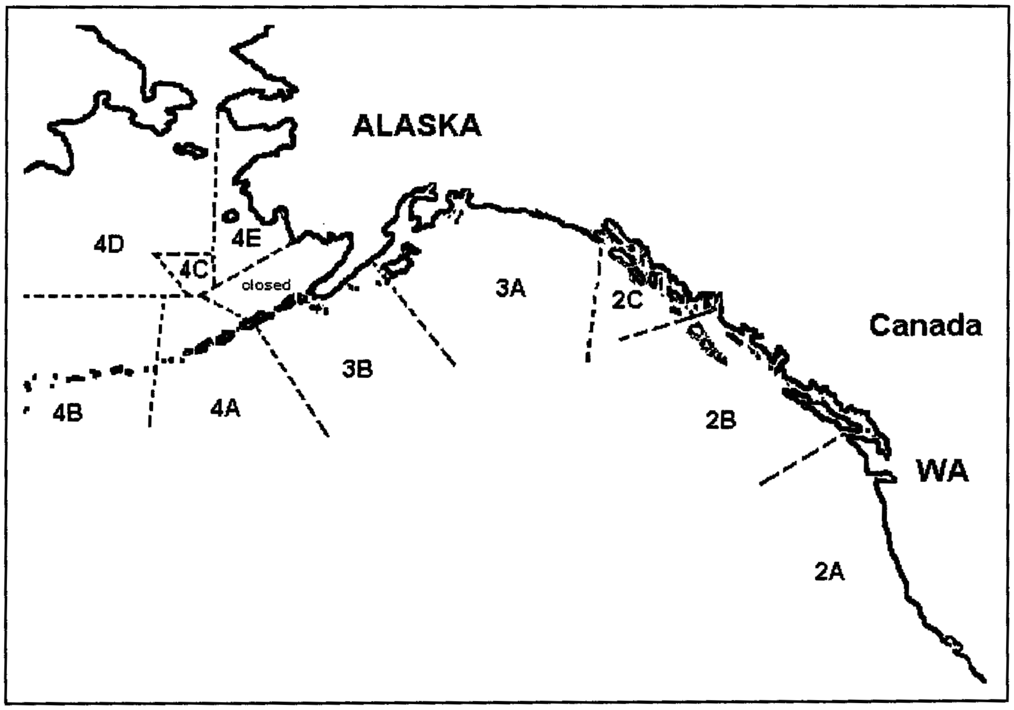

Figure 2. IPHC halibut management areas [IPHC 1999].

Although salmon management is also subject to international agreement and federal oversight outside of state waters, for all practical purposes the Alaska Board of Fisheries controls salmon catches off Alaska. ADF&G manages the salmon fisheries according to guideline harvest ranges established by the Board. These guideline harvest ranges are intended to allow for the satisfaction of escapement objectives, while serving to allocate catch among subsistence, sport, and commercial fishers.

The mixing of stocks and species from several drainages complicates management of Cook Inlet salmon fisheries. Consequently, ADF&G employs a combination of in-season management measures including time, area, and gear restrictions for the commercial fisheries in districts represented in Figure 3.

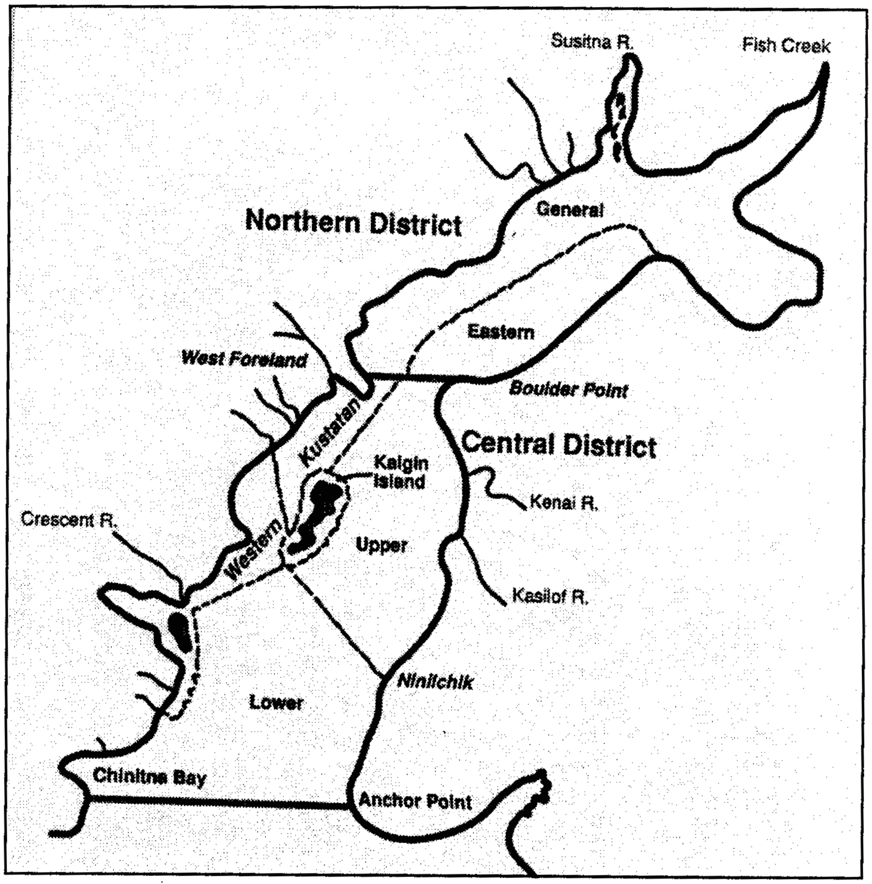

Figure 3. Cook Inlet salmon management districts [Mundy et al. 1993].

Cook Inlet personal-use fisheries include dip net fisheries in fresh water and along shore immediately adjacent to the Kasilof and Kenai rivers and the China Poot and Fish creeks. In addition, there are set gillnet fisheries in Kachemak Bay and near the mouth of the Kasilof River.

Cook Inlet saltwater sportfishing regulations specify a daily bag and possession limit of six other salmon (coho, sockeye, chum, and pink) in combination. Bag and possession limits for chinook salmon differ depending on whether the catches are taken above or below Bluff Point near Homer. To the north of Bluff Point, the daily bag and possession limit is one chinook salmon. To the south of Bluff Point, the daily bag and possession limit is two chinook salmon. In addition, there is an annual catch limit of five chinook salmon from Cook Inlet salt waters (north of a line between Cape Douglas and Point Adam [Figure 4]).

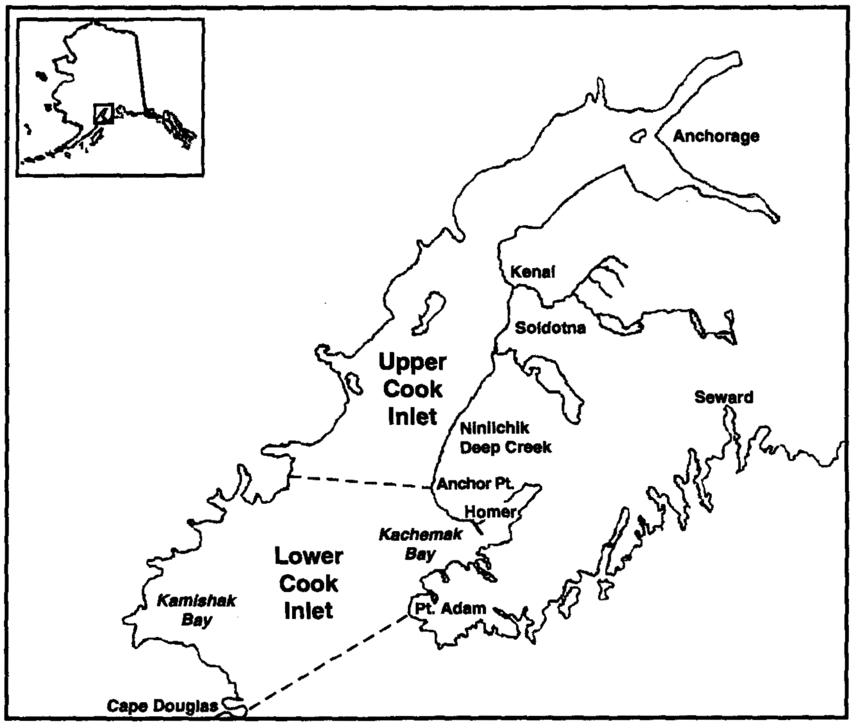

Figure 4. Cook Inlet map showing Cape Douglas and Pt. Adam.

During the past two decades, the share of halibut catch taken in the sport fishery has grown from less than 25 to over 18%. Recent sport catches of halibut from Cook Inlet, Prince William Sound, Resurrection Bay, Kodiak, Yakutat, and adjacent portions of the Gulf of Alaska (IPHC Area 3A) have exceeded 7.5 million pounds round weight [IPHC 1998]. (See Figures 5a, b.)

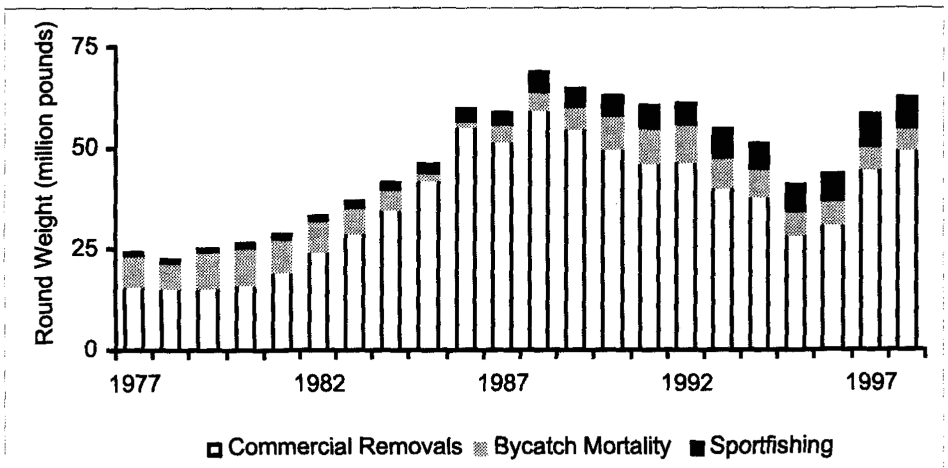

Figure 5a. Commercial and sport catches, and legal and sub-legal bycatch mortality (million lbs. round weight) of Pacific halibut from IPHC management area 3A [IPHC 1998].

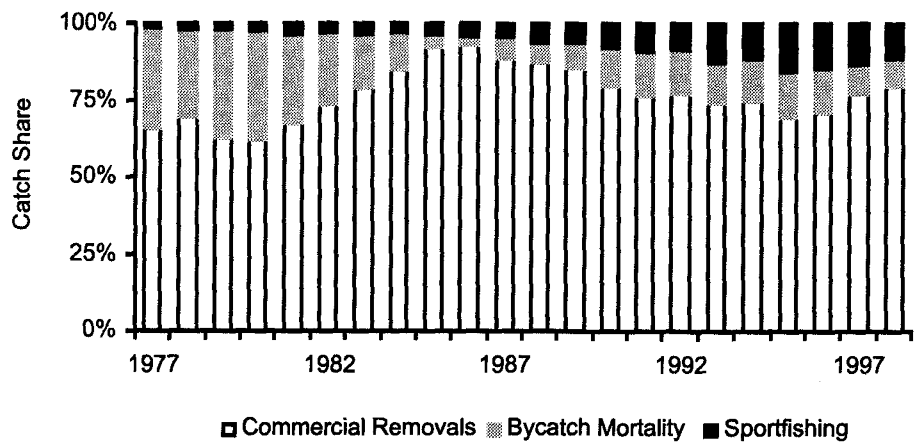

Figure 5b. Commercial and sport catches, and legal and sub-legal bycatch mortality (%) of Pacific halibut from IPHC management area 3A [IPHC 1998].

The growth of recreational catches (Figures 5a, b), combined with the adoption of individual fishing quotas in the commercial fishery, and growth in the number of vessels licensed to offer charter services (Figure 6) have led to proposals to cap sportfishing harvests of halibut.

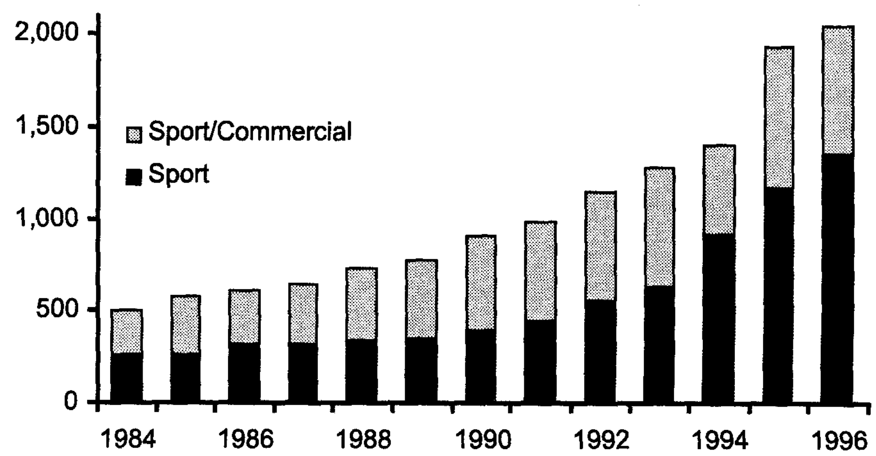

Figure 6. Sport and sport/commercial fishing vessels licensed by IPHC to fish halibut off Alaska. The series ends in 1996 when licensing functions were delegated to the Alaska Commercial Fishery Entry Commission [IPHC 1999].

The economics of the commercial halibut fishery have been subject to considerable analysis, beginning with Crutchfield and Zellner [1962]. The demographics of the commercial halibut fishery were examined in the EA/RIR for the implementation of the halibut/sablefish IFQ program [NPFMC 1991a, b]. Criddle [1994] describes the bioeconomics of the commercial halibut fishery. The national Research Council's (NRC) Committee to Review IFQs [1999] includes an evaluation of the adoption of individual fishing quotas in the commercial halibut fishery. Lin et al. [1988], Homans [1993], and Herrmann [1996] develop econometric models of the exvessel demand for halibut. The economics of Alaska's commercial salmon fishery have also been the subject of rigorous study and are described in, for example, Herrmann [1994], Herrmann and Greenberg [1994], and Herrmann [1993].

In contrast, until recently, there has been little formal analysis of Alaska's marine recreational fisheries for halibut and salmon. Coughenower [1986] provides a qualitative description of the halibut guide/charter fishery. Jones and Stokes [1987] provide a small sample estimate of the consumer surplus associated with Cook Inlet marine recreation fisheries for halibut and salmon. Layman et al. [1996] provide a recent estimate of the economic benefits to chinook salmon sport fishers on the Gulkana River, Alaska, and Lee et al. [1999] describe the results of a survey that will be used to obtain estimates of the consumer surplus that accrues to participants in marine recreational fisheries off the Kenai Peninsula. This analysis relies extensively on the data developed in Lee et al. [1999].

Methods

There are two components to a comprehensive evaluation of marine sport fisheries: estimation of angler net benefits and assessment of the economic impact generated by marine recreational fishing. Recreators fish because the benefits that they anticipate from fishing and associated activities exceed the costs they expect to incur. While assessment of the net non-market benefits that accrue to recreators is difficult, several estimation techniques have achieved broad acceptance. Although this analysis does not develop estimates of the consumer surplus associated with marine recreational fishing, those estimates are being developed in continuing analyses of survey responses described in Lee et al. [1999].

Marine recreational fishers can fish from shore, from private boats, from rented vessels, or hire charter/guide services. The expenditures associated with each of these choices fuel regional economic activity, thus changes in participation that arise from changes in trip attributes affect regional economic activity. Impact analysis estimates the direct, indirect, and induced effects on output (production), income and employment by industry and aggregated industries. Direct effects are production changes associated with immediate final demand changes. Indirect effects are those associated with changes in inputs to the production process. Induced effects are those caused by changes in household spending patterns due to changes in household income generated by direct and indirect effects. Most economic activities generate secondary impacts (indirect effects). That is, when goods or services are purchased, the seller in turn purchases goods and services. Secondary impacts are generated whether the initial activity involves commerce or recreation. However, different activities generate different impacts. Moreover, the impact of alternative activities depends on the scale considered. It is traditional to examine economic impacts at local, regional, and national scales. Our focus on the Kenai Peninsula dictates a regional based impact assessment. Input–Output (I–O) is the most widely applied tool for assessing regional economic impacts.

Our analytic framework consists of two parts: a model of the relationship between trip attributes and participation rates and an I–O model that estimates the economic impact of various levels of participation. Participation rates are estimated using an econometric model of the form:

$$\mathrm{P}(T_i) = f(cost_i, catch_{ij}, size_{ij}, other) \text{ for all } i \text{ and } j$$

where $P(T_i)$ is the probability of taking trip *i*, $cost_i$ is the cost of trip *i*, $catch_{ij}$ is the number of fish of species *j* caught on trip *i*, $size_{ij}$ is the average size of fish of species *j* caught on trip *i*, and *other* includes binary variables to differentiate between the responses of resident and non-resident recreators. The data used for estimating the parameters of this model are reported in Lee et al. [1999].

The I–O framework is based on identifying sectors of regional economies as defined by a sector's usage of inputs in the production process and the subsequent distribution of a sector's output throughout the economy. Relationships are measured by dollar values of exchanges of goods and services among different regional economic sectors, through imports or exports from other regions, and final demand by households, government entities, and other economic factors. The annual dollar values of I–O models have been used extensively outside of Alaska for impact analysis of development and government policy changes. I–O models in other states have described resource issues such as forestry [Summers and Birss 1991], regional impacts of federal grazing policies [Geier and Holland 1991], community development strategies [Geier et al. 1994], and the impact of federal land use decisions on regional economies [Fawson and Criddle 1994]. I–O models have also been employed to model the Alaska statewide economy [Logsdon et al. 1977; Weddelton 1986].

To → / From ↓		Purchasing Sectors					Local Final Demand				
		1	...	j	...	n	Households	Private Investment	Government	Exports	Total Gross Outputs
Producing Sectors	1	X_{11}	...	X_{1j}	...	X_{11}	C_1	I_1	G_1	E_1	X_1
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮
	i	X_{i1}	...	X_{ij}	...	X_{ij}	C_i	I_i	G_i	E_i	X_i
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮
	n	X_{n1}	...	X_{nj}	...	X_{nj}	C_n	I_n	G_n	E_n	X_n
Labor		L_1	...	L_j	...	L_n	L_C	L_I	L_G	L_E	L
Other Value Added		V_1	...	V_j	...	V_n	V_C	V_I	V_G	V_E	V
Imports		M_1	...	M_j	...	M_n	M_C	M_I	M_G		M
Total Gross Outlay		X_1	...	X_j	...	X_n	C	I	G	E	X

Figure 7. Simplified input–output transactions table [Richardson 1972].

We selected IMPLAN, developed for the U.S. Forest Service [Olson et al. 1993] and the most commonly used I–O model, as a base for our model. Regional and specialized I–O models can be derived from IMPLAN through adjusting the national level data to fit the economic composition and estimated trade balance for a specific region.

The IMPLAN database includes 21 economic and demographic variables for 528 industrial sectors for all counties (and boroughs) of the United States. The database is largely built off of employment and income data sets including County Business Patterns, ES 202, and Regional Economic Information System. In cases where there are disclosure problems, IMPLAN uses national averages as estimates for income and employment. The IMPLAN database is recognized as the best source of U.S. secondary regional economic data. Nevertheless, although the national level data is regularly updated, the regional data is updated infrequently. Moreover, regions may have unique economic sectors or linkages that are not well represented in the basic IMPLAN model. Consequently, it is necessary to update, regionalize, and groundtruth the model before relying on it to predict regional economic impacts. In Alaska, with small numbers of firms (frequent disclosure problems), and a rapidly evolving and heavily resource-dependent economy, it is particularly essential that the transaction coefficients be thoroughly updated and carefully groundtruthed with local data and expert knowledge.

Because the recreational fishing sector is not explicitly reflected in IMPLAN, we have added a programming module to IMPLAN that provides specialized treatment of the economic activities generated by recreational fishing. This is accomplished by disaggregating the existing IMPLAN sectors, which comprise assemblages of recreational sectors. The recreational fishing module utilizes IMPLAN generated response coefficients and secondary regional economic data as inputs in model formulation. The secondary model data is augmented with primary data for the target industries (e.g., the sport/charter industry) supplied by primary data collection. Thus, this module, through its I–O framework, explicitly accounts for linkages in regional coastal economies between various economic sectors, according to production and consumption patterns.

Individual sportfishing activities are accommodated differently from direct income-generating activities such as guiding, harvesting, and processing. The characteristics of sportfishing necessitate that these recreational activities be accounted for by expenditure patterns in retail and service sectors, rather than treated as an identifiable economic sector. The recreational fishing module allocates recreational expenditures among these sectors. The sportfishing expenditure data to be used in the recreational fishing module were developed as a side-product of our Alaska Sea Grant funded survey of sport fishers.

Results/Progress

Baseline expenditures

The baseline expenditures for residents fishing in the lower Cook Inlet marine fishery were calculated for 1997 using information from the annual Alaska Department of Fish and Game Alaska sport fish survey [ADF&G 1998] and data reported in Lee et al. [1999]. Specifically, the ADF&G survey was used in combination with Lee et al. [1999] to estimate the total number of fishers and the total days fished. All other figures were derived exclusively from Lee et al. [1999].

Number of fishing angler days

The annual ADF&G survey estimates the total number of anglers and days fished for all of the major sport fishing regions in Alaska. The survey for 1997 estimated the number of residents sportfishing in the Kenai marine fishery to be 154,510 anglers, nearly identical to the 151,590 estimated from Lee et al. [1999]. From the ADF&G survey the total number of days fished was estimated at 373,877. However, not all of this effort was directed towards the eastern (Cook Inlet) side of the Kenai. To estimate the effort for this study, in terms of days fished, only the anglers fishing the Cook Inlet portion were used.

Estimation of the total days fished in Cook Inlet by sport fishers, for halibut and salmon, is not a straightforward task. To calculate these days we decided to use the annual ADF&G survey. This survey shows a consistent estimate of the number of recreational fishing days for several years. For example, the 1997 annual ADF&G survey shows the total number of days fished on both sides of the Kenai to be 2.42 days per angler. This number is fairly consistent with past findings in the ADF&G survey (see Table 1).

Table 1. ADF&G estimated average angler days for fishers fishing the marine waters off the Kenai Peninsula 1990–1997.

Year	Average Days
1990	2.28
1991	2.18
1992	2.37
1993	2.38
1994	2.42
1995	2.55
1996	2.50
1997	2.42

A slightly troubling aspect of calculating the total days fished was that Lee et al. [1999] found a higher number of average days fished than did the ADF&G survey. This is troubling given that nearly all other similar categories in the two surveys have very consistent findings. With both surveys finding almost the identical number of fishers in 1997 this means that Lee et al. [1999] estimated a higher amount of effort in the Kenai region than did the ADF&G survey. For example, for anglers just taking halibut trips Lee et al. [1999] estimated an average of 3.04 days per angler. This number was even higher when the average angler days were calculated for trips targeting any type of salmon and/or halibut. We ultimately decided to use the effort data that was reported in the ADF&G survey, because it has a long track record of obtaining consistent answers and because it has been accepted by many different studies.

Once it was decided to use effort as reported by the ADF&G survey it became necessary to estimate just those fisheries that are in, or launched from, the Cook Inlet side of the Kenai Peninsula. All Kenai Peninsula areas reported in the ADF&G survey were included except the areas listed as Seward and "other Gulf coast east of Gore Point". Included in the survey were two areas that we originally had questions about. The first was the Barren islands: members of the charter boat industry indicated that the majority of the boats fishing the Barren Islands originated in Homer[1]. Likewise, we were told that most of the boats fishing the regions termed "other Cook Inlet/Gulf Coast west of Gore Point" were either taking place in the Cook Inlet waters or from vessels originating from Homer[2].

Assuming that most of the fishers fishing the Barren Islands or "other Cook Inlet/Gulf Coast west of Gore point" in the ADF&G study originate from Homer, this brings the percentage of fishers leaving Homer much more in line with the percentages estimated in Lee et al. [1999]. Figure 8 shows the percentages of fishers fishing out of Homer from the two surveys with and without the Barren Islands and "other Cook Inlet/Gulf Coast west of Gore Point" data added to the Homer trips.

[1] Ward, Bob. Homer Charter Association, Personal Communication 1999.
[2] Ward, Bob. Homer Charter Association, Personal Communication 1999.

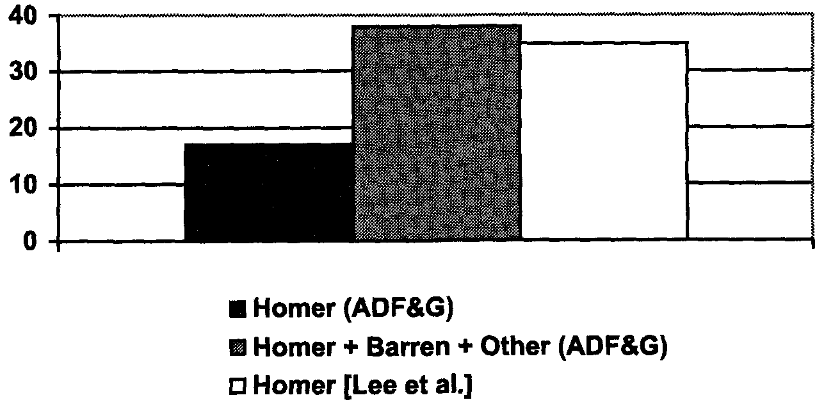

Figure 8. Percent of respondent fishing days reported fishing out of Homer for the ADF&G study by checking Homer or combining Homer and Barren Islands and "other Cook Inlet/Gulf Coast west of Gore Point" and the percent fishing out of Homer from Lee et al. [1999].

Table 2 shows the total number of recreational fishing days for people or vessels fishing at or leaving from the Cook Inlet side of the Kenai Peninsula in 1997. Using the ADF&G survey, we estimate total angler days to be 259,615.

Table 2. Estimated number of person-days fished in the Cook Inlet portion of the Kenai marine sport fishery in 1997.

	Area	Days	Percent of Total
Charter	Halibut Cove (Kachemak Bay)	156	
	Homer (Kachemak Bay)	3,787	
	Tutka (Kachemak Bay)	382	
	Barren Islands	12,519	
	Anchor River Whiskey Gulch, Deep Creek, and Ninilchik River Areas	40,849	
	Other Cook Inlet	935	
	Other Cook Inlet/Gulf	44,392	
	Sub-Total	103,020	39.7%
Private	Halibut Cove (Kachemak Bay)	978	
	Homer (Kachemak Bay)	30,239	
	Tutka (Kachemak Bay)	2,404	
	Barren Islands	1,970	
	Anchor River Whiskey Gulch, Deep Creek, and Ninilchik River Areas	64,886	
	Other Cook Inlet	442	
	Other Cook Inlet/Gulf	19,975	
	Sub-Total	120,894	46.6%
Shore	Homer Spit (Kachemak Bay)	30,034	
	Seldovia Bay	2,007	
	Anchor River Whiskey Gulch, Deep Creek, and Ninilchik River Areas	1,446	
	Shoreline – Other	2,214	
	Sub-Total	35,701	13.8%
TOTAL		259,615	

The ADF&G survey does not break down the estimated effort by area of residency. For our effort we need to examine locals (who live on the Kenai), Alaskans (not including locals) and non-residents separately. Although the Lee et al. [1999] survey was given out to all fishers fishing the marine waters off of the Kenai Peninsula, our impact study will focus on only the Cook Inlet portion of the fishery. Overall, Homer was the most frequent location (45.2%), with Seward (31.5%) and Deep Creek/ Ninilchik (29.5%) the next most frequent choices. These percentages total more than 100% because they include trips that visited multiple sites. Figure 9 shows the percentage of trips weighted when the totals are divided by the total reported trips whether they were multiple trips or not.

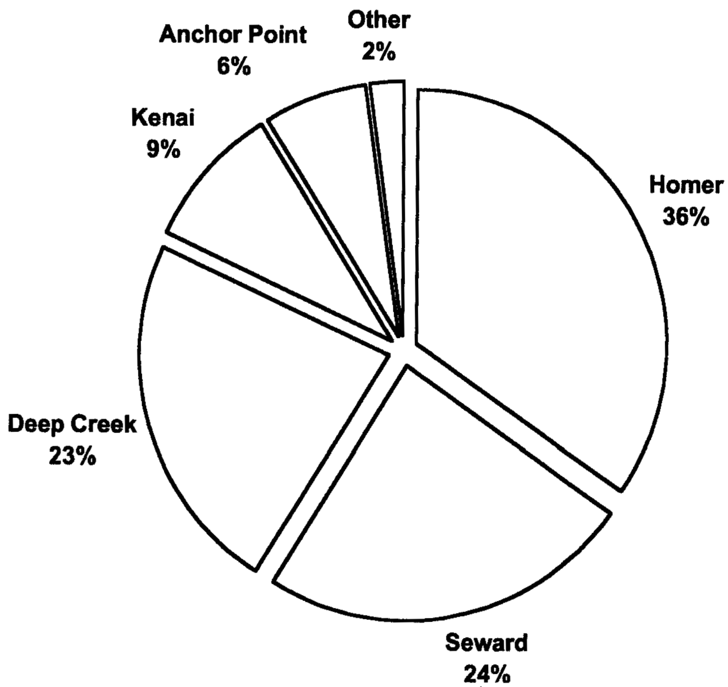

Figure 9. Location of the respondent's most recent Kenai saltwater fishing trip [Lee et al. 1999].

At this point it should be noted that much of the days fished by area and fishing mode reported in Lee et al. [1999] come from responses to a survey question that was designed to gather information on the respondent's ***most recent trip***. This may skew the information for the fishery toward the end of the year somewhat, especially for Alaskans who may take multiple trips. Our survey was administered in the middle of the fishing season in 1998. After deleting trips before 1997, 73% of the respondents listed 1997 as their most recent trip and 27% listed 1998. The 1997 trips would tend to be near the end of the season and the 1998 would be more at the beginning. Figure 10 shows the distribution of the month and year in which the most recent trip occurred.

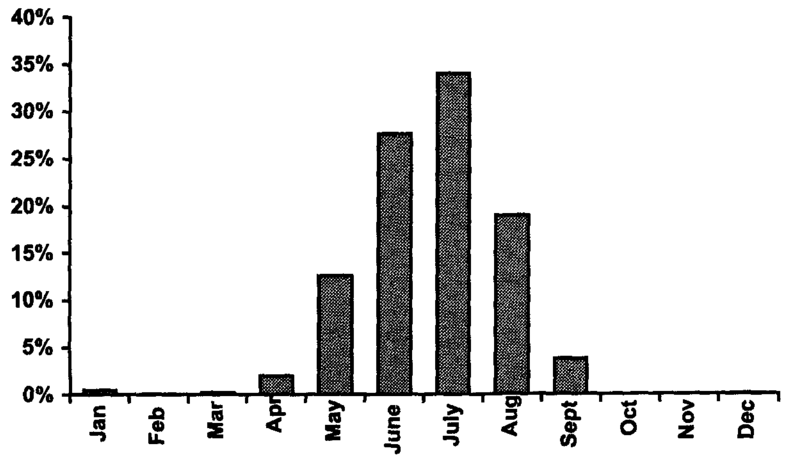

Figure 10. Month in which respondents started their most recent trip.

Next we compare our non-resident vs. resident breakdown of days fished by respondents of the ADF&G survey for the Cook Inlet portion of the fishery. To derive the proportion of days fished from the Lee et al. [1999] survey it is worthy to note that the survey response rate (from total mailed surveys whether they were delivered or not) was 73.56% from non-residents and 58.36% from Alaskans. As the surveys were sent out from a random draw, to estimate the true proportions of total fishers made up of Alaskans the Alaskan figures were inflated by 1.26 so that the proportion of non-resident and Alaskans return to the total would be comparable. To compute the days fished for all of 1997 we took the average days fished on the last trip by residency and type of trip (adjusted to allow for the differences in the response rates) and multiplied them by the number of trips (by type) from the ADF&G survey. For comparison, Figure 11 shows the estimated percentage of days fished for residents from the two surveys.

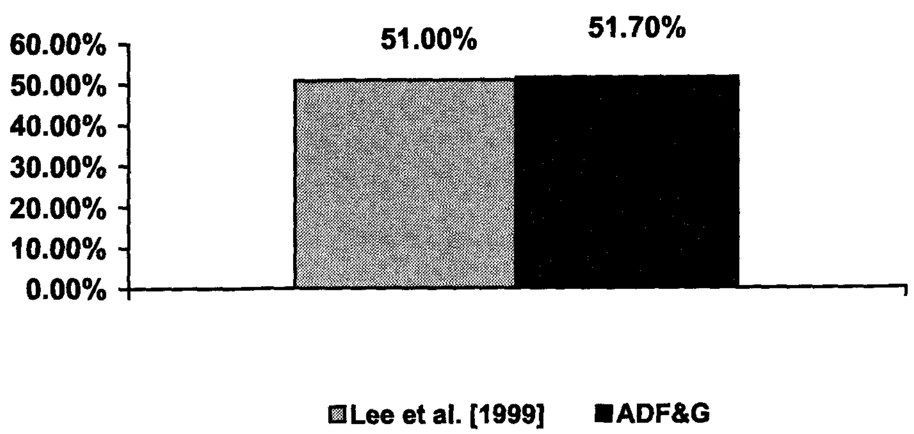

Figure 11. Percent of resident (all Alaskans) fishing days off of the Kenai Peninsula from the ADF&G survey (all Kenai fresh and saltwater) and the Lee et al. [1999] survey (Cook Inlet portion – saltwater).

These two figures are very similar. (Note that the Lee et al. [1999] survey numbers reported above are for residents fishing in the marine waters and the numbers from the ADF&G survey are for all fisheries (fresh and saltwater) off both sides of the Kenai Peninsula.) The Lee et al. [1999] survey is broken down further into locals, Alaskans (non-local) and non-residents by days fished (see Figure 12).

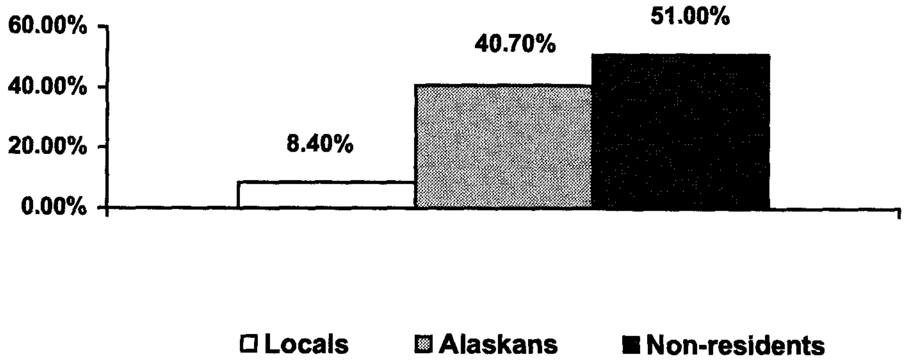

Figure 12. Percent of local, Alaskans (non-locals) and non-resident fishers fishing days off of the Kenai Peninsula from the Lee et al. [1999] survey (Cook Inlet portion).

Figure 13 shows the breakdown of days fished in the Cook Inlet portion of the Kenai Peninsula by type of fishing from both surveys.

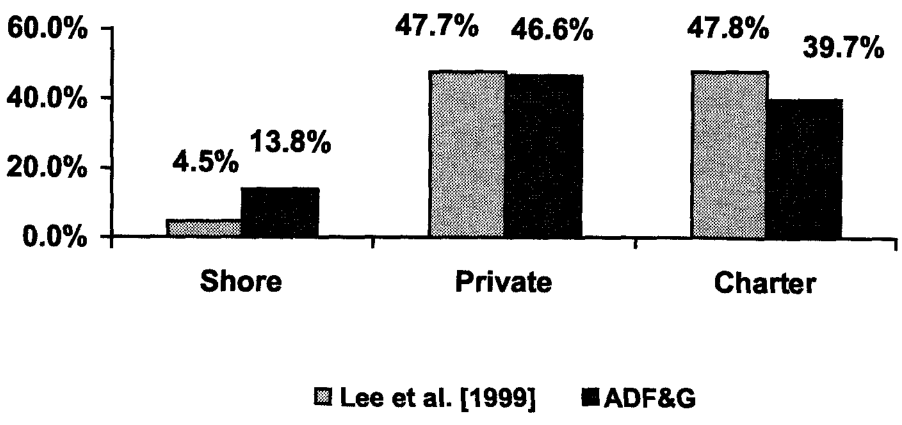

Figure 13. Percent of local, Alaskans (non-locals) and non-resident fishers fishing days off of the Kenai Peninsula from the ADF&G survey (all of 1997) and the Lee et al. [1999] survey (Cook Inlet Portion – last trip in taken in last five years).

Again, the two surveys are fairly close; however, there are some differences. The Lee et al. [1999] survey has a slightly increased reported charter effort and decreased shoreline effort, with the private boat effort nearly identical between the two surveys. The decreased reported shore effort may be due to the fact that effort being reported from the ADF&G survey is for all types of fish including shoreline rockfish, etc. The effort being reported in Lee et al. [1999] is only for salmon and halibut. We would expect that since Lee et al. is only for halibut and salmon, the reported shoreline effort would be lower since a lot of shoreline effort would be for rockfish, etc.

In Figure 14 the number of fishing angler days off of the marine Cook Inlet waters of the Kenai Peninsula (divided by fisher residence) were further broken out by whether the trip was for shore fishery, private boat or charter.

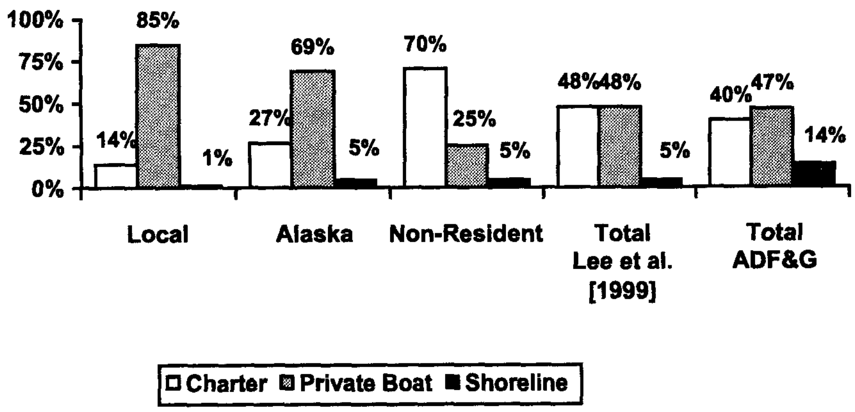

Figure 14. Frequency of fishing mode for all Cook Inlet marine fisheries off the Kenai (charter, private boat, and shore trips) for both the Lee et al. [1999] survey (last five years) and the ADF&G survey (1997).

Overall, findings from the ADF&G survey indicate that while the effort of most non-Alaskans is based in the charter fishery, Alaskans maximize effort using private vessels. Fewer respondents among either group took trips that included shore-based fishing compared to the other modes, probably an indication that Kenai Peninsula marine fisheries are not well suited to shore-based fishing. Finally, Table 3 reports the percentage of total effort by residency and type of fishing, as per Lee et al. [1999].

Table 3. The percentages of days fished by resident and type of activity.

	Charter	PB	Shore	Total
Local	1.2%	7.1%	0.1%	8.4%
AK (non-local)	10.8%	28.0%	1.9%	40.7%
Non-Resident	35.9%	12.6%	2.5%	51.0%
Total	47.8%	47.7%	4.5%	100%

These are the figures that we use to divide up the total days fished in the Cook Inlet portion of the Kenai Peninsula marine waters. When the figures in Table 3 are multiplied by the 259,625 total fishing days reported in the ADF&G survey, we can estimate the average fishing days by fishers and type of fishing (see Table 4).

Table 4. The estimated 1997 days fished by resident and type of activity.

	Charter	PB	Shore	Total
Local	3,028	18,405	304	21,737
AK (non-local)	28,006	72,723	4,865	105,594
Non-Resident	93,113	32,777	6,395	132,199
Total	124,147	123,905	11,564	259,615

Average daily fishing and non-fishing expenditures

Lee et al. [1999] asked Kenai fishers to provide detailed information regarding their expenditures on their most recent salmon and halibut fishing trips. The average daily expenditures for the fishers are weighted by days spent on the Kenai for the non-fishing expenditures and by fishing days for the fishing expenditures. The average living expenditures are weighted on all days spent on the trip (both fishing and non-fishing). Table 5 reports the average fishing and non-fishing expenditures for fishers fishing the marine waters of Cook Inlet off the Kenai Peninsula when the last trip occurred in 1997 or 1998.

Table 5. Average daily expenditures for marine sportfishing trips off the Kenai Peninsula by residency and fishing type ($/day).

	Local*			Alaska			Non-Resident		
	Shore	Private	Charter	Shore	Private	Charter	Shore	Private	Charter
Auto or Truck Fuel	7.82	7.82	7.82	14.57	12.99	15.81	9.34	7.81	8.08
Auto or RV Rental					0.39	3.97	28.91	2.92	18.92
Airfare					0.35	5.15	26.9	24.76	32.04
Other Transportation	0.70	0.70	0.70		1.31	1.83	0.93	2.30	2.33
Lodging	3.15	3.15	3.15	3.86	6.20	21.19	14.83	7.83	22.94
Groceries	8.00	8.00	8.00	12.43	14.44	13.76	7.47	10.72	9.93
Restaurant and Bar	10.74	10.74	10.74	3.43	9.58	13.95	10.2	6.65	9.63
Total Transportation and Lodging	30.41	30.41	30.41	34.29	45.26	75.66	98.58	62.99	103.87
Charter or Guide			112.86			116.4			140.75
Fishing Gear	2.14	7.12	2.00	4.50	5.53	3.58	20.00	17.12	15.5
Fish Processing		0.92	10.5		2.33	7.14	9.62	7.87	32.72
Derby		0.36	11.7		0.18	2.13	0.95	1.65	1.37
Boat Fuel and repairs		15.89			31.53			15.76	0
Moorage or Haul Out		8.36			5.48			9.00	0
Total Fishing	2.14	32.65	137.06	4.50	45.05	129.25	30.57	51.4	190.34
Total of all expenditures on a non-fishing day	30.41	30.41	30.41	34.29	45.26	75.66	98.58	62.99	103.87
Total of all expenditures on a fishing day**	32.55	63.06	167.47	38.79	90.31	204.91	129.15	114.39	294.21

* For the local expenditures, the aggregate non-fishing expenditures for all types of fishing were used because of the low number of observations. For instance, the survey only had three observations on local shoreline expenditures.

** On the days fished, the total expenditures are the sum of the fishing expenditures and the living expenditures which were averaged across the total days spent on a trip.

As one would expect, the expenditures rise the further one is away from the Kenai. For the local residents (living on the Kenai Peninsula) total transportation and living expenditures are $30.41 per day. Transportation and living expenses for non-local Alaska residents ranged between $34.29 to $75.66 per day and for non-residents between $62.99 to $103.87. (Not all of these base expenditures will end up being spent in the Kenai Peninsula, or elsewhere in Alaska, as will be discussed later.) Living expenditures were quite a bit less for non-residents who fished off a private vessel than for the other two types of fishing due to the fact that many of these trips were to visit friends and family.

For fishing expenditures, local expenditures ranged between of $2.14 and $137.06, non-local Alaskan expenditures ranged between $4.50 and $129.25; and non-residents between $30.57 and $190.34. These expenditures varied greatly with the different type of fishing mode (see Table 6 for summary).

Table 6. Average (across resident types) daily expenditures for marine sport fishing trips off the Kenai Peninsula by trip type ($/day).

	Shore	Private Boat	Charter
Auto or Truck Fuel	11.87	9.82	11.27
Auto or RV Rental	14.74	1.65	11.26
Airfare	13.72	12.77	18.44
Other Transportation	1.78	1.71	1.93
Lodging	9.32	6.59	20.79
Groceries	11.39	12.05	11.13
Restaurant and Bar	10.10	7.56	11.88
Total Transportation and Lodging	72.92	52.14	86.70
Charter or Guide			128.64
Fishing Gear	12.21	11.58	9.53
Fish Processing	4.91	5.04	20.48
Derby	0.48	0.95	2.55
Boat Fuel and repairs		22.21	0.00
Moorage or Haul Out		7.52	0.00
Total Fishing	17.60	47.29	161.19
Total of all expenditures on a non-fishing day	72.92	52.14	86.70
Total of all expenditures on a fishing day*	90.52	99.43	247.89

* On the days fished the total expenditures are the sum of the fishing expenditures and the living expenditures which were averaged across the total days spent on a trip.

The average expenditure for shoreline fishing was $17.60, for private boat $47.29, and $161.19 for charter. However, the total private and shoreline living expenditures are nearly equal with the living expenditures for private vessel fishers the lowest. This is most likely due to the fact that many of those fishing off private vessels are visiting friends or family in the Kenai and fishing off their vessels. By far, the largest expenses are associated with the charter industry. Figure 15 shows the expenses for the charter industry by residency.

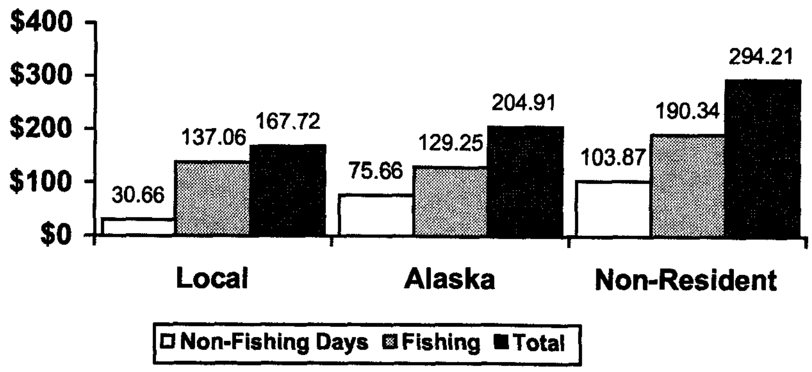

Figure 15. Average daily expenditures, by residency, for charter fishing in lower Cook Inlet (Alaskan residents do not include Kenai residents).

The next step in estimating the baseline expenditures for fishing effort in the Cook Inlet waters of the Kenai Peninsula is to estimate what percent of these expenditures are spent on the Kenai vs. the rest of Alaska (for this section "Alaska" will mean Alaska outside of the Kenai Peninsula) vs. outside of Alaska. This is not an easy question and not directly determined from the Lee et al. [1999] survey. We are ultimately interested in the amount spent on the Kenai Peninsula and the rest of Alaska. The following assumptions were made for individual daily expenditures:

Auto and Truck Fuel. Allocate expenses by amount of days spent in each area (Kenai vs. Alaska).

Auto or RV Renta Fees. Assume that all rentals take place in Alaska outside of the Kenai (most likely in Anchorage or Fairbanks). This assumption may underestimate expenditures made on the Kenai but probably not too much. There were not any reported rentals by Kenai residents.

Airfare. Assume that the all of airfare expenses are going out of the state. This will also slightly underestimate expenditures in the Alaska portion of the study.

Lodging (trailer parks, campgrounds, hotels, motels, B&B, etc.). Allocate expenses by amount of days spent in each area (Kenai vs. Alaska).

Food and Drink [Groceries] purchased at grocery or convenience store. Allocate expenses by amount of days spent in each area (Kenai vs. Alaska).

Food and Drink purchased at restaurants or bars. Allocate expenses by amount of days spent in each area (Kenai vs. Alaska).

Guides or Charter Fees. Spent on the Kenai.

Fishing Gear (bought only for this trip). We are assuming that Alaskans purchase 75% on the Kenai and 25% elsewhere in Alaska and that non-residents and Kenai residents purchase 100% on the Kenai. This is a pretty arbitrary assignment based on our own fishing experiences and talking with industry experts. Since these fishing expenditures are expenditures made for this trip only, the purchases could take place in a variety of places. Most likely, non-residents will purchase the majority of their gear on site; however, some gear may be purchased before arriving on the Kenai. Alaskans will have a better idea of what they need to fish and may purchase a substantial amount of gear before arriving on the Kenai. Locals are assumed to have purchased most of their gear for this particular trip on site. Because the gear purchase questions were specific to the most recent trip, most larger purchases that may be made outside of Alaska, like fishing rods, will have previously been made and are not reported here.

Fish Processing and Packing Fees. Assumed to have been made on the Kenai.

Fishing Derby Entry Fees. A Kenai expense.

Boat Fuel, Lubricants, and Repairs. Again, a somewhat arbitrary assumption that locals and non-locals will buy 75% of their boat fuel on the Kenai and 25% somewhere else in Alaska.

Moorage and Haul Out Fees. A Kenai expense.

Other Transportation. (such as cruises, packages, etc.). A relatively minor expense that is assumed to flow out of Alaska.

Days spent on the Kenai and in Alaska

Lee et al. [1999] asked the Kenai fishers how many days they fished on their last trip, how many days of this trip was spent on the Kenai and how many days were spent away from residence. Unfortunately, the survey did not distinguish the non-resident non-Kenai trip days between the amount of time they spent in Alaska vs. the amount of time they spent on their trip outside of Alaska for non-residents. To estimate this we calculated the ratio of time spent on the Kenai and in Alaska for non-residents who flew to Alaska and those who did not fly (see Table 7) per fishing day.

Table 7. The ratio of days fished to total Alaska days spent on Kenai fishing trip for non-residents and percent of non-residents who flew.

	Total	Flew	Did Not Fly	% Flew
Shore Fishers	8.29	3.15	16.63	50%
Private Fishers	4.76	3.94	5.94	64%
Charter Fishers	7.63	4.89	11.56	63%

To estimate the amount of time spent in Alaska, we assumed the amount of time spent by tourists who drove to be the same as that spent by tourists who flew. Therefore, we assume that whether a resident flew or not s/he spent, on average, 3.15 days in Alaska for each fishing day (inclusive of the fishing day), 3.94 for those fishing in private boats, and 4.89 for those fishing on charters.

Using these figures, the total days spent on the Kenai and elsewhere in Alaska per fishing day are reported in Table 8.

Table 8. Estimated ratio of days to total days fished spent in the Kenai and elsewhere in Alaska (not including the Kenai) per fishing day.

		Shore	Private	Charter
	Fishing Days	1.00	1.00	1.00
Local	Kenai Days/Fishing Day	1.29	1.00	1.00
	Other Alaska Days/Fishing Day	0.00	0.00	0.00
AK (non-local)	Kenai Days/Fishing Day	1.03	1.45	1.73
	Other Alaska Days/Fishing Day	0.06	0.00	0.52
Non-Resident	Kenai Days/Fishing Day	2.00	2.92	2.03
	Other Alaska Days/Fishing Day	1.15	1.02	2.86

Total expenditures assuming 100% of trip attributable to fishing

By combining the estimated daily expenditures, the estimated time spent per fishing day, and using the above assumptions on expenditures, the baseline expenditures were calculated. Tables 9–11 show the total estimated expenditures for Kenai Residents for the 1997 Cook Inlet marine fisheries off the Kenai Peninsula. Tables 12–14 show the expenditures for Alaskans living outside the Kenai area. Tables 15–17 show the estimated expenditures for non-residents. Table 18 summarizes the individual expenses for residents and Table 19 summarizes the total expenses by residency and fishing mode.

Table 9. Estimated 1997 expenditures for Kenai residents fishing the shoreline in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon. Unless otherwise noted, reported values are totals.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	0.1%	304						
Days spent on Kenai[1]	1.29		392						
Days spent in Alaska[2]	0.00		0						
Auto				7.82		3,067			3,067
RV									
Lodge				3.15		1,235			1,235
Groceries				8.00		3,137			3,137
Restaurant & Bar				10.74		4,212			4,212
Charter									
Gear				2.14	651				651
Processing									
Derby									
Boat Fuel									
Haul									
TOTAL					651	11,651	0	0	12,302

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 10. Estimated 1997 expenditures for Kenai residents fishing off a private boat in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	7.1%	18,405						
Days spent on Kenai[1]	1.00		18,405						
Days spent in Alaska[2]	0.00		0						
Auto				7.82		143,928			143,928
RV									
Lodge				3.15		57,976			57,976
Groceries				8.00		147,241			147,241
Restaurant & Bar				10.74		197,671			197,671
Charter									
Gear				7.12	131,045				131,045
Processing				0.92	16,933				16,933
Derby				0.36	6,626				6,626
Boat Fuel				15.89	292,458				292,458
Haul				8.36	153,867				153,867
TOTAL					600,928	546,817	0	0	1,147,745

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 11. Estimated 1997 expenditures for Kenai residents fishing off a charter boat in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	1.2%	3,028						
Days spent on Kenai[1]	1.00		3,028						
Days spent in Alaska[2]	0.00		0						
Auto				7.82		23,676			23,676
RV				0.00					
Lodge				3.15		9,537			9,537
Groceries				8.00		24,221			24,221
Restaurant & Bar				10.74		32,517			32,517
Charter				112.86	341,698				341,698
Gear				2	6,055				6,055
Processing				10.5	31,790				31,790
Derby				11.7	35,423				35,423
Boat Fuel									
Haul									
TOTAL					414,967	89,951	0	0	504,918

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 12. Estimated 1997 expenditures for Alaskans (non-local) fishing the shoreline in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	1.9%	4,865						
Days spent on Kenai[1]	1.03		5,011						
Days spent in Alaska[2]	0.06		292						
Auto				14.57		73,005		4253	77,257
RV									
Lodge				3.86		19,341		1127	20,468
Groceries				12.43		62,282		3628	65,910
Restaurant & Bar				3.43		17,186		1001	18,188
Charter									
Gear				4.5	16,418		5,473		21,891
Processing									
Derby									
Boat Fuel									
Haul									
TOTAL					16,418	171,814	5,473	10,009	203,713

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 13. Estimated 1997 expenditures for Alaskans (non-local) fishing off a private boat in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	28.0%	72,723						
Days spent on Kenai[1]	1.45		105,448						
Days spent in Alaska[2]	0.00		0						
Auto				12.99		1,369,766			1,369,766
RV				0.39				41,125	41,125
Lodge				6.2		653,776			653,776
Groceries				14.44		1,522,665			1,522,665
Restaurant & Bar				9.58		1,010,189			1,010,189
Charter									
Gear				5.53	301,617		100,539		402,156
Processing				2.33	169,444				169,444
Derby				0.18	13,090				13,090
Boat Fuel				31.53	1,719,707		573,236		2,292,943
Haul				5.48	398,520				398,520
TOTAL					2,602,377	4,556,397	673,775	41,125	7,873,673

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 14. Estimated 1997 expenditures for Alaskans (non-local) fishing off a charter boat in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	10.8%	28,006						
Days spent on Kenai[1]	1.73		48,450						
Days spent in Alaska[2]	0.52		14,563						
Auto				15.81		766,000		230,243	996,242
RV				3.97				250,163	250,163
Lodge				21.19		1,026,662		308,592	1,335,255
Groceries				13.76		666,676		200,388	867,065
Restaurant & Bar				13.95		675,882		203,155	879,037
Charter				116.4	3,259,895				3,259,895
Gear				3.58	75,196		25,065		100,261
Processing				7.14	199,963				199,963
Derby				2.13	59,653				59,653
Boat Fuel				0	0				
Haul				0	0				
TOTAL					3,594,706	3,135,221	25,065	1,192,542	7,947,534

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 15. Estimated 1997 expenditures for non-residents fishing the shoreline in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	2.5%	6,395						
Days spent on Kenai[1]	2.00		12,789						
Days spent in Alaska[2]	1.15		7,354						
Auto				9.34		119,451		68,684	188,135
RV				28.91				582,332	582,332
Lodge				14.83		189,663		109,056	298,719
Groceries				7.47		95,535		54,933	150,468
Restaurant & Bar				10.2		130,449		75,008	205,458
Charter									
Gear				20	127,892				127,892
Processing				9.62	61,516				61,516
Derby				0.95	6,075				6,075
Boat Fuel									
Haul									
TOTAL					195,482	535,098		890,013	1,620,594

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 16. Estimated 1997 expenditures for non-residents fishing off a private boat in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	12.6%	32,777						
Days spent on Kenai[1]	2.92		95,709						
Days spent in Alaska[2]	1.02		33,433						
Auto				7.81		747,490		261,110	1,008,599
RV				2.92				377,095	377,095
Lodge				7.83		749,404		261,778	1,011,182
Groceries				10.72		1,026,004		358,399	1,384,403
Restaurant & Bar				6.65		636,467		222,328	858,795
Charter									
Gear				17.12	561,145				561,145
Processing				7.87	257,956				257,956
Derby				1.65	54,082				54,082
Boat Fuel				15.76	516,568				516,568
Haul				9.00	294,995				294,995
TOTAL					1,684,747	3,159,365		1,480,709	6,324,821

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 17. Estimated 1997 expenditures for non-residents fishing off a charter boat in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days			Expenditures					
	Ratio	% of Total	Person	$/Day	Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	1.00	35.9%	93,113						
Days spent on Kenai[1]	2.03		189,020						
Days spent in Alaska[2]	2.86		266,304						
Auto				8.08		1,527,281		2,151,736	3,679,016
RV				18.92				8,614,727	8,614,727
Lodge				22.94		4,336,117		6,109,012	10,445,129
Groceries				9.93		1,876,968		2,644,398	4,521,366
Restaurant & Bar				9.63		1,820,262		2,564,507	4,384,768
Charter				140.75	13,105,691				13,105,691
Gear				15.5	1,443,255				1,443,255
Processing				32.72	3,046,666				3,046,666
Derby				1.37	127,565				127,565
Boat Fuel									–
Haul									–
TOTAL					17,723,177	9,560,627		22,084,379	49,368,183

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 18. Total estimated 1997 expenditures for all residents fishing in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Days	Expenditures				
		Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	259,615					
Days spent on Kenai[1]	478,252					
Days spent in Alaska[2]	321,945					
Auto			4,773,663		2,716,025	7,489,688
RV					9,865,441	9,865,441
Lodge			7,043,712		6,789,565	13,833,277
Groceries			5,424,730		3,261,746	8,686,476
Restaurant & Bar			4,524,836		3,065,999	7,590,835
Charter		16,707,284				16,707,284
Gear		2,663,274		131,077		2,794,351
Processing		3,784,267				3,784,267
Derby		302,514				302,514
Boat Fuel		2,528,733		573,236		3,101,969
Haul		847,381				847,381
TOTAL		26,833,453	21,766,941	704,313	25,698,776	75,003,482

[1] Includes days fished.
[2] Excludes days spent on Kenai.

Table 19. Total estimated 1997 expenditures by residency and fishing mode for fishers fishing the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon.

	Fishing	Non-Fishing	Total
Residency			
Local	1,016,546	648,419	1,664,965
Alaska	6,917,814	9,107,106	16,024,920
Non-Resident	19,603,406	37,710,191	57,313,597
Total	27,537,766	47,465,716	75,003,482
Fishing Mode			
Shore	218,024	1,618,585	1,836,609
Private Boat	5,561,827	9,784,412	15,346,239
Charter	21,757,916	36,062,719	57,820,634
Total	27,537,766	47,465,716	75,003,482

The following discussion is assuming that 100% of each trip taken, as well as the trip expenditures, were attributed to the desire to fish the Kenai for saltwater halibut and salmon. Obviously this is not the case. Some of these travelers would have taken the Alaskan and Kenai trips, and made at least partial expenditures, even if the Kenai saltwater fishery had not been attractive enough to have drawn them to fish. For example, visitors on business trips may well have visited Alaska whether or not they were planning to fish on the Kenai. It is fairly accurate to assume that these fishing expenses would not have occurred if the respondents had not fished but the assumptions on whether the trip would have been taken, and whether the other living and traveling expenses would have occurred, is harder to estimate. More will be said about this later. For now, the following living and traveling expenses (reported in Tables 9–19) are all estimated to have occurred as a direct result of the respondent's desire to fish on the Kenai for saltwater salmon and halibut.

Each of the nine individual total expense categories, broken out by residency and fishing mode, were used in the baseline scenario. These expenses are totaled and summarized in Table 18. The total expenses from fishing-related activities for salmon and halibut off the Kenai Peninsula for 1997 were estimated to be $75,003,482. This is further broken out by area. It was estimated that this fishery provided $26.8 million to the Kenai in direct fishing expenses and $21.7 million to the Kenai in living and traveling expenses as the result of the fishery. In addition, the fishery was estimated to have provided approximately one million dollars to the rest of Alaska in fishing expenses and $25.6 million in living and traveling expenses. From this fishery the total direct expenditures to the Kenai were $48.6 million, and $26.4 million to the rest of Alaska.

By category, the largest fishing expense was charter and guide fees totaling $16.7 million. Processing, boat fuel, and gear all brought in approximately $3 to $4 million. Nearly all fishing expenses are estimated to have been spent on the Kenai. For living expenses the single largest category was RV rentals as lodging, which was estimated to have brought in $13.8 million. All other expenses ranged between $7 and $10 million.

Table 19 breaks out the total expenditures by residency and fishing mode. Non-residents were estimated to have spent three-quarters of the $75 million, or $57 million. By fishing mode, the charter industry brought in 77% of the total expenditures, approximately $58 million. Expenditures for the private boat industry brought in the bulk of the rest.

Total expenditures assuming that less than 100% of each trip was attributable to fishing

There are many reasons that a visitor may visit Alaska. Lee et al. [1999] identified nine primary trip purposes. Table 20 shows the reasons that residents who fished the Cook Inlet portion of the saltwater halibut and salmon fishery visited Alaska.

Table 20. Primary purpose of visit to Alaska for Kenai Peninsula saltwater halibut and salmon anglers from Lee et al. [1999].

Primary Reason for Trip	All	Alaskans (less locals)	Non-Residents
Fishing on Kenai main reason	63.5%	87.7%	43.0%
Visit/Vacation Alaska	14.3%	2.5%	24.4%
Relatives	7.0%	2.0%	11.2%
Kenai Freshwater Fish	8.7%	4.9%	12.0%
Business	2.5%	1.0%	3.7%
Saltwater/Freshwater Fishing	1.6%	0.5%	2.5%
Visit Friends	0.9%	1.5%	0.4%
Cruise Ship	0.7%	0%	1.2%
Hunting	0.9%	0%	1.7%

The majority (63.5%) of all respondents' main reason for traveling on their fishing trip was to fish. This was overwhelmingly true for the Alaska residents, where nearly 90% listed fishing on the Kenai (for saltwater halibut or salmon) as the main reason for the trip. However, less than half (43%) of the non-residents' main purpose was to saltwater fish. For the non-residents, another large reason to take the trip was to visit and vacation in Alaska (24.4%). Freshwater fishing and visiting relatives followed this.

It is not likely that there is a one-to-one correspondence between visits to Alaska and the desire to fish on the Kenai. For that reason the following assumptions (see Table 21) were made as to what residents would do if they had to cancel the Kenai saltwater fishing portion of their trip to the Kenai.

Table 21. Assumed effects of the cancellation of the saltwater fishing portion of the Kenai trip.

Primary Reason for Trip	Alaskans (less locals)	Lower-48
Saltwater Fishing on Kenai	Cancel Entire Trip	Cancel Entire Trip
Visit/Vacation in Alaska (non-Kenai focus)	Cancel Kenai Trip replace these days with days in other parts of Alaska	Cancel Kenai Trip replace these days with days in other parts of Alaska
Visit Relatives	Still take full trip	Still take full trip
Freshwater Fishing on Kenai	Reduce days spent in Kenai and Alaska by amount of days lost saltwater fishing	Reduce days spent in Kenai and Alaska by amount of days lost saltwater fishing
Business Trip	Still take full trip	Still take full trip
Combined Saltwater/freshwater fishing	Reduce days spent in Kenai and Alaska by amount of days lost saltwater fishing	Reduce days spent in Kenai and Alaska by amount of days lost saltwater fishing
Visit Friends	Still take full trip	Still take full trip
Cruise Ship	No observations	Still take full trip
Hunting	No observations	Still take full trip

To estimate the amount of reduction in time spent on the Kenai and in Alaska for a reduced fishing effort we ran the scenarios in Table 20 for the amount of days (instead of number of people) fished, days spent on Kenai, and days spent in Alaska. We then used the assumptions about changes in fishing visitation rates made in Table 21 to estimate the changes in visitation rates found in Table 22.

Table 22. Estimated reduction in visitation rates for a 100% reduction in fishing effort (days).

	Locals	Alaskans	Non-Residents
Fishing Reduction	100%	100%	100%
Kenai Living Reduction	100%	85.5%	60.5%
Alaska Living Reduction	100%	77.9%	27.9%

These are very broad assumptions and there are other likely scenarios such as substitute fishing trips, etc. However, we believe that these assumptions are better than assigning 100% of the expenditures from the trips to the saltwater halibut- and salmon-fishing component. These percentages can also be used to estimate the amount of the baseline expenditures attributable to the fishing component of the trip assuming a dollar-for-dollar expenditure pattern with days spent in Alaska[3]. The calculations in Table 22 indicate that, for Alaskans, 86% of the Kenai living and transportation expenditures can be attributed to the fishing component of the trips as can 77.9% of the living and transportation expenditure in Alaska. For non-residents (Table 22) we estimate that approximately 60.5% of the living and transportation expenditures in the Kenai are a direct result of the fishing component of the trip, but that only 27.9% of the total expenditures in Alaska are directly attributable to the fishing component of the trip.

Using the assumptions in Table 22, we redid all expense Tables (9–19) to reflect the estimated actual expenditures as the direct result of fishing the saltwater Kenai halibut and salmon fishery. Only the recalculations of Tables 18 and 19 are produced here (see Tables 23 and 24)[4].

[3] There is still the issue, for living expenditures, of whether Alaskans would have spent some portion of these amounts to live and do other things on the lost fishing days. We assume that most of these living expenditures are trip specific but there is likely to be some overlap with what the Alaskan residents would have spent on living doing an alternative activity.
[4] The recalculations of Tables 9–17 can be obtained by writing the authors.

Table 23. Total estimated 1997 expenditures for all residents fishing in the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon that are attributed directly to the saltwater halibut and salmon fishing trip.

	Days	Expenditures: Fishing (Kenai)	Other (Kenai)	Fishing (Alaska)	Other (Alaska)	Total
Days Fished	259,615					
Days spent on Kenai[1]	334,634					
Days spent in Alaska[2]	97,542					
Auto			3,479,128		879,623	4,358,751
RV			–		4,206,146	4,206,146
Lodge			4,668,221		2,055,320	6,723,541
Groceries			3,891,004		1,016,043	4,907,047
Restaurant & Bar			3,224,754		961,555	4,186,309
Charter		16,707,284				16,707,284
Gear		2,663,274		131,077		2,794,351
Processing		3,784,267				3,784,267
Derby		302,514				302,514
Boat Fuel		2,528,733		573,236		3,101,969
Haul		847,381				847,381
TOTAL		26,833,453	15,263,107	704,313	9,118,687	51,919,560

[1] Includes days fished.
[2] Excludes days spent on Kenai

Table 24. Total estimated 1997 expenditures by residency and fishing mode for fishers fishing the marine waters of Cook Inlet off the Kenai Peninsula for halibut and salmon that are attributed directly to the saltwater halibut and salmon fishing trip.

	Fishing	Non-Fishing	Total
Residency			
Local	1,016,546	648,419	1,664,965
Alaska	6,917,814	7,729,804	14,647,618
Non-Resident	19,603,406	16,003,571	35,606,977
Total	27,537,766	24,381,794	51,919,560
Fishing Mode			
Shore	218,024	642,698	860,722
Private Boat	5,561,827	6,893,339	12,455,166
Charter	21,757,916	16,845,757	38,603,673
Total	27,537,766	24,381,794	51,919,560

Using the estimate of living and transportation expenditures attributed directly to the saltwater halibut and salmon fishing trip reduced total expenditures from $75 million to $52 million. All of this $23 million dollar reduction in expenditure estimates comes from the living and transportation reductions of $6.5 million from the Kenai and $16.5 million from outside of Alaska. Table 24 indicates that non-residents still make up the majority of the expenditures (69%) while the charter industry makes up 74% of the total expenditures by fishing mode.

Input–Output model

Changes were introduced to the baseline model by correcting four separate zip code models that included the western Kenai Peninsula, but excluded Seward and a small part of the borough on the western shore of Cook Inlet. Changes in the model are given in employment numbers. The value-added and industry output components were also changed proportionately. When these industries were added, the average per job value-added and industry output from the national model were used. These changes took place before any modifications of RPCs (Regional Production Coefficients) or production functions.

The Kenai–Nikiski model

The first model is for the Kenai–Nikiski area. Expert interviews were held with John Williams, former Borough Mayor, Becky Hultberg from the Borough Economic Development Office, and Rick Ross and Laura Measles of the Kenai Chamber of Commerce. The model had 92 sectors from IMPLAN. The expert interviews and correlation of the model with other data sources including the agricultural statistics publication from USDA, the Kenai Borough School District employment roster, and other miscellaneous sources yielded the extensive changes. A detailed breakdown for this and the models below is in the final report for the project, Herrmann et al. [2000].

The Homer model

The sector-by-sector correction of the Homer/Seldovia model was completed with input from Derotha Ferraro, Homer Chamber of Commerce, and Shari Hobbs, Homer Mayor's office. Also taken into account were the ES202 files from the Alaska Department of Labor. When there was not agreement between interview subjects, their answers were averaged. In sectors where ES202 data was relatively complete, these data were used. Absent any conflicting information, IMPLAN database numbers were accepted as the best estimates.

The Anchor Point and Ninilchik model

The documentation for the communities of Ninilchik and Anchor Point relied mainly upon the expert testimony of three people, one who was considered expert for both communities, one considered expert in Anchor Point, and one for Ninilchik. They were, respectively, real estate agent Emmett Trimble, business owner Simone Klutts, and business owner Vicki Stik. All were recommended by the Kenai Peninsula Borough Economic Development District. They were presented with the value-added and employment report from the IMPLAN zip code model and asked to determine the accuracy of all sectors.

Soldotna and balance of northern Kenai Peninsula model

The documentation for these communities relied mainly upon the expert testimony of Kurt Eriksson, National Bank of Alaska Soldotna, and Tom Boedeker. They were presented with the value-added and employment report from the IMPLAN zip code model and asked to determine the accuracy of all sectors.

Simulations

Our focus to date has been on refining the data and models. Although we have run test simulations to debug the models, we have not begun our formal simulation analysis.

Discussion

We are now poised to begin using the models to explore the effects of changes in sportfishing opportunity on angler net benefits and the ultimate impact of those changes on the regional economy through the evaluation of various scenarios. The regional economic impacts of these scenarios will be explored by representing the effects of the contingent behavior of anglers in the I–O model.

Preliminary Conclusions

It would be premature to draw conclusions from the data or simulations at this time.

Student Involvement

Students working on this project were Chuck Hamel, M.S. student, supported by CMI, Mike Orr, an undergraduate whose time (5–8 hours per week for the 1997–98 academic year) was donated to the project, and Isaac Wedin, an M.S. student supported by Alaska Sea Grant.

Acknowledgements

We are grateful for information provided by the Kenai, Seward, and Homer Chambers of Commerce, Becky Hultberg and Craig Layman (Kenai Peninsula Borough Economic Development District), Sheri Hobbs (City of Homer), John Williams (former Kenai Peninsula Borough mayor), Tim Evers (Deep Creek Charter Association), Frank Libal (Anchor Point Charter Association), Robert Ward (Homer Charter Association), Karl Kircher (Kenai Peninsula Fishers's Association), Theo Matthews (United Cook Inlet Drifters Associations), Nancy and John Hillstrand (Alaska Custom Seafoods), Kurt Eriksson (National Bank of Alaska, Soldotna), Doug Coughenower (Alaska Sea Grant Marine Advisory Program), and Emmett Trimble, Simone Klutts, Vicki Stik, and Tom Boedeker.

Study Products

Reports

Criddle, K.R., J.A. Greenberg, H.Geier, C.Hamel, M. Herrmann, S.T. Lee and C. Lewis. 1998. An economic assessment of the marine sport fisheries in lower Cook Inlet, p. 5–12. *In* University of Alaska Coastal Marine Institute Annual Report No. 5. OCS Study MMS 98–0062, University of Alaska Fairbanks.

Presentations

Overviews of the project methodology and progress-to-date were presented at the annual CMI meetings in February 1998 and 1999, in a seminar at the MMS offices in Anchorage in April 1998, and at the information transfer meeting in Anchorage (January 1999).

References

Alaska Department of Fish and Game (ADF&G). 1998. Harvest, catch, and participation in Alaska sport fisheries during 1997. Division of Sports Fish. Fishery Data Series No. 98-25.

Alaska Department of Fish and Game. 1999. http://www.state.ak.us/local/akpages/FISH.GAME/sportf/geninfo/regs/ci-99/cook99.htm

Coughenower, D.D. 1986. Homer, Alaska guided sport fishing industry study. Marine Advisory Bulletin No. 22, Alaska Sea Grant College Program, University of Alaska Fairbanks.

Criddle, K.R. 1994. Economics of resource use: A bioeconomic analysis of the Pacific halibut fishery, p. 37–52. *In* D.G. Shaw [ed.], Proc. Fourth International Symp. of the Conference of Asian and Pan-Pacific University Presidents, September 1993, Anchorage, AK. Alaska Sea Grant College Program, University of Alaska Fairbanks.

Crutchfield, J.A., and A. Zellner. 1962. Economic aspects of the Pacific halibut fishery. Fish. Indust. Res. 1: 1–73.

Fawson, C., and K.R. Criddle. 1994. A comparative analysis of time series approaches to modeling intersectoral and intercounty employment linkages in rural regional labor markets, J. Reg. Sci. 34:57–75.

Geier, H. and D. Holland. 1991. Economic aspects of federal livestock grazing policy: a regional economic analysis for the Okanogan–Ferry Area in Washington. Washington State Univ. Pullman, WA. Dept. of Agric. Econ. Staff Paper A.E. 91–3.

Geier, H., D. Holland, and E. Schuster. 1994. Using IMPLAN to analyze small county economies for identification of development opportunities. USDA Forest Service Intermountain Research Station Research Paper.

Herrmann, M. 1993. Using an international econometric model to forecast Alaska salmon revenues. Mar. Resour. Econ. 8: 249–271.

Herrmann, M. 1994. The Alaska salmon fishery: an industry in economic turmoil. J. Aquat. Food Prod. Techn. 3: 5–22.

Herrmann, M. 1996. Estimating the induced price increase for Canadian Pacific halibut with the introduction of the individual vessel quota program. Can. J. Agric. Econ. 44: 151–164.

Herrmann, M., and J.A. Greenberg. 1994. A revenue analysis of the Alaska pink salmon fishery. North Am. J. Fish. Manage. 14: 537–549.

Herrmann, M., S.T. Lee, C. Hamel, K.R. Criddle, H.T. Geier, J.A. Greenberg and C.E. Lewis. 2000. An Economic Assessment of the Sport Fisheries for Halibut, and Chinook and Coho Salmon in Lower Cook Inlet. Final Report. OCS Study MMS 2000–0xx, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks. In press.

Homans, F.R. 1993. Modeling regulated open access resource use. Doctoral dissertation, Department of Agricultural Economics, University of California, Davis.

International Pacific Halibut Commission (IPHC). 1998. Pacific halibut stock assessment and fishery evaluation (SAFE), Appendix A. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska as Projected for 1999. North Pacific Fishery Management Council, Anchorage, AK.

International Pacific Halibut Commission. 1999. http://www.iphc.washington.edu/halcom/pubs/annrep/AnnualReport96.pdf.

Jones and Stokes Assoc. Inc. 1987. South-central sport fishing economic study. Alaska Department of Fish and Game, Division of Sport Fisheries, Anchorage, AK.

Layman, R.C., J.R. Boyce, and K.R. Criddle. 1996. Economic valuation of the chinook salmon sport fishery of the Gulkana River, Alaska under current and alternate management plans. Land Econ.72: 113–128.

Lee, S.T., M. Herrmann, I. Wedin, K.R. Criddle, C. Hamel, and J. Greenberg. 1999. Summary of angler survey: saltwater sport fishing off the Kenai Peninsula, Alaska. Final report, Alaska Sea Grant Project 98–403 R14-17, 40 p.

Lin, B.-H., H.S. Richards, and J.M. Terry. 1988. An analysis of the exvessel demand for Pacific halibut. Mar. Resour. Econ. 4: 305–314.

Logsdon, C.L., K.L. Casavant, and W.C. Thomas. 1977. Input–output tables for Alaska's economy: A first look, Agric. Exp. Sta., Univ. of Alaska, Bull. No. 48.

Mundy, P.R., K.K. English, W.J. Gazey, and K.E. Tarbox. 1993. Evaluation of the harvest management strategies applied to sockeye salmon populations of Upper Cook Inlet, Alaska, using run reconstruction analysis, p. 107–140. *In* G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn II [eds.], Proc. Intern. Symp. on Management Strategies for Exploited Fish Populations, Alaska Sea Grant College Program, University of Alaska Fairbanks.

National Research Committee to Review Individual Fishing Quotas. 1999. Sharing the Fish: Toward a National Policy on Individual Fishing Quotas, National Research Council, National Academy Press.

North Pacific Fishery Management Council (NPFMC). 1991a. Environmental Impact Statement, Regulatory Impact Review, Regulatory Flexibility Analysis for the Proposed Individual Fishing Quota Management Alternatives for the Halibut Fisheries in the Gulf of Alaska and Bering Sea/Aleutian Islands. North Pacific Fishery Management Council, Anchorage, AK.

North Pacific Fishery Management Council (NPFMC). 1991b. North Pacific Fisheries Management Council Sablefish and Halibut Fixed Gear Fisheries Individual Fishery Quota System Draft Implementation Plan. North Pacific Fishery Management Council, Anchorage, AK.

Olson, D., S. Lindall and D.W. Maki. 1993. Micro IMPLAN Software Manual. Minnesota IMPLAN Group, St. Paul, MN.

Richardson, H.W. 1972. Input–Output and Regional Economics. Halstead Press, New York.

Summers, P., and H. Birss. 1991. Revitalizing the timber dependent regions of Washington. Northwest Policy Center, Univ. of Washington Graduate School of Public Affairs, Seattle, WA. Report for the Washington Dept. of Trade and Economic Development.

Weddelton, J. 1986. The 1982 Alaska Input–Output model, Univ. of Alaska Fairbanks. Unpublished M.S. Thesis.

The Relationship of Diet to Habitat Preferences of Juvenile Flatfishes in Kachemak Bay, Alaska: Phase I

Brenda L. Norcross <norcross@ims.uaf.edu>
Brenda A. Holladay <holladay@ims.uaf.edu>
Arny L. Blanchard <arnyb@ims.uaf.edu>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

Task Order 14278

Abstract

This pilot study examined the diet of 80 juvenile flathead sole collected in Kachemak Bay, Alaska over a range of seasons, depths, and substrates. Samples were gathered prior to the present project during a study of seasonal juvenile flatfish habitat which defined the preferred range of depth and substrate for flathead sole and rock sole, the most abundant flatfishes in Kachemak Bay. Diets were examined based on season of capture (winter, spring, or summer), depth preference (<40 m: shallower than preferred; 40–80 m: preferred; >80 m: deeper than preferred), substrate preference (<50% mud: larger than preferred; >50% mud: preferred), and fish size. Ten fish with stomach contents (predators) were examined from winter (regardless of depth or substrate), 10 predators from spring (regardless of depth or substrate), and 60 predators from summer collections (10 within each of 6 substrate/depth combinations). Diets were described based on the numbers of individuals of each prey taxon consumed, and were separately described based on prey biomass. Where a single prey taxon accounted for ≥10% of the diet either by number of individuals consumed or by biomass, that taxon was considered to be important to the diet based on numerical or biomass criteria. Where a prey taxon accounted for ≥10% of the diet both by numbers of individuals and biomass, we were reasonably sure that the prey taxon was substantially important in the diet of the fish caught in that parameter. Statistical comparisons among the use of a prey taxon on any one parameter, e.g., use of Polychaeta during winter, spring, and summer, were performed by applying a logistic model to presence/absence of prey. The significance level was set to $\alpha = 0.05$.

The 65 prey taxa consumed by juvenile flathead sole in this study were divided into 13 general taxonomic groups for analysis: Foraminiferida, Polychaeta, Bivalvia, Crustacea (unidentified), Ostracoda, Copepoda, Euphausiacea, shrimps, crabs, Mysidacea, Cumacea, Isopoda, and Gammaridea. The subphylum Crustacea provided the greatest variety of prey taxa and the largest count of individual prey consumed.

Flathead sole collected during summer usually had stomach contents (N = 60 predators of 79 fish examined) indicating they fed more often than fish collected during spring (N = 10 predators of 21 fish examined) or winter (N = 10 predators of 40 fish examined). No prey taxon accounted for ≥10% of both numbers of individuals and biomass consumed in all seasons. Copepods were important numerically in each season, but provided very little biomass in any season. Based on both numerical and biomass criteria, mysids and amphipods were important in the winter diet, polychaetes were important in the spring diet, and mysids were important in the summer diet. Sample size was not sufficient to determine whether seasonal diets were significantly different based on prey presence/absence.

Euphausids were important in all depth ranges when using both count and biomass criteria. Additionally, based on these criteria, gammarid amphipods were important in depths of < 40 m; mysids were important in depths of 40–80 m; and both shrimps and mysids were important in depths of > 80 m. Mysids were consumed equally at all depth strata (χ^2=0.15, p=0.926), and shrimps were consumed by more predators where depth > 80 m (χ^2=8.36, p = 0.015).

Based on numerical and biomass criteria, "shrimps" was an important taxon in both less preferred (< 50% mud) and preferred (> 50% mud) substrates, euphausids were important in < 50% mud, and mysids were important in > 50% mud. The logistic model detected no significant difference in number of predators consuming polychaetes, mysids, gammarid amphipods, euphausids, and shrimps over the two substrates. The number of predators consuming Copepoda was greater on substrate < 50% mud than on the preferred substrate (χ^2=3.75, p = 0.053).

No prey taxon was important to all sizes of flathead sole based on both prey counts and biomass. The taxa Mysidae and Copepoda were important to small fish (28–51 mm total length) based on prey counts and biomass; Mysidae and Gammaridea were important to medium fish (52–77 mm); and Euphausiacea and shrimps were important to large fish (78–165 mm). Copepoda (χ^2=7.53, p = 0.023) and shrimps (χ^2=7.32, p = 0.026) were consumed with different frequency among fish of different sizes. The number of small, medium, and large predators consuming Mysidacea, Gammaridae, and Polychaeta were not significantly different.

Though this small sample size (N = 80 predators) was insufficient to determine if flathead sole occur in preferred habitats due to the prey associated with those habitats, this research indicated that certain prey taxa were consumed within limited ranges of depth and substrate. In particular, shrimps were consumed at depths > 80 m and by flathead sole ≥52 mm. Copepods are consumed on substrates < 50% mud and by flathead sole ≤77 mm. Mysids were consumed equally at all depths and on both substrates. Polychaetes and gammarid amphipods were consumed equally on both substrates and by all sizes of flathead sole.

Study Products

Holladay, B.A. and B.L. Norcross. 1998. Relationship of diet to habitat preferences of juvenile flatfishes. University of Alaska Coastal Marine Institute Annual Research Review, February 1998, Fairbanks.

Holladay, B.A., B.L. Norcross and A. Blanchard. 1998. The relationship of diet to habitat preferences of juvenile flatfishes in Kachemak Bay, Alaska. Preliminary Report, MMS Task Order #14278. University of Alaska Coastal Marine Institute, University of Alaska Fairbanks. 13 p.

Holladay, B.A., B.L. Norcross and A. Blanchard. 1999. A limited investigation into the relationship of diet to the habitat preferences of flathead sole. Final Report. OCS Study MMS 99-0025. University of Alaska Coastal Marine Institute, University of Alaska Fairbanks. 27 p.

Norcross, B.L. and B.A. Holladay. 1998. The relationship of diet to habitat preferences of juvenile flatfishes in Kachemak Bay, Alaska, p. 45–54. *In* V. Alexander, University of Alaska Coastal Marine Institute Annual Report No. 5. OCS Study MMS 98-0062, University of Alaska Fairbanks.

Norcross, B.L. and B.A. Holladay. 1999. The relationship of diet to habitat preferences of juvenile flatfishes in Kachemak Bay, Alaska. University of Alaska Coastal Marine Institute Annual Research Review, February 1999, Fairbanks.

Feeding Ecology of Maturing Sockeye Salmon (*Oncorhynchus nerka*) in Nearshore Waters of the Kodiak Archipelago

Albert V. Tyler <ffavt@uaf.edu>
Bruce C. McIntosh <fsbcm1@uaf.edu>

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

Charles O. Swanton <charles_swanton@fishgame.state.ak.us>

Alaska Department of Fish and Game
1300 College Road
Fairbanks, AK 99701-1599

Task Order 15160

Abstract

As demands for additional commercial fisheries opportunities increase, forage species may be sought after by industry. We are examining the role of forage species as a part of the food energy requirements of the sockeye salmon, and looking at the potential impacts that nearshore development in relation to oil exploration leases may have on the prey species of the salmon—hence the coupling of this research with the Minerals Management Service. The North Shelikof Strait oil and gas lease area is known to be both a migration corridor and a foraging area for Kodiak's Pacific salmon.

During 1998, a majority of sockeye salmon sampled from Kodiak migration pathways of sockeye were shown to be feeding until late July when feeding was reduced, confirming earlier published findings. Both time and area effects on feeding prevalence and dietary content were found to be significant. We are continuing our intensive study of feeding prevalence and dietary content of sockeye salmon sampled from five Kodiak Archipelago locations along migration corridors and migration terminus areas.

Background and Relevance

Sockeye salmon are the economic mainstay of the Kodiak commercial salmon fishing industry. The role of the freshwater environment for sockeye salmon production is well understood [Koenings and Burkett 1987; Stockner 1987], but knowledge of marine life history suffers from numerous data gaps, except in the areas of ocean distribution and offshore food web dynamics [Burgner 1991; Pearcy et al. 1988; Brodeur 1990]. The final stages of maturation in salmon are critical to successful reproduction. Growth is directed toward storage of energy reserves and production of gonadal tissue immediately prior to cessation of feeding and ascension to freshwater spawning grounds [Brett 1995]. Man-made perturbations can increase metabolic demands, decrease prey diversity and reduce prey abundance, adversely affecting growth and available energy stores [Brett 1983, 1995; Higgs et al. 1995].

Current knowledge of the nearshore feeding ecology of mature sockeye is limited to several research efforts, spanning an area from Oregon to the Sea of Okhotsk, and shows sockeye salmon to vary feeding patterns by location presumably in response to prey availability. This precludes generalization to other locations, as most studies are site specific [Andrievskaya 1966; Nishiyama 1977; Brodeur 1990; Beachum 1986; Helton 1991]. A recurrent theme in these studies is that euphausiids, fish larvae, decapods, and amphipods are the major dietary components of maturing fish in coastal waters. However, in 1994 predominant prey items (listed by rank) for fish sampled within Kodiak waters were sand lances (*Ammodytes hexapterus*), snails (*Limacina helicina*) and euphausiids (*Thysanoessa spinifera*) (Swanton 1997a). Research areas still to be addressed include the feeding prevalence of mature fish, the stage of feeding cessation, and identification of major prey taxa. Evaluation of the food web dynamics and feeding habits of mature salmon is necessary for an understanding of potential ingestion pathways for hydrocarbon contamination. Prey taxa, identified in initial studies in the Kodiak area, exhibit varied life history strategies including habitat utilization. Assessment of differences (temporal and spatial) in contamination of these habitats can lead to a more concise evaluation of the impact on salmon once prey utilization is known. Identification of feeding prevalence and stage of cessation provides a clearer understanding of contamination potential via ingestion.

The North Shelikof Strait lease area is important for maturing sockeye salmon of Kodiak origin. Prevailing currents in lower Cook Inlet and Shelikof Strait potentially extend impacts from oil and gas development throughout the inshore areas of the Kodiak Archipelago and eastern Alaska Peninsula. The results of this research would be applicable to contingency planning for spill prevention, development, and natural gas exploration, as well as establishing pre-impact baseline measures. These results could also affect fisheries management policy by identifying significant forage species for sockeye in nearshore waters, thus affording these populations protection from potential commercial exploitation. Once key forage species are identified in relation to area and month, it will be possible to interpret what is known and published of their biology with respect to potential impacts from oil and gas development.

The primary focus of this study will be restricted to sockeye salmon. As the principle target of the Kodiak salmon industry, sockeye landings comprised approximately 93% of the total ex-vessel value for salmon in the Kodiak area during 1996 [Kevin Brennan, ADF&G, personal communication]. Differences in migration patterns, stock composition, life stage and run timing for each of the other Pacific salmon species would require separate methodologies, beyond the proposed scope of this project. Similar studies could be initiated for the Cook Inlet region, as well as for other areas having established commercial fisheries and local processing facilities. Protocols and methods developed within this study could be expanded to these areas, allowing for comparison of findings across a broad geographic area. Limitations of personnel and resources, within the context of this study, preclude expanding this research effort outside of the Kodiak Management Area. This research project will be two years in duration.

Objectives

1) Determine the incidence of feeding (% of stomachs with prey) sockeye salmon from three locations known to be migration corridors (Eastside Kodiak, Westside Kodiak, and Alaska Peninsula areas) on a weekly basis during June through August.
2) Estimate incidence of feeding of sockeye salmon from two areas each <5 km from their natal stream terminus (Ayakulik and Moser–Olga Bay sections) weekly June through August.

3) Identify and quantify the major prey taxa for sockeye salmon within the Shelikof Strait migration corridor and determine if location has an effect on prey types utilized. Identification will be made to species level where possible.

4) The identification of potential mechanisms of indirect effects on sockeye salmon, through prey utilization, due to development in oil and gas lease areas.

Null hypotheses to be tested

H_o 1) There are no temporal or spatial differences in incidence of feeding for migrating, mature sockeye salmon.

H_o 2) There is no difference in incidence of sockeye salmon feeding between terminal harvest areas and migration corridor areas.

H_o 3) There is no change, temporally, in incidence of feeding for fish in terminal areas.

H_o 4) Dietary content of sockeye salmon (major prey taxa consumed) is similar among areas and is consistent with these fish being opportunistic feeders.

Methods and Data Analyses

This project will be conducted in conjunction with the existing Alaska Department of Fish and Game (ADF&G) catch–age sampling program. Catch–age sampling is conducted in shore-based processing facilities on a weekly basis throughout the duration of the commercial fishing season. The current Kodiak catch–age sampling program collects scales from sockeye salmon commercially caught within each of the seven geographic districts that constitute the Kodiak Management Area. These scale samples are used to generate age composition estimates of the harvest and, in some districts, are employed for stock composition estimates using scale pattern analysis. Sample size for each area/period in the existing ADF&G catch–age sampling program is n=600. Each area is identified by a district, a section within that district and a statistical code. Each period is defined by a statistical week, numbered consecutively 1–53 for a calendar year.

All limited entry permit holders are required by statute to record the date, district and section their catch was obtained in on an ADF&G fish ticket (i.e., a harvest record) at the time of delivery for sale. These districts and sections (as described in Alaska Commercial Finfish Regulations for the Kodiak Area) are coded by statistical area. Gear type, permit holder(s), catch, delivery and processing dates and times are available as well. Characterization of the overall commercial harvest, within each area and island wide, is generated through ADF&G fish ticket summaries and age composition data. Sockeye salmon in the commercial catch are assumed to be mature fish of predominately local origin.

This study will use the same procedures and information in identifying the harvest area, gear type and date for the catch that is sampled. For this study each sample will consist of a minimum of n=100 sockeye salmon stomachs obtained from the commercial fishery and that were caught within a single identified area and period. The boundaries of the five study areas of interest are defined in Figure 1. Each sample period will coincide with an ADF&G statistical week. An attempt will be made to obtain a sample from each area during each period. The first scheduled commercial fishery begins 9 June; the first sampling period will be the week of 7 June to 13 June. Sampling will take place in each consecutive period through week 35, dependent upon a fishery occurring within a study area during that period. The minimum target sample size for determining feeding prevalence will be n=100 stomachs examined. The minimum volumetric subsample (for determining composition of ingested prey items) will be n=30.

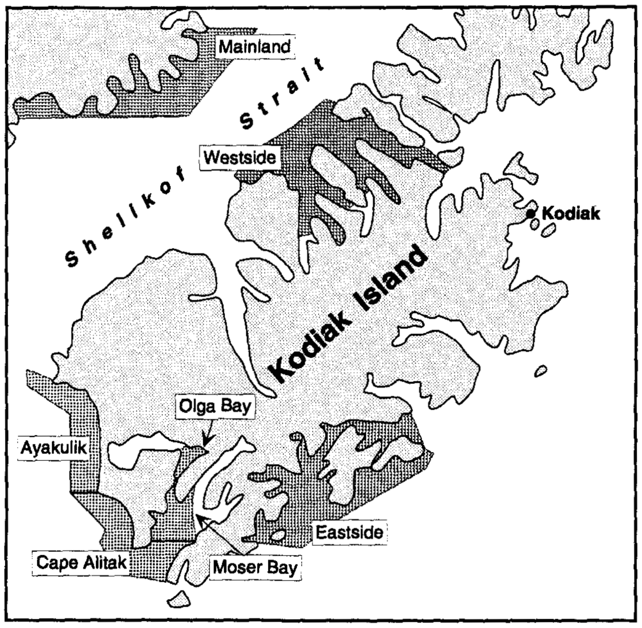

Figure 1. Sampled areas indicating migration corridors.

Samples will be collected and examined at shore-based processing facilities located in the ports of Kodiak, Larsen Bay and Alitak. Standard industry practice in the processing of sockeye salmon consists of:

1) Removing the head, gills and opercular plate with a mechanical guillotine.
2) Slicing open the body cavity, from the vent to the pectoral girdle.
3) Manually removing the viscera from the body cavity.
4) Separation and salvage of the roe from the viscera.

Sampling for this project will involve procuring physically intact and complete digestive tracts immediately after the viscera has been removed from the fish in the processing operation. These will be collected by ADF&G personnel stationed directly on the processing line. There will be no prior selection for size, sex, exterior physical condition of the fish or stomach fullness. After obtaining the stomachs they will be examined for presence or absence of food items. Those stomachs containing food items will be retained as a subsample and frozen whole (minus extraneous viscera) for prey composition analysis at University of Alaska School of Fisheries and Ocean Sciences (UAF/SFOS) facilities in Fairbanks.

The commercial deliveries from which samples are collected are expected to be random and representative of the catch. Samples from all areas except Moser–Olga will be obtained from deliveries of purse seine caught fish, due to the non-selectivity of this gear type. The Moser–Olga area is exclusively a set-gillnet fishery by regulation; all fish sampled that originate from within this area will have been caught with this gear type. Advanced notice of the arrival of deliveries, from the fishing grounds, is provided by processing personnel to ADF&G sampling crews on a confidential basis. This information will be used in selecting among potential samples to minimize the lapse between the time of capture and time of processing, and to ensure that the samples are representative of the study areas.

In the pilot study conducted in 1994 it was found that salmon held in refrigerated holds displayed little additional degradation of stomach contents after the initial effects of post-capture digestion. Samples suitable for prey analysis were obtained from catches 72 hours old. This is most likely due to brine chilling of the catch to core temperatures approaching 0 °C, typical of most current industry practice. For this study sampling will be restricted to catch that is less than 60 hours old, and has been chilled prior to delivery and processing. This time frame will be shortened if indicated in initial quality control sampling.

In the initial stages of sampling, the quality of stomachs and contents will be monitored carefully. During this period adjustments can be made in protocols to maximize the utility of subsequent samples obtained. In addition, quality control samples will be taken to examine the effects of freezing on the sample tissues. Comparisons will be made between samples that are fresh, frozen and preserved with a fixative (e.g., formalin).

Our goal is to examine 100 stomachs from each of the five aforementioned areas on a weekly basis between 9 June and 31 August, 1998 and 1999. Sampling will consist of H_0 1—addressed through sampling for presence or absence of food items, termed "incidence of feeding" or "feeding prevalence";. H_0 2—stomach fullness (in 10% increments) is determined visually, with numeric and weight subsampling performed on 15 stomachs per area/time strata; and H_0 3—identification of prey taxa (to lowest taxonomic level possible). A 2 × 2 factorial experimental design (intrinsic factors: time and area) with a logistic model [Cox and Snell 1989] fit to binomial data (feeding/non-feeding) will be employed with parameters estimated using maximum likelihood estimation [Wilkinson 1990]. Differences in incidences of prey type by time and area will be tested using chi-square tests [Beachum 1986].

H_0 4 will be addressed through the analysis of frequency of occurrence and percent composition by weight of ingested prey, generated from subsampling of stomach contents in each sample. In the two-factor design (factors: area and time) that will be employed, five factor levels will be used for area and twelve factor levels for time. Analysis of variance will be used for identification of significant area, time and area–time effects on dietary content, using comparisons within and between factor levels. In the event some samples are unavailable, empty cells will be addressed through interpolation, post-hoc temporal stratification or partial analyses.

Data management

The primary data generated from this project will consist of binomial feeding state (feeding or not feeding, termed feeding prevalence), prey category weights from each specimen examined and associated percentages. Categorical and quantitative data generated from each specimen will be managed in spreadsheet fashion and organized by sample stratum. A dedicated statistical package will be used for the analyses. The raw data files (ASCII) with header information will be provided to CMI for archival purposes. At a minimum, this data set (along with logbooks, notes and miscellaneous materials) will also be archived within the Western Region office of ADF&G.

Logistics

Sampling of the commercial catch will take place in concert with existing ADF&G sockeye and chinook (*Oncorhynchus tshawytscha*) salmon age, length, and sex composition programs [Nelson 1997; Swanton 1997b]. Commercial salmon fishing within the proposed study area commences 9 June. At a minimum, stomach samples will be collected from fish processing facilities located in Alitak Bay, Larsen Bay, and the city of Kodiak. Attempts will be made to sample only from those facilities that do not employ mechanical evisceration equipment. Initial determination of feeding state and fullness will be made at time of collection (where practicable). Subsamples for prey identification and quantification will be frozen on site and processed at UAF/SFOS facilities in Fairbanks. Sampling will be conducted by graduate student Bruce McIntosh with assistance from available ADF&G technicians; feeding state, fullness and all dietary content analyses will be conducted by McIntosh either at ADF&G facilities in Kodiak or at the UAF/SFOS facilities in Fairbanks.

Results

Stomach samples were taken during the scheduled field period as follows:

1) A total of 6334 stomachs were examined during the interval 7 June to 26 August 1998. Sampling goals were met each week during this period except for a few cases. Samples were taken in the ports of Kodiak and Alitak from lots of fish caught in known designated areas.
2) An excess of stomachs (1037) was frozen weekly throughout the sampling period.
3) Samples were taken in a representative manner through the entire migration corridor which consisted of the following areas: Ayakulik, Westside Kodiak, Eastside Kodiak, Mainland, Cape Alitak.
4) Adequate numbers of samples were taken from the terminal harvest area of Olga Bay.

Preliminary Conclusions and Data Analysis

Data analysis was begun in October 1998 and proceeded through March 1999 when preparations were begun for the 1999 sampling period.

1) Statistical analyses were carried out for possible differences in incidence of feeding, i.e., ratios of sockeye with and without prey items. Significant differences occurred among most sampling localities for any one-week sampling period. The analysis will be repeated in 1999 and the data examined for trends and compared for the two years. No conclusions have been drawn at present.
2) Statistical analyses of incidence of feeding showed significant difference among weeks for a given sampling area during the 1998 sampling period. Fewer stomachs had prey items as the season progressed.
3) Analysis of frozen samples was begun, with several hundred stomachs being processed. Large numbers of pagurid crab larvae were prevalent among the stomachs this year. This is a distinctly different finding from the preliminary study carried out in 1994, when crab larvae were rare [Swanton 1997a].

Acknowledgements

Alaska Department of Fish and Game has provided logistical support, including transportation to remote field sites on Kodiak Island. Laboratory and office support was provided by the UAF School of Fisheries and Ocean Sciences. Fish stomach sampling opportunities were provided by Wards Cove Packing Inc. The research was supported by funding from CMI.

Student Involvement

Mr. Bruce Macintosh is the M.S. degree candidate working on this project. The project will constitute his thesis.

Study Products

Quarterly reports starting July 1998.

Annual report (this report) for 1998–99.

Annual presentation to CMI TSC on 23 February 1999.

35 mm slides from annual presentation have been submitted.

Field and laboratory data: Data has been recorded on forms especially developed for this project. Copies will be submitted to the ADF&G repository at the completion of this project.

References

Andrievskaya, L.D. 1966. Food relationships of the Pacific salmon in the sea. Vopr. Ikhtiol. 6:84–90.

Beachum, T.D. 1986. Type, quantity, and size of food of Pacific salmon (*Oncorhynchus*) in the Strait of Juan de Fuca, British Columbia. Fish. Bull. 84:77–89.

Brett, J.R. 1983. Life energetics of sockeye salmon, *Oncorhyncus nerka,* p. 29–66. *In* W.P. Aspey and S.I. Lustick [eds.], Behavioral Energetics: The Cost of Survival in Vertebrates. Ohio State University Press, Columbus.

Brett, J.R. 1995. Energetics, p. 3–68. *In* C. Groot, L. Margolis and W.C. Clarke [eds.], Physiological Ecology of Pacific Salmon. University of British Columbia Press, Vancouver, BC.

Brodeur, R.D. 1990. A synthesis of the food habits and feeding ecology of salmonids in marine waters of the North Pacific (INPFC Doc.) FRI-UW-9016. Fish Res. Inst., Univ. of Washington, Seattle. 38 p.

Burgner, R.L. 1991. Life history of sockeye salmon (*Oncorhynchus nerka*), p. 4–117. *In* C. Groot and L. Margolis [eds.], Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, BC.

Cox, D.R. and E.J. Snell. 1989. Analysis of binary data. Chapman and Hall, New York.

Helton, D.R. 1991. An analysis of the Port Moller offshore test fishing forecast of sockeye and chum salmon runs to Bristol Bay, Alaska. M.S. Thesis, University of Washington, Seattle.

Higgs, D.A., J.S. MacDonald, C.D. Levings and B.S. Dosanjh. 1995. Nutrition and feeding habits in relation to life stage, p. 161–315. *In* C. Groot, L. Margolis and W.C. Clarke [eds.], Physiological Ecology of Pacific Salmon. University of British Columbia Press, Vancouver, BC.

Koenings, J.P. and R.D. Burkett. 1987. Population characteristics of sockeye salmon (*Oncorhynchus nerka*) smolts relative to temperature regimes, euphotic volume, fry density, and forage base within Alaska lakes, p. 216–234. *In* H.D. Smith, L. Margolis, and C.C. Wood [eds.], Sockeye Salmon (*Oncorhynchus nerka*) Population Biology and Future Management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Nelson, P.A. 1997. Kodiak Management Area commercial catch and escapement sampling procedures. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K97–36, Kodiak.

Nishiyama, T. 1977. Food-energy requirements of Bristol Bay sockeye salmon *Oncorhynchus nerka* (Walbaum) during the last marine life stage, p. 289–320. *In* Res. Inst. North Pac. Fish. Spec. Vol.

Pearcy, W.G., R.D. Brodeur, J.M. Shenker, W.W. Smoker, and Y. Endo. 1988. Food habits of Pacific salmon and steelhead trout in midwaters trawl catches and oceanographic conditions in the Gulf of Alaska, 1980–1985. Bull. Ocean Res. Inst. 26(II):29–78.

Swanton, C.O. 1997a. Feeding prevalence and dietary content of sockeye salmon *Oncorhynchus nerka* in coastal waters of the Kodiak Archipelago during July 1994. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report, Kodiak. In press.

Swanton, C.O. 1997b. Assessment of harvests of Cook Inlet origin Chinook salmon in commercial and marine sport fisheries in the Kodiak Management Area, 1997–1999. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Kodiak. Unpublished data Collection Operational Plan. 91 p.

Stockner, J.G. 1987. Lake fertilization: The enrichment cycle of lake sockeye salmon production, p. 198–215. *In* H.O. Smith, L. Margolis and C.C. Wood [eds.], Sockeye Salmon (*Oncorynchus nerka*) Population Biology and Future Management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Wilkinson, L. 1990. The System for Statistics. SYSTAT, Inc. Evanston, IL.

Correction Factor for Ringed Seal Surveys in Northern Alaska

Brendan P. Kelly[1] <ffbpk@uaf.edu>
Lori J. Quakenbush[2] <loriq@ims.uaf.edu>
Brian D. Taras[3] <btaras@alum.mit.edu>

[1]Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 11120 Glacier Highway, Juneau, AK 99801
[2]Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK 99775-7220
[3]Solid Solutions, P.O. Box 81825, Fairbanks, AK 99708-1825

Task Order 15162

Abstract

Over 150 subnivean breathing holes and lairs, excavated by ringed seals, were located in the shore-fast ice of the Beaufort Sea by specially trained Labrador retrievers during the spring in 1998 and 1999. Air temperature sensors recorded ambient and lair temperature simultaneously for 12 lairs in 1999 indicating the frequency and duration of lair occupation by seals. Distance to pressure ridges or ice hummocks (ambush cover) was measured at basking holes and breathing holes not used for basking to evaluate basking site selection. Basking surveys were conducted daily from a tower. Ten ringed seals were live-captured in breathing holes; subsequently the use of subnivean lairs and basking sites by eight of the seals was monitored by way of VHF radio tags glued to the seals' hair. The under-ice movements of three seals were monitored acoustically using ultra-sonic transmitters also glued to the hair. The haul-out behavior and movements of three seals continues to be monitored by way of instruments transmitting to ARGOS satellites. Analysis of the telemetry data has begun and will provide insights in to the environmental influences on haul-out behavior and estimates of the proportion of seals visible during aerial surveys.

Introduction

Ringed seals are an important resource for Native people of northern and western Alaska, and they are an important ecological component of the northern marine ecosystem [Scott 1951; McLaren 1958a, b; Stirling and McEwan 1975; Usher 1976; Stirling and Smith 1977; Nelson 1982; Smith and Hammill 1987; Smith and Wright 1989; Hammill and Smith 1991; Huntington 1992; Stirling and Øritsland 1995]. The distribution and density of ringed seals in shore-fast ice habitats may be affected by on-ice activities including oil exploration and development in the Arctic [Burns and Kelly 1982; Kelly et al. 1986, 1988, Burns and Frost 1988; Richardson *et al.* 1995].

Shore-fast ice is important as a breeding habitat for ringed seals [McLaren 1958b; Burns 1970; Smith 1973]. Ringed seals maintain breathing holes through the ice by abrading the ice with the claws of their front flippers. The holes become snow covered in the fall or early winter, and the seals continue to breathe at the ice surface but under the snow [Smith and Stirling 1975]. Where the snow drifts to depths of 20–150 cm above breathing holes, the seals excavate snow caves (lairs) above the breathing holes. The lairs provide a protected site for the seals to haul out with ready access only through the underlying breathing hole. In late spring or early summer, the seals bask on top of the ice next to breathing holes or access holes of opened or collapsed lairs. It is while the seals are lying next to these "basking holes" that they are available to be counted during aerial surveys.

In the Beaufort Sea, during winter and early spring, when the shore-fast ice is most stable, it is used by the oil industry for seismic surveys, ice road and gravel island construction. The effects of these human activities on ringed seals have been investigated in studies sponsored by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) and the Minerals Management Service (MMS). Study methods have included visually examining the fate of seal holes over time [Burns and Kelly 1982], telemetrically tracking seal movements [Kelly et al. 1988; Kelly and Quakenbush 1990], measuring sound levels from industrial activities at seal holes (Holliday et al. 1984], and estimating seal densities with aerial surveys [Burns and Harbo 1972; Burns et al. 1981; Frost et al. 1988]. Estimating the density of ringed seals in areas of industrial activity has relied most heavily on aerial survey data [Frost et al. 1988, 1997]. Although, aerial surveys can cover extensive areas, their utility has been limited by three major factors: (1) seasonal changes in the distribution of seals are not understood, (2) the proportion of seals visible during surveys is not known, and (3) changes in seal numbers at basking sites complicate interpretations of population estimates.

By necessity, aerial surveys are limited to the spring basking period. As the basking period progresses, however, many seals abandon their winter home ranges so that by the time surveys are flown the distribution and density has changed [Burns and Kelly 1982; Kelly and Quakenbush 1990]. Relating the distribution and density of ringed seals to industrial activities requires consideration of the timing of survey efforts and industrial activities. It is important, therefore, to determine the relationship between ringed seal distribution during the periods of industrial activities and during the aerial surveys.

An unknown proportion of the seals are visible on the ice during surveys; others are on the ice but not visible in their subnivean lairs, and yet others are under the ice itself [Kingsley et al. 1985; Small and DeMaster 1995]. Estimates of the proportion of seals unseen during aerial surveys are needed for estimating absolute population size. Previous estimates of the world's population of ringed seals have varied from 2 to 7 million [Kelly 1988]. The large variance is due, in part, to the lack of data on the proportion of the population not seen during aerial surveys. It is now recognized that proper management of marine mammals requires reliable estimates of actual population size [Lerczak et al. 1994].

Aerial surveys of ringed seals have been used to estimate population size [Stirling et al. 1977; Kingsley et al. 1985] and to determine relative abundance and distribution, particularly with reference to industrial activities [Burns and Harbo 1972; Burns and Kelly 1982; Frost and Lowry 1988; Frost et al. 1988]. Temporal or spatial comparisons based on aerial survey data have assumed that the unseen proportion is effectively constant both within and between years. The assumption is untested for ringed seals, but data for harbor seals (*Phoca vitulina richardsi*) indicate that variation in the proportion of those seals under water and unseen can change population estimates by 25% or more. Telemetric monitoring of harbor seals in several locations demonstrated that the proportion of seals out of the water varied between 0.35 and 0.76 [Huber et al. 1992; Withrow and Loughlin 1995]. While similar proportions may or may not apply to ringed seals, an additional proportion of ringed seals that are out of the water remain hidden within subnivean lairs [Kelly 1988].

Variability in survey estimates of seal density between years could be due to changes in the age structure of the population and/or the timing of the collapse of lairs, which is a function of temperature and snow conditions. Immature seals molt earlier than older seals and they tend to appear on top of the snow in mid to late May regardless of snow conditions that affect lair integrity [Kelly et al. 1986; Kelly, unpublished data]. The proportion of ringed seals unseen during a survey may be larger and more variable than that found for harbor seals.

The influence of local weather on the proportion of seals visible has often been noted. For example, strong winds are thought to negatively influence the number of seals basking. Meteorological data, however, have been measured at terrestrial sites (typically airports) some distance from the sea ice environment experienced by seals.

Associated with the breakdown of winter home ranges are changes in group size of seals visible on the ice surface. Winter home ranges break down as new cracks begin to open in the ice and seals move to basking areas [Finley 1979; Burns et al. 1981; Kingsley et al. 1985]. Group size appears to be greatest at cracks and breathing holes that are farthest from pressure ridges and other deformities in the ice capable of concealing polar bears [Burns et al. 1981; Kingsley and Stirling 1991]. The reliability of survey data declines as seals become increasingly clustered [McLaren 1961; Harkonen and Heide-Jorgensen 1990; Frost et al. 1997].

To aid in the interpretation of aerial survey data, we have located seal lairs and breathing holes using trained dogs and telemetrically monitored the behavior and movements of ringed seals before, during, and after aerial surveys. We developed those methods in Beaufort Sea studies supported by MMS/OCSEAP in 1981–1984 [Burns et al. 1981; Burns and Kelly 1982; Kelly 1983, 1984, 1985; Kelly et al. 1985, 1986, 1988; Kelly and Quakenbush 1987; Burns and Frost 1988] and subsequently used them in the Bering and Chukchi seas as well as in the Canadian High Arctic [Kelly et al. 1987, 1989; Wartzok et al. 1987, 1992a; Elsner et al. 1989; Kelly 1990, 1996a, b; Kelly and Quakenbush 1990; Kingsley et al. 1990; Kelly and Wartzok 1991, 1996, 1998]. We have also begun monitoring on-ice weather and the micro-climates within subnivean lairs in order to more accurately relate the probability of sighting seals to environmental variables.

Methods

Study area

The study area extends seaward from Prudhoe Bay (70°22.0′N 148°22.0′W) to just beyond Reindeer Island (70°29.1′N 148°21.4′W) and is adjacent to the Northstar oil development area. Shore-fast ice covers the area from October to July in most years. Water depths are mostly less than 9 m with a maximum of 12 m. Snowfall (measured at Prudhoe Bay) averages between 75 and 100 cm per year, and approximately 10 cm usually has accumulated on the ice by the time seals begin whelping in late March. Subnivean lairs, however, require a minimum of 20 cm of snow depth and pupping lairs typically are found in much deeper snow. Such snow depths are found in drifts that form on the windward and leeward sides of pressure ridges and other deformities in the ice.

Locating seal holes

We began field work for this project in April and May 1998 with two objectives; to train Labrador retrievers to locate the subnivean breathing holes and lairs of ringed seals and to begin monitoring the seasonal patterns of lair use by ringed seals.

Three Labrador retrievers have been trained to associate the odor of ringed seal with the command "natchiq". Training for two dogs (aged 8 and 6 months) began in February 1998 in Fairbanks and Juneau. When a dog was presented with a piece of ringed seal skin and blubber the trainer would say "natchiq". The dogs were then encouraged to retrieve pieces of seal thrown within their view. By throwing the pieces into soft snow or heavy brush, we required the dogs to re-locate them by smell. As the dogs set out to retrieve the seal pieces, the trainers repeated the command, "natchiq". Once the dogs had associated the command with the odor of ringed seal, the training progressed to finding pieces of seal that were hidden when the dogs were not present. An assistant would hide the seal piece in snow or deep vegetation, and the trainer would give the command and direct the dog on a path downwind of the hiding place. Initially, the dogs were directed along paths that would take them within a few meters of the seal pieces, and the distances were gradually increased to as much as 500 m.

Training continued on the sea ice of the Beaufort Sea from 19 April to 21 May 1998. The dogs readily made the transition from locating pieces of seal to finding seals holes under the snow. The dogs began finding seal holes their first day on the ice. Additional training on the ice revolved around finding seal holes in a variety of wind conditions, training the dogs to work ahead of snow machines and to indicate a seal hole by digging in the snow, and ensuring that the dogs responded to seal odor but not fox odor. When seals were captured, dogs were able to associate the odor with the live animal, which further reinforced the training. In 1999, an additional dog (one-year-old) was trained without using pieces of seal skin and blubber. This dog worked with the trained dogs and could locate seal lairs and holes on her own by the end of the season.

Monitoring lair occupation

In winter and spring, the air in subnivean lairs is warmed by the sea water below and additionally by body heat when a seal is present in the lair. Occupation of lairs can be determined by monitoring lair temperatures [Kelly et al. 1986; Smith 1987; Kelly 1988; Kelly and Quakenbush 1990; Kingsley et al. 1990]. We recorded air temperatures inside and outside of lairs using Hobo Temperature Loggers (Onset Computer Corporation). A 1-cm diameter steel rod was used to penetrate the snow above each lair, and a 5-mm diameter temperature probe was inserted. Loose snow was then packed in around the temperature probe. The probe was connected by a small electrical cable to the logger itself which was mounted on a wooden stake above the lair. Another temperature sensor located on the logger recorded ambient temperature simultaneously.

Basking holes

We measured the distance to the nearest pressure ridge or ice hummock (>0.5 m high) near seal holes used for basking and near breathing holes that were never used for basking. The number of such deformations within a 30-m radius of each hole was recorded.

Meteorological data

We operated a meteorological station on the ice within the study area (70°28.5′N 148°22.9′W) from 23 April to 8 June 1999. Air temperature, snow temperature (10 cm above ice surface), wind speed, and wind direction were recorded every 15 minutes using a Campbell Scientific CR10 data logger and SM192 Storage Module and an R.M. Young 05103 Wind Monitor. Light intensity was measured every half-hour using two Hobo Light Meters (Onset Computer Corporation). One sensor faced straight up, and the other faced true south. Barometric pressure was recorded hourly at Reindeer Island.

Seal capture

Ringed seals were captured in nets that pursed below them when they entered breathing holes. The nets were modified from our previous design [Kelly 1996a] so that they closed more rapidly (< 2 sec) and functioned in shallower water (≥ 4 m). Nets were monitored by way of a transmitting listening system planted in the snow next to the breathing holes. When seals were heard breathing in a hole, a coded radio signal was transmitted to a triggering device that dropped a lead weight to purse the net.

Telemetry

The amount of time spent out of the water and the location of those haul-out bouts were monitored telemetrically using VHF radio transmitters (164–166 MHz) and satellite transmitters (PTTs at 401.65 MHz) glued to the hair of seals with fast curing epoxy cement. Under-ice movements of seals were tracked using ultra-sonic transmitters similarly attached to seals and received via an array of four hydrophones [Wartzok et al. 1992a, b].

Radio tags were monitored hourly using a telemetry receiver with an 8-element Yagi antenna on a 50-ft high tower from two locations. The antenna was rotated through 360° while monitoring and the direction from which each signal was received was recorded. Each time a seal came out of the water, as indicated by the presence of its radio signal, we attempted to locate it to determine whether it was in or outside of a lair. On-ice tracking was conducted on foot or on skis using a hand-held directional antenna system consisting of two "H" antennas on a cross-boom connected by coaxial cables to a null combiner (Telonics; Mesa, Arizona). With this antenna configuration the direction of the signal is clearly detected as the lack of signal (or null) between two strong signals. If a seal was observed basking, considerable efforts were made to confirm that the visible seal was indeed a tagged animal.

Aerial tracking

A Cessna 185 and a Piper Super Cub were flown at 151 m over the study area to listen for VHF signals that might not be received from the ground stations and conduct seal surveys prior to the planned surveys by Frost et al. [1997].

Results

Field data collection in 1999 ended on 10 June; however, radio signals continued to be monitored from aerial surveys and other work conducted by LGL Alaska Research Associates and the seals instrumented with PTTs have continued to supply locations and haul-out activity. Data analyses have just begun, thus only preliminary results can be presented here.

Locating seal holes

We located 51 seal holes in the study area in 1998 and 103 in 1999. The greater number found in 1999 reflect the dogs' greater experience and more time spent searching over a larger area. The ratio of breathing holes to lairs was close to unity (1.22:1 in 1998 and 0.98:1 in 1999).

Monitoring lair occupation

Air temperature was monitored every 3–5 minutes in eight lairs in 1998 and in 12 lairs in 1999 for periods ranging from 5 to 47 days (Table 1). Distinct diurnal rhythms were observed in ambient air temperatures, but that signal was dampened inside of lairs by the warming of the air by seawater from below and the insulating snow cover above. Body heat, however, produced strong signals within lairs and haul-out bouts were readily discerned (Figure 1).

Table 1. Ringed seal lairs for which temperature was recorded and the duration of those records in 1998 and 1999.

Lair	Resolution	Start date	End date
98H004	±0.25°C	20 Apr 98	17 May 98
98H007	±0.25°C	21 Apr 99	20 May 98
98H019	±0.40°C	7 May 98	21 May 98
98H021	±0.25°C	30 Apr 98	4 May 98
98H021	±0.25°C	12 May 98	18 May 98
98H022	±0.40°C	7 May 98	21 May 98
98H026	±0.25°C	29 Apr 98	18 May 99
98H034	±0.40°C	7 May 98	12 May 99
98H036	±0.40°C	7 May 98	20 May 98
99H003	±0.30°C	20 Apr 99	26 Apr 99
99H008	±0.30°C	21 Apr 99	7 Jun 99
99H012	±0.30°C	23 Apr 99	6 Jun 99
99H014	±0.30°C	24 Apr 99	7 Jun 99
99H015	±0.30°C	25 Apr 99	7 Jun 99
99H018	±0.30°C	25 Apr 99	7 Jun 99
99H019	±0.30°C	28 Apr 99	29 May 99
99P020	±0.30°C	26 Apr 99	7 Jun 99
99H037	±0.30°C	3 May 99	6 Jun 99
99H042	±0.30°C	4 May 99	6 Jun 99
99H045	±0.30°C	9 May 99	6 Jun 99
99H050	±0.30°C	10 May 99	7 Jun 99

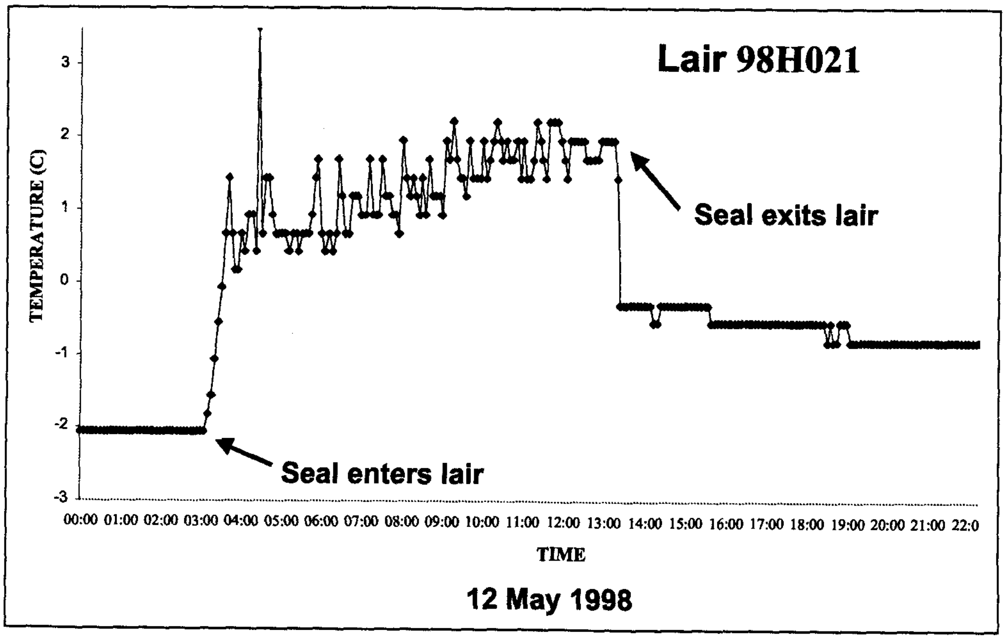

Figure 1. Temperature record of a ringed seal haul out inside a lair found in the Beaufort Sea in 1998.

Seal capture

We set nets in 19 seal breathing holes in April and May 1999. We triggered net closures in 15 of those holes when we heard seals breathing and successfully captured seals 10 times. Five seals escaped before the net closed. In four holes the nets were removed after 4–8 days without evidence of seals visiting them. One seal was captured twice, and another escaped without being tagged.

Telemetry

VHF radio transmitters were glued to eight seals and three of those also had PTTs attached to their hair. Another three seals had ultra-sonic transmitters glued to their hair in addition to the radio transmitters (Table 2).

Table 2. Ringed seals captured and telemetrically monitored in 1999.

Capture date	Seal ID	Sex	Weight (kg)	VHF radio	Other transmitter
28 April 99	–	M			(escaped)
06 May 99	RI99	M	57	164.340 MHz	
07 May 99	RI99	M	57	164.340 MHz	(recapture)
06 May 99	SW99	F	50	164.120 MHz	PPT
13 May 99	MA99	F	50	164.300 MHz	Sonic; 69.0 KHz
14 May 99	VR99	F	59	164.080 MHz	Sonic; 72.0 KHz
15 May 99	SM99	M	56	164.180 MHz	
21 May 99	SP99	F	50	164.040 MHz	Sonic; 75.0 KHz
23 May 99	CH99	F	54	164.210 MHz	PPT
24 May 99	OR99	F	52	164.280 MHz	PTT

The eight radio-tagged seals used as many as four different lairs each; the median number of lairs per seal, however, was two. Except for one, all seals were found on one or more occasion resting on top of the snow at basking holes. Five of the seals were tracked to a single basking hole, and two seals each were tracked to two basking holes. One seal was never found in a lair although it did rest out of the water at a basking hole, and another seal was tracked only to lairs. The first haul-out bouts at basking holes by seven tagged seals were observed on 21 May, 28 May, 29 May, 30 May, 2 June, 3 June, and 3 June. The transition from using lairs versus basking sites was not abrupt; the seals first observed basking on 28 and 29 May subsequently rested in lairs as late as 31 May and 6 June, respectively. The proportion of tagged seals hauled out at mid day ranged from 0 to 0.75.

The three seals tagged with PTTs continue to hau out close to their capture sites and are still being tracked. According to data downloaded from the satellite, on 15 June 1999, SW99 was 3 km northwest of her capture site, and CH99 was 2.5 km southwest of her capture site. OR99 was 4 km northeast of her capture site on 14 June 1999. Three-dimensional underwater tracks were recorded for two of the three seals tagged with ultra-sonic transmitters. Tracks indicative of foraging behavior [Kelly and Wartzok 1996] were recorded on several occasions 2–3 km from the lairs used by those seals.

Aerial tracking

Transect lines (13–17) within B3 9 [Frost *et al.* 1997] were flown on 30 May and transect lines 11–17 were flown on 1 June. Weather prevented any earlier surveys. All VHF signals heard on both surveys were also heard from the ice monitoring stations. Two other surveys were flown over our study area. The Alaska Department of Fish and Game personnel have flown transects across the Beaufort Sea annually since 1996 for the Minerals Management Service [Frost et al. 1997]. Another aerial survey effort planned by LGL Alaska Research Associates under contract by BP Alaska was unknown to us before our study began. We found that their survey altitude of 91 m was causing our radio-tagged seals to dive. On two occasions while we were tracking a seal's signal, the signal disappeared as the LGL plane flew over. LGL adjusted their flight altitude over our study area to 151 m and no additional cases of seals diving in response to the aircraft were recorded. Coordination between these two projects will be necessary prior to the next field season.

Logistics

Helicopter support to remove the field camp from Reindeer Island was not necessary in 1999. The Sagavanirktok River broke up slowly due to cold temperatures. Snowfall in the Brooks Range was apparently low and the river flow over the top of the ice did not reach the Westdock causeway. We were able to transport our camp by snowmachine and sled to the causeway. This was in contrast to 1998 when Sagavanirktok River water had surrounded the causeway by 23 May and blocked snowmachine access.

Discussion

Aerial surveys for ringed seals have been used: (1) to estimate overall population size; (2) to compare local inter-annual changes in density; and (3) to compare densities from area to area. The tradeoff in timing the survey as late as possible to catch the peak number of seals hauled out, comes with the risk that their distribution no longer represents their winter range when most industrial activity occurred. The assumption that the proportion of seals visible on the ice is constant from year to year and area to area for the duration of the survey has never been tested. Most survey designs assume that the most comparable inter-annual period is the one during which the largest densities were observed.

McLaren [1961] found that the maximal number of ringed seals observed on ice occurred in late spring, and that the timing of the peak likely varied with latitude. He also found that as large groups of seals formed in late spring, the reliability of population estimates decline. Harkonen and Heide-Jorgensen [1990] echoed those points and indicated that in the Baltic Sea break-up usually begins in early April and most ice is melted by mid-May. At higher latitudes the ice persists well into summer. Ognetov [1993] surveyed ringed seals in the East Siberian Sea from 2–21 June 1989 and 22 May–9 June 1990. He noted changes in distribution as the seals emerged from lairs and began to bask in the open. He described the change as a mass emergence of seals, but our observations of the radio-tagged seals indicated a more gradual transition from using lairs to hauling out at basking sites.

McLaren [1966] noted that the number of seals visible on the ice in Frobisher Bay, Baffin Island, Canada peaked between 27 June and 8 July. Smith and Hammill [1981] observed seals on the ice of southeastern Baffin Island in 1978 and reported peak densities on 1 June and 21 June in different portions of their study area. They suggested that immigration accounted for the later peak.

In the Canadian portion of the Beaufort Sea, Smith [1973] observed the maximal number of ringed seals visible on the ice in late June and early July. He considered the optimal survey period to be 2-3 weeks prior to ice break-up, generally the first two weeks of July in that region. Stirling et al. [1975] also concluded that late June, immediately prior to break-up, was optimal for aerial surveys in the eastern Beaufort Sea. They speculated that inter-annual variation in the timing of break-up might dramatically affect the number of seals visible on the ice. Farther east in the Barrow Strait Region of the Canadian arctic, Finley [1976] and Smith *et al.* [1978] observed marked increases in the density of seals visible on the ice in late June and early July. They chose 18–25 June and 16–28 June, respectively, as preferred survey dates. In further investigations, Finley [1979] again concluded that peak numbers occurred at the end of June. Smith *et al.* [1979] surveyed the same area on 16–18 July 1978 and concluded they had missed the peak number of seals on the ice. Hammill and Smith [1989] compared results of surveys in the Barrow Strait region in 1975 and 1984–1986. They concluded that aerial survey data are difficult to interpret because of weather and seasonal effects on the timing and pattern of haul out.

The optimal time to survey ringed seals in the Beaufort Sea, offshore of Alaska, was determined to be the second and third weeks of June according to Burns and Harbo [1972]. They suggested that seals would not have begun moving away from their winter home ranges yet and the ice surface would not be flooded with water from snow melt and river run-off. Those conclusions are consistent with our observations and the continued occupation of the study area by the three seals tagged with PTTs. On the other hand, in 1998, river run-off had flooded ice near shore by 23 May. Burns and Kelly [1982] surveyed the Beaufort Sea coast of Alaska from 2–9 June 1981. They noted rapid changes in the distribution of seals just prior to break-up, and they advanced their surveys in 1982 to 25 May to obtain data on densities and distribution that were representative of early spring distributions [Kelly et al. 1988]. They noted a slight increase in numbers after 1 June but discontinued the surveys on 4 June due to extensive surface water. Frost and Lowry [1988] planned to survey that region from 27 May to 16 June to 'coincide with ice conditions which were optimal for sighting seals and with the peak period of seal haul out". In 1985, 1986, and 1987, however, they noted that substantial snow melt and/or ice break-up by the first week of June negatively influenced seal densities on the ice [Frost et al. 1988].

Frost et al. [1997] have scheduled their recent surveys (1996–1999) for late May to early June to avoid the onset of break-up and flooding from river run-off. They also cited Kelly and Quakenbush [1990] to indicate that ringed seals spend increasing amounts of time out of the water as spring progresses. That indeed was the case with 13 radio-tagged seals tracked in 1982–1984 and the seals we monitored in 1999, although the increase was in total time spent out of the water and was observed for seals within lairs (not visible) as well as those visible at basking holes. Frost et al. [1997] stated that observed annual variability in seal densities likely reflects differing ice conditions at the time surveys were conducted. Break-up in some years occurred during or before surveys. They suggested surveying in mid-May before there is any chance of break-up.

The data collected in 1999, with further analysis, will be valuable for estimating the proportion of seals visible during aerial surveys. The simultaneous collection of on-ice meteorological data and seal haul-out behavior will be used to model the influence of weather and snow conditions on the proportions of seals visible to aerial observers. Additional monitoring of seal behavior and movements in subsequent years will be needed to observe the effects of year-to-year variation in weather and snow conditions.

Preliminary Conclusions

We have demonstrated that monitoring lair temperatures is a practical, simple method of monitoring dates of lair occupation. The behavior of our radio-tagged seals indicated that the onset of basking does not preclude subsequent lair use. We suspect that the dynamics of snow metamorphosis strongly influence the timing of lair abandonment, and those dynamics are functions of snow depth, ice thickness, ice deformation, cloud cover, and the thermal record of the preceding winter as well as spring air temperatures.

Snow melt and ice break-up in the Beaufort Sea were earlier in the early and mid 1980s than in the 1970s. Year-to-year variation remains great, however, with 1998 and 1999 examples of early and late break-ups, respectively. Continued monitoring of ringed seal haul-out behavior will provide information on the relevant environmental influences as well as direct estimates of the proportion of seals visible during aerial surveys.

Acknowledgements

This project is funded by the Coastal Marine Institute, the National Marine Mammal Laboratory (National Marine Fisheries Service), and the Natural Resources Fund (University of Alaska). ARCO Alaska, Inc. provided extensive logistic support in the form of snowmachines, generator, fuel, room and board, air transportation of our field crew, and ground transportation of our field gear. Mike Joyce, Linda Allen, Michael Stewman and the crew at the Seawater Treatment Plant (ARCO Alaska) were extremely helpful with logistics in the field. Special thanks to Ole Olsgard and Dennis Wall in the shop for helping us keep everything running. Alaska Clean Seas provided two snowmachines and the Spill Response Team delivered them directly to our camp. Four undergraduate students from the University of Alaska Southeast—Raychelle Daniel, Shannon Crowley, Oriana Harding, and Karen Blejwas—put in many long hours in the field. Two University of Alaska Fairbanks graduate students, Michael Simpkins and Jamie Womble also assisted the project. The efforts of all students were essential to the project's success and are well appreciated. Oriana Harding continues to be of great assistance in data reduction. Doug Wartzok of the University of Missouri St. Louis was responsible for the acoustic array that allowed underwater tracking. John Bengston and Peter Boveng of the National Marine Mammal Laboratory provided the PTTs and excellent help in the field. We are grateful to Matthew Sturm, Cold Regions Research and Engineering Laboratory, for his assistance in establishing the meteorological station. We appreciate the efforts of pilots Dave Neel, Arctic Wilderness Lodge, and Sandy Hamilton, Arctic Air Alaska, for flights over our study area. Kathy Frost and Sue Hills provided coordinates of the aerial survey transects flown over our study area and Lloyd Lowry listened for our radio signals when those transects were flown. Michael Williams, LGL Alaska Research Associates, was willing to adjust flight altitudes over our study area to minimize disturbance to tagged seals. He and his crew assisted us in listening for radio signals during the LGL flights. The U.S. Fish and Wildlife Service; U.S. Geological Service, Biological Research Division; the University of Alaska, Institute of Arctic Biology; and the Alaska Cooperative Fish and Wildlife Research Unit assisted our project by loaning telemetry equipment. Finally, three Labrador retrievers—Raven, Jamberry, and Reba—made the study possible by locating seal holes, often under adverse conditions.

Study Products

Two reports on the progress of this project have been delivered in spoken presentations. On 23 February 1999, Oriana Harding presented a seminar, "Behavioral ecology of ringed seals," at the University of Alaska Southeast, and on the same date Brendan Kelly spoke to the Coastal Marine Institute on developing a "Correction factor for ringed seal surveys in Northern Alaska".

References

Burns, J.J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi seas. J. Mamm. 51:445–454.

Burns, J.J., and K.J. Frost. 1988. Winter ecology of ringed seals (*Phoca hispida*) in Alaska. Final rep., OCSEAP Res. Unit 232, Part 1, to U.S. Dept. Comm., NOAA, Natl. Ocean Serv., Ocean Assess. Div., Alaska Office, Anchorage. 105 p.

Burns, J.J., and S.J. Harbo. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:279–290.

Burns, J.J., and B.P. Kelly. 1982. Studies of ringed seals in the Alaskan Beaufort Sea during winter: impacts of seismic exploration. Unpubl. ann. rep., OCSEAP Res. Unit 232, to U.S. Dep. Comm., NOAA, Off. Mar. Pollut. Assess., Juneau, Alaska. 57 p.

Burns, J.J., B.P. Kelly, and K.J. Frost. 1981. Habitat use and winter ecology of ringed seals in the Beaufort Sea. Unpublished Annual Report, Part 2, OCSEAP Research Unit 232, to U.S. Dept. Commerce, NOAA Office of Marine Pollution Assessment, Juneau, Alaska. 81 p.

Elsner, R., D. Wartzok, N.B. Sonafrank, and B.P. Kelly. 1989. Behavorial and physiological reactions of arctic seals during under-ice pilotage. Can. J. Zool. 67:2506–2513.

Finley, K. 1976. Studies of the status of marine mammals in the central district of Franklin, N.W.T., June–August 1975. Prepared for Polar Gas Project (Toronto, Ont.) L6L Ltd., Toronto, ON.

Finley, K. J. 1979. Haul-out behaviour and densities of ringed seals (*Phoca hispida*) in the Barrow Strait area, N.W.T. Can. J. Zool. 57:1985–1997.

Frost, K.J., and L.F. Lowry. 1988. Effects of industrial activities on ringed seals in Alaska, as indicated by aerial surveys, p. 15–25. *In* W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy [eds.], Port and Ocean Engineering Under Arctic Conditions, Vol. II: Symposium on noise and marine mammals. Geophysical Institute, University of Alaska, Fairbanks, Alaska.

Frost, K.J., L.F. Lowry, J.R. Gilbert, and J.J. Burns. 1988. Ringed seal monitoring: relationships of distribution and abundance to habitat attributes and industrial activities. Final Rep., OCSEAP Res. Unit 667, to U.S. Dep. Comm., NOAA, Natl. Ocean Serv., Alaska Off., Anchorage. 101 p.

Frost, K.J., L.F. Lowry, S. Hills, G. Pendleton, and D. DeMaster. 1997. Monitoring distribution and abundance of ringed seals in northern Alaska. Alaska Department of Fish and Game. Final interim report, May 1996–March 1997, Cooperative agreement 14-35-0001-30810.

Hammill, M.O., and T.G. Smith. 1989. Factors affecting the distribution and abundance of ringed seal structures in Barrow Strait, Northwest Territories. Can. J. Zool. 67:2212–2219.

Hammill, M.O., and T.G. Smith. 1991. The role of predation in the ecology of the ringed seal in Barrow Strait, Northwest Territories, Canada. Mar. Mamm. Sci. 7:123–135.

Harkonen, T., and M.-P. Heide-Jorgensen. 1990. Density and distribution of the ringed seal in the Bothnian Bay. Holarctic Ecol. 13:122–129.

Holliday, D., V, W.C. Cummings, and B.J. Lee. 1984. Acoustic and vibration measurements related to possible disturbances of ringed seals, *Phoca hispida*. Submitted to National Oceanographic and Atmospheric Administration OMPA/OCSEAP, 6 January 1984, Tracor Document No. T-82-SD-001, Tracor Applied Sciences, San Diego, CA.

Huber, H., S. Jeffries, R. Brown, and R. DeLong. 1992. Abundance of Harbor Seals (*Phoca vitulina richardsi*) in Washington and Oregon, 1992. 1992 Annual Report to the MMPA Assessment Program.

Huntington, H.P. [ed.]. 1992. Wildlife Management and Subsistence Hunting in Alaska. Belhaven Press, London.

Kelly, B.P. 1983. Ringed seal snow lairs: use patterns and thermal significance. Fifth Biennial Conference on the Biology of Marine Mammals. (Abstract).

Kelly, B.P. 1984. Ringed seal winter ecology and impacts of seismic exploration in the Alaskan Beaufort Sea (1983). Annu. Rep. RU#232, Part 2, Outer Continental Shelf Environmental Assessment Program, Juneau, Alaska.

Kelly, B.P. 1985. Dependence by ringed seals on subnivean lairs. Sixth Biennial Conference on the Biology of Marine Mammals. (Abstract).

Kelly, B.P. 1988. Ringed seal, p. 59–75. *In* J.W. Lentfer [ed.], Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations. Marine Mammal Commission, Washington, DC.

Kelly, B.P. 1990. Tracking ringed seals under the ice of Resolute Passage, N.W.T.—Spring 1990. Interim report to Fisheries and Oceans, Winnipeg and The Resolute Bay Hunters and Trappers Association, Resolute Bay, N.W.T., Canada.

Kelly, B.P. 1996a. Live capture of ringed seals in ice-covered waters. J. Wildl. Manage. 60:678–684.

Kelly, B.P. 1996b. Behavior of ringed seals diving under shore-fast sea ice. Ph.D. Dissertation. Purdue University, West Lafayette, Indiana.

Kelly, B.P., S.C. Amstrup, C. Gardner, and L.T. Quakenbush. 1987. Predation on ringed seals in the western Beaufort Sea. Seventh Biennial Conference on the Biology of Marine Mammals, 5–9 December 1987, Miami, Florida. (Abstract).

Kelly, B.P., J.J. Burns, and L.T. Quakenbush. 1988. Responses of ringed seals *Phoca hispida* to noise disturbance, p.27–38. *In* W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy [eds.],. Port and Ocean Engineering Under Arctic Conditions, Vol. II: Symposium on noise and marine mammals. Geophysical Institute, University of Alaska, Fairbanks, Alaska.

Kelly, B.P., and L.T. Quakenbush. 1987. Trained dogs and wild seals. Whalewatcher, J. Amer. Cetacean Soc. 21:8–11.

Kelly, B.P., and L.T. Quakenbush. 1990. Spatiotemporal use of lairs by ringed seals (*Phoca hispida*). Can. J. Zool. 68:2503–2512.

Kelly, B.P., L. Quakenbush, and J.R. Rose. 1985. Telemetric studies of winter habitat use by ringed seals. Proc. 1985 Arctic Sci. Conf. 36:56 (Abstract).

Kelly, B.P., L. Quakenbush, and J.R. Rose. 1986. Ringed seal winter ecology and effects of noise disturbance. Outer Cont. Shelf Environ. Assess. Program, Final Rep. Princ. Invest., NOAA, Anchorage, Alaska, OCS Study MMS 89-0026; NTIS PB89-234645. 61:447–536.

Kelly, B.P., and D. Wartzok. 1991. Activity patterns of ringed seals (*Phoca hispdia*) breeding in shore-fast ice. Sixth International Symposium on Okhotsk Sea and Sea Ice. Mombetsu, Hokkaido, Japan. (Abstract).

Kelly, B.P., and D. Wartzok. 1996. Ringed seal diving behavior in the breeding season. Cana. J. Zool. 74:1547–1555.

Kelly, B.P., and D. Wartzok. 1998. Do predators cause seals to revise optimum foraging calculations? Abstract submitted to the World Marine Mammal Conference. Monaco. January 1998.

Kelly, B.P., D. Wartzok, and L.T. Quakenbush. 1989. Under–ice range of ringed seals in the Beaufort Sea. Eighth Biennial Conference on the Biology of Marine Mammals. Pacific Grove, CA. (Abstract).

Kingsley, M.C.S., M.O. Hammill, and B.P. Kelly. 1990. Detecting ringed seal lairs by the heat they radiate. Mar. Mamm. Sci. 6:339–347.

Kingsley, M.C., and I. Stirling. 1991. Haul–out behaviour of ringed and bearded seals in relation to defense against surface predators. Can. J. Zool. 69:1857–1861.

Kingsley, M.C.S., I. Stirling, and W. Calvert. 1985. The distribution and abundance of seals in the Canadian High Arctic, 1980–82. Can. J. Fish. Aquat. Sci. 42:1189–1210.

Lerczak, J.A., R.C. Hobbs, D.P. DeMaster, and B.L. Taylor. 1994. Evaluation of a proposed regime for calculating PBRs. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle, WA 98115–0070.

McLaren, I.A. 1958a. The economics of seals in the eastern Canadian Arctic. Fish. Res. Bd. Can. Circular No. 1, Montreal, QE.

McLaren, I.A. 1958b. The biology of the ringed seal seals (*Phoca hispida* Schreber) in the eastern Canadian Arctic. Fish. Res. Bd. Can. Ms. Rep. (Biology) 653. 146 p.

McLaren, I.A. 1961. Methods of determining the numbers and availability of ringed seals in the eastern Canadian Arctic. Arctic 14:162–175.

McLaren, I.A. 1966. Analysis of an aerial census of ringed seals. J. Fish. Res. Bd. Can. 23:769–773.

Nelson, R.K. 1982. Harvest of the sea: coastal subsistence in modern Wainwright. Rep. for the North Slope Borough's Coastal Management Program, North Slope Borough, Barrow, Alaska.

Ognetov, G.N. 1993. Characteristics of distribution of ringed seal (*Phoca hispida*) on shore ice on the East Siberian Sea. Ehkologiya 2:44–52.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego.

Scott, R.F. 1951. Wildlife in the economy of Alaska Natives. Trans. North Am. Wildl. Conf. 16:511.

Small, R.J., and D.P. DeMaster. 1995. Alaska marine mammal stock assessments 1995. U.S. Dept. Comm., NOAA Technical Memorandum NMFS–AFSC–57, 93 p.

Smith, T.G. 1973. Censusing and estimating the size of ringed seal populations. Fish. Res. Bd. Can. Techn. Rep. No. 427.

Smith, T.G. 1987. The ringed seal, *Phoca hispida*, of the Canadian western Arctic. Can. Bull. Fish. Aquat. Sci. 216. Ottawa. 81 p.

Smith, T.G., and M.O. Hammill. 1981. Ecology of the ringed seal, *Phoca hispida*, in its fast ice breeding habitat. Can. J. Zool. 59:966–981.

Smith, T.G., and M.O. Hammill. 1987. Variability in arctic marine production shown by decrease in body condition and reduced reproductive output of ringed seal populations in the Amundsen Gulf and southeastern Beaufort Sea. ICES 1987 Symp/No. 19, Dept. of Fisheries and Oceans, Arctic Biological Station.

Smith,T G., and I. Stirling. 1975. The breeding habitat of the ringed seal (*Phoca hispida*); The birth lair and associated structures. Can. J. Zool. 53:1297–1305.

Smith, T.G., and H. Wright. 1989. Economic status and role of hunters in a modern Inuit village. Polar Record 25:93–98.

Smith, T.G., K. Hay, D. Taylor, and R. Greendale. 1978. Ringed seal breeding habitat in Viscount Melville Sound, Barrow Strait and Peel Sound. INA Publ. No. QS–8160–022–EE–A1. ESCOM Rep. No. AI–22. Ottawa. 85 p.

Smith, T.G., G.A. Sleno, and D. Taylor. 1979. An aerial survey of marine mammals in the region north of Cornwallis Island, N.W.T. Fisheries and Marine Technical Report 837, Arctic Biological Station, Fisheries and Marine Service, Dept. Fisheries and the Environment.

Stirling, I., R. Archibald, and D. De Master. 1975. Distribution and abundance of seals in the eastern Beaufort Sea. Beaufort Sea Technical Report #1, Beaufort Sea Project, Dept. of the Environment, Victoria, B.C.

Stirling, I., W.R. Archibald, and D. DeMaster. 1977. Distribution and abundance of seals in the eastern Beaufort Sea. J. Fishe. Res. Bd. Can. 34:976–988.

Stirling, I., and E.H. McEwan. 1975. The caloric value of whole ringed seals (*Phoca hispida*) in relation to polar bear (*Ursus maritimus*) ecology and hunting behavior. Can. J. Zool. 53:1021–1027.

Stirling, I., and N.A. Øritsland. 1995. Relationships between estimates of ringed seal (*Phoca hispida*) and polar bear (*Ursus maritimus*) populations in the Canadian Arctic. Can. J. Fish. Aquat. Sci. 52:2594–2612.

Stirling, I., and T.G. Smith. 1977. Interrelationships of Arctic Ocean mammals in the sea ice habitat, p. 129–136. *In* Circumpolar Conference on Northern Ecology. Section II. Natl. Res. Council. Ottawa.

Usher, P.J. 1976. Evaluating country food in the northern native economy. Arctic 29:105–120.

Wartzok, D., R. Elsner, B.P. Kelly, G. Mimken, and L.T. Quakenbush. 1987. Visual, acoustic, and vibrissal contributions to under–ice navigation by ringed seals, *Phoca hispida*. Seventh Biennial Conference on the Biology of Marine Mammals, December 1987, Miami, Florida. (Abstr.)

Wartzok, D., R. Elsner, H. Stone, B.P. Kelly, and R.W. Davis. 1992a. Under-ice movements and sensory basis of hole finding by ringed and Weddell seals. Can. J. Zool. 70:1712–1722.

Wartzok, D., S. Sayegh, H. Stone, J. Barchak, and W. Barnes. 1992b. Acoustic tracking system for monitoring under–ice movements of polar seals. Journal of the Acoustical Society of America 92:682–687.

Withrow, D.E., and T.R. Loughlin. 1995. Haulout behavior and method to estimate the proportion of harbor seals missed during molt census surveys in Alaska. Annual report for 1994 under the NMFS, MMAP population assessment program, NOAA, NMFS, Office of Protected Resources, Silver Spring, MD 20910 May 1995. 39 p.

Circulation, Thermohaline Structure, and Cross–Shelf Transport in the Alaskan Beaufort Sea

Thomas J. Weingartner <weingart@ims.uaf.edu>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775–7220

Task Order 15163

Abstract

I propose to obtain time–series measurements of current and water properties from moored instruments deployed along the outer shelf and slope of the Alaskan Beaufort Sea for a period of one year. My goals are to: 1) quantify the vertical and cross–shore spatial and temporal scales of variability in the circulation and the density (thermohaline) field in this region, and 2) estimate the transport within the eastward flowing subsurface undercurrent. The flow and the density structure on the outer shelf and slope affect the cross–shelf transfer of momentum, water properties—heat, salt, nutrients and contaminants. The region is also an important migratory corridor for marine mammals, particularly bowhead whales, which feed there during part of the year. On average, the near–surface flow (<~50 m depth) here, and over the inner shelf, is westward and forced by the winds. However, flow reversals are common and often a result of upwelling of the undercurrent. Further, the pressure field responsible for the undercurrent must influence the dynamics of the inner shelf. The undercurrent originates in the eastern Arctic as a result of inflow through Fram Strait and is fed by outflows from the Eurasian shelf seas. Hence it is circumpolar in its extent and in its water properties. It could thus transport pollutants from these regions to the Alaskan shelf. The proposed observations will provide information crucial in guiding model development and evaluating the performance of pollution transport models. The study site is practical (from the resource manager's perspective and for logistical reasons), and optimal from a scientific perspective because measurements here will capture the integrated effects of the circumpolar forcing which we believe accelerate the undercurrent.

Logistics

Two moorings were deployed in late September 1998 from the Canadian icebreaker *Sir Wilfred Laurier*, and both were scheduled for retrieval using the same vessel in September 1999. Due to weather conditions only one mooring was recovered; an attempt to retrieve the second mooring will be made in September 2000.

The Alaskan Frozen Tissue Collection and Associated Electronic Database: A Resource for Marine Biotechnology, Phase II

Joseph A. Cook <ffjac@uaf.edu>
Gordon H. Jarrell <fnghj@uaf.edu>
Huascar Azurduy
John Chythlook

University of Alaska Museum
University of Alaska Fairbanks
Fairbanks, AK 99775–6960

Task Order 15164

Abstract

The Alaska Frozen Tissue Collection (AFTC) is the primary regional archive for frozen zoological samples and a major contributor to biotechnology studies of the North Pacific and Arctic oceans. It has become the world's third largest frozen tissue collection for wild mammals. These specimens span five decades of field work, and include samples from throughout Alaska's waters. This is the largest collection of these species worldwide and it is heavily used by marine scientists.

Between 1 July 1998 and 30 June 1999 the AFTC accessioned tissues from 419 marine mammals representing 14 species, as well as fish and marine invertebrate samples. Twenty loans representing 277 individual animals have been made to 13 research projects and two educational exhibits. Cooperative agreements have been developed or continued with individual collectors and organizations, including the North Slope Borough, the Alaska Marine Mammal Tissue Archival Project (AMMTAP), and an ongoing Alaska Department of Fish and Game (ADF&G) subsistence seal harvest project.

Introduction

Archives such as museum collections are crucial to the study of long–term ecological change. While significant environmental change is usually long term, most environmental assessment projects are relatively short term and few agencies gather or archive specimens. Many projects generate unique and important samples, frequently at tremendous expense, but these are often destroyed or lost after fulfilling their primary function. Also, the high cost of sampling fauna in remote locations dictates archiving as much information as possible, often and most durably in the form of museum specimens. In Alaska most marine sampling can be described as remote. Because it is difficult to predict which data will be important for future research, or even what methods may be available, accumulation of well–documented specimens is vital. The AFTC provides a protocol and facility to ensure that such material is available to the general scientific community in perpetuity.

The AFTC was started in 1991 and contains primarily mammal and bird specimens, but both the collection and its associated database are organized to incorporate specimens from fish, amphibians, and mollusks. In general, tissues in the AFTC are vouchered by standard museum preparations stored at room temperature in one of the Museum's zoological collections. Thus, a typical recently acquired marine mammal might be represented by skeletal material catalogued in the storage range, several vials of organ samples in the ultra–cold freezers of the AFTC, original collection data in archives, and associated morphological, taxonomic, and geographic data in the mammal collection's database. These varied preparations for a specimen provide the opportunity for truly integrated multidisciplinary studies. Such studies of marine systems are now being realized because of the availability of the AFTC.

Methods

Past support from CMI leveraged state support in the form of a permanent half–time position. We are expanding the AFTC with current CMI support by creating an additional graduate assistantship, ensuring that material from Native subsistence hunts is actively archived. This position allows us to accomplish several things:

- Expand the scope of the collection by continuing to recruit contributions of marine mammal, bird, fish, and invertebrate specimens from Cook Inlet, Shelikov Strait, and the Beaufort and Chukchi seas, especially those taken by subsistence hunters of marine mammals. We have had plentiful cooperation from Native communities and state and federal agencies and now we have the personnel to consistently respond to these opportunities.
- Free existing staff to concentrate on the increasingly demanding aspects of collection management, permit management, and security. The tasks of handling, storing, and documenting the present volume of the collection continue to grow. We need to develop additional back–up systems for the freezers, an automated object–tracking system, and project–level tracking in our database to group accessions and specimen loans. These efforts will increase the accountability of collection users, and allow us to develop a web interface for collection usage.
- CMI support will secure the AFTC subsistence coordinator as a second permanent, state–funded position, thus ensuring a broad, long–term, systematic record of marine populations in Alaska.

Dessauer & Hafner [1984] describe methods for curation of frozen tissue collections. The AFTC is housed in two ultra–cold (–80°C) freezers in the Museum. Samples are in 2–ml plastic cryo–tubes and organized in boxes stacked in metal racks for efficiency. The freezers have temperature–activated local and remote alarms at the university's Department of Safety Services. A third ultra–cold freezer is located next to the AFTC and is immediately available in the event that a primary freezer fails.

The AFTC catalog numbers are assigned from pre–numbered data sheets, usually in the field. Separate tubes for different tissues are color coded with inserts in the tops of the tubes. For large mammals, a 2–cc portion of tissue is subsampled from heart, liver, kidney, and skeletal muscle. In the event of particularly rare specimens, several tubes of each tissue are saved.

Samples must be well documented. To assure that the taxonomic identity of the sample can be verified, traditional dry or fluid–preserved voucher specimens are deposited in one of the Museum's zoological collections. Exceptions are made for species for which the taxonomic identity is unequivocal and for which voucher specimens are unwieldy (e.g., bowhead whales). The original data sheets are retained in bound volumes by the mammal collection. Data for mammals, including specimens without vouchers, are maintained in the catalog database of the mammal collection. A summary database can be interrogated on the Museum's web site (www.uaf.edu/museum/mammal).

Like other Museum specimens, samples from the AFTC are available to all qualified investigators. In contrast to other museum specimens, frozen tissues are intended for consumptive analysis. Therefore requests for frozen specimens are evaluated carefully by the curator. Depending on the rarity and/or age of the requested samples, the curator may require documentation of the capability of the requester to successfully analyze the samples and publish the results. In all cases, less than half of the original sample is loaned. Most users are amplifying DNA by polymerase chain reaction (PCR) and therefore require only minute quantities of tissue.

Results

Collection growth

The AFTC continues to build an unparalleled collection of marine mammals of various vintages. A large number of these specimens are the result of continued collaboration with the Alaska Department of Fish and Game. Lloyd Lowery (ADF&G, Fairbanks) allowed us to subsample frozen tissues from thirty phocid seals taken from 1984 to 1986 from the R/V *Alpha Helix*. These samples significantly enhance the mammal collection because many of these individuals were already represented by previously catalogued skeletal specimens. Ted Miller (Memorial University of Newfoundland) was instrumental in our acquisition of the early ADF&G seal parts. He is using the large series of phocid bacula from that accession and has decided to archive bacula from 20 Canadian hooded seals (*Cystophora cristata*) at MUN.

Table 1. A summary of marine mammal accessions in FY99.

SPECIES	SOURCE	MATERIAL	#
harbor seal	ADF&G (Frost)	mandible	1
various hair seals	ADF&G (Burns)	skulls, fetal seals in alcohol	~50
Stejneger's beaked whale	NMFS (Mahoney)	skull (uncleaned)	1
bearded seal	UAM (Winker)	skull (beachcast)	1
various hair seals	ADF&G (Lowry)	tissue samples (1984–86)	30
bowhead (54), belukha (12), harbor porpoise (1), various hair seals (10)	NSB (O'Hara)	tissue samples	77
polar bear	USGS–BRD (Evans)	tissue samples	60
bowhead	ADF&G (Sheffield)	tissue samples	3
polar bear	citizen	pre–MMPA rug mount	1
hooded seals	Univ. of Newfoundland	bacula	20
walrus	USF&WS (Togiak NWR)	tissue samples	6
various hair seals	ADF&G (Sheffield)	tissue samples	30
harbor seals	ADF&G (Vanek)	heads with tissues	10
harbor seals	ADF&G (Jemison)	tissue samples	23
various hair seals, belukha, grey whale	ADF&G (Sheffield)	tissue samples	57
Steller sea lion	UAF–IMS (Springer)	head	1
harbor seals	ADF&G (Vanek)	heads with tissues	36
bowhead and belukha	ADF&G (Sheffield)	tissue samples	4
ringed seals (3), belukha (1)	NMFS (Mahoney)	frozen animal, beluka skull	
Steller sea lion	ADF&G (Pitcher)	bacula (from 1964)	7
harbor seal	NMFS (Adams)	whole frozen neonate	1

Tom Evans of the U.S. Fish and Wildlife Service (USF&WS) delivered tissue samples from 60 polar bears gathered between 1985 and 1992. Combined with the 40 Canadian blood samples received last May from Malcolm Ramsay, our holdings of this critical species now have substantial geographic and temporal scope. Gerry Shields (UAF) has been using these genetic samples for his continuing study of the molecular systematics and phylogeography of ursids. That work has resulted in seven peer–reviewed publications to date (and a doctoral dissertation).

Other important acquisitions included the beach–cast skull of a Cuvier's beaked whale (*Ziphius cavirostris*) from Barbara Mahoney (National Marine Fisheries Service [NMFS], Anchorage), the donation of a pre–Marine Mammal Protection Act polar bear rug from Barbara McConnell of Sacramento, a beach–cast skull of a bearded seal from Kevin Winker (UA Museum curator of birds) and tissue samples from bowheads taken at Kaktovik and Barrow (North Slope Borough and ADF&G).

Thirty sea lion heads collected by the North Pacific Universities Research Consortium from the subsistence hunt in the Pribilof Islands were prepared as skulls with tissues. Muscle and skin samples from two harbor seals from the Akutan area were sent to the NMFS Southwest Fisheries Laboratory for use by Robin Westlake in genetic analyses. Vibrissae from 18 harbor seals were provided to Amy Hirons of Don Schell's (Institute of Marine Science [IMS]) lab for ongoing stable isotope work.

There were five substantial marine mammal accessions in the first quarter of 1999. Gay Sheffield (ADF&G, Fairbanks) collected tissues from 30 ice seals taken in subsistence hunts on the northwest coast of Alaska. These include ringed seals (*Phoca hispida*), bearded (*Erignathus barbatus*), and spotted seals (*P. largha*). Sheffield also located, and provided to the AFTC, 45 more tissue samples from these species seals collected from the R/V *Alpha Helix* by Lloyd Lowry in 1984 through 1986. Some samples match skulls already in the catalogued collection. Sheffield has been a consistent supporter of the AFTC and will receive a museum appreciation award in May 1999.

The Alaska Native Harbor Seal Commission (ANHSC) and the Alaska Department of Fish and Game (Vicki Vanek, ADF&G, Kodiak) contributed heads and tissues from ten harbor seals. Lauri Jemison (ADF&G, Juneau) sent in heads, tissues, and parasites from 23 harbor seals. These were extremely well prepared and documented with samples already prepared for subsequent transfer to four ongoing investigations. Togiak National Wildlife Refuge donated tissue samples from six walrus.

Collection use

The AFTC sent samples from 30 harbor seals provided by the Alaska Native Harbor Seal Commission to Michael Castellini (IMS, UAF) and to Sarah Iverson (Dalhousie University, Halifax) for metabolic analyses. Teeth from the same seals were sent to Laurie Jemison (ADF&G, Juneau) for age analysis. Samples from two of these were also sent to Greg O'Corry–Crowe (NMFS, LaJolla) for Robin Westlake's doctoral work.

The mammal collection contributed the full skeleton of a Cuvier's beaked whale to the new Near Island Research Laboratory at the Fishery Industrial Technology Center at Kodiak. The loan was noted by statewide newspapers because it is articulated for a permanent exhibit at the new building.

Joshua Snodgrass, working with Diane Gifford–Gonzalez at the University of California (UC) Santa Cruz, spent a week gathering materials for a guide to the post–cranial osteology of northern Pacific pinnipeds. Their main objective is to provide a useful and widely available guide for archaeologists and paleontologists, who often must try to identify isolated and/or fragmentary elements to taxon. The impetus for this project is based on Paul Koch and Rob Burton's work. Burton visited the collection from Santa Cruz one year ago and their research is revealing a changing stable isotope signature in Pacific coast pinnipeds and that a large proportion of the pinniped bones recovered from paleo–Indian middens have been misidentified in the past.

Table 2. Summary of marine mammal usage in FY99.

SPECIES	USER	MATERIAL	#
harbor seals	Jemison, ADF&G	teeth for age analysis	35
Cuvier's beaked whale	Near Island Research Laboratory, Kodiak	full skeleton for display	1
various pinnipeds	Snodgrass, UC Santa Cruz	full skeletons for development of faunal key	25
harbor seals	Iverson, Univ. Dalhousie	blubber samples	30
various pinnipeds	Davis, UAF Archeology	full skeletons for ID of species in archeological middens	9
harbor seals	O'Corry–Crowe, SWFC	tissue for genetic stock distinction	2
harbor seals	Hirons, IMS	vibrissae for stable–isotope analysis	18
bowhead	Batcheler, Univ. Essen	skin with vibrissae for functional anatomy.	2
sea lions and fur seals	Brunner, Univ. Sydney	skulls measured for taxonomic revision of Otariidae	80
walrus and harbor porpoise	Wayne, UCLA	tissue for molecular genetic analysis of evolution.	2
Townsend's fur seal	Brunner, Univ. Sydney	borrow of skulls from MVZ	2
southern fur seal and California sea lion	Brunner, Univ. Sydney	borrow skulls from Chicago Field Museum	2
belukha	Mahoney, NMFS	teeth for aging	2
Calif. sea lion	Brunner, Univ. Sydney	borrow skulls from Swedish National Museum	8
Townsend's fur seal	Brunner, Univ. Sydney	borrow skeleton from MVZ	1
walrus	Chin, UAM	mandibles for exhibit	2
harbor seals	Burek, veterinary pathologist	pathological tissue for diagnosis	2
harbor seals	Boveng, NMML	teeth, age analysis	25
harbor seals	O'Corry–Crowe, SWFS	tissue for genetic analysis	25
Weddell seals	Strobeck, Univ. Alberta	blood for paternity analysis	4

Sylvia Brunner, working with Peter Shaughnessy at the University of Sydney, spent one month in August and September measuring all otariid seal skulls in the collection for a taxonomic revision of sea lions and fur seals. Dr. Brunner's project has involved a nine–month tour to all of the world's major collections of marine mammals. She returned in order to continue working with our specimens of fur seal and sea lion. Most otariid diversity is in the Southern Ocean, but the within–species samples for northern fur seals are large enough to evaluate variation associated with age and sex. The Museum conducted four permitted transactions under the Marine Mammal Protection Act in support of Dr. Brunner's taxonomic revision of otariid seals. One of these resulted in the re–identification of eight mid–nineteenth–century specimens at the Swedish National Museum. Dr. Brunner remained in residence working in the mammal collection until early April.

Laura Litsky, a student working with Glen VanBlaricom at the University of Washington, visited the Museum for a week in March as part of her effort to develop a comprehensive catalog of all material from

Steller sea lions. Litsky was here to discuss database structure, and to learn protocols for subsampling frozen specimens at the National Marine Mammal Laboratory.

Tyson Sacco, a doctoral student from UCLA, visited the collection for two weeks to measure 303 bear skulls, including 73 polar bears, for his thesis project, "Ecomorphology and Evolutionary Biology of the Ursidae".

Tissue samples from a walrus and a harbor porpoise were sent to Klaus Koepfli, a doctoral student in Robert Wayne's laboratory at UCLA. The samples will be used to characterize the molecular evolution of a gene in the pathway that synthesizes cellular cholesterol. Teeth from two belukha whales were sent to Barbara Mahoney (NMFS, Anchorage) for aging.

Some of the earliest specimens to be catalogued into the AFTC are blood samples from Antarctic Weddell seals collected in 1991. Donald Siniff of the University of Minnesota requested four of these in May for paternity analyses in order to complete a pedigree of the White Island population and test genetic distances and population subdivision in the McMurdo Sound region.

Collaborations with agencies involved in marine mammal research continue to grow. In September, Gordon Jarrell spent four days in Barrow working with the North Slope Borough's wildlife biologists on sampling protocols. He also helped with the necropsy of four subsistence–taken bowhead whales. We have also begun discussions with the U.S. Fish and Wildlife Service and the Alaska Native Sea Otter Commission regarding the archiving of both existing and future samples from subsistence–taken sea otters.

Discussion

The AFTC continues to grow rapidly, recruiting specimens of Alaska marine mammals that have been residing in several agencies involved in marine mammal management. There are still important series of historic specimens essentially idle in agency freezers and storage facilities, but in each case that we know of the owners have agreed to eventually transfer the material to the AFTC, or agreed to arrange for subsampling into the AFTC. An end to this phase is finally in sight. Soon we will have incorporated the historic backlog of existing samples from Alaska into the AFTC and we are increasingly focusing on bringing material into the collection as it is collected.

There have been substantial gains here as well. The National Marine Fisheries Service, Native co–management projects, and ADF&G are now including the AFTC in their sampling protocols. The Alaska Native Harbor Seal Commission is now sending all samples collected from subsistence hunters directly to the AFTC and forwarding all requests for specimens that it receives to the Museum. The ANHSC recognizes that this will make the specimens available to the greatest number of users, integrate their specimens with an already–substantial resource, and ensure a consistent record of specimen usage.

The AFTC has widespread support for its general emphasis on arctic fauna. We will be adding an additional 27–cubic–foot freezer plus carbon dioxide backup systems for the existing freezers in the near future. We will also begin moving the database onto its own networked server using enterprise–caliber software and the data model developed at the UC Berkeley Museum of Vertebrate Zoology.

Acknowledgements

Many biologists throughout Alaska have enthusiastically embraced the concept of a regional tissue archive. We cannot name all of those individuals, but sincerely appreciate the various contributions to the AFTC. At the Alaska Department of Fish and Game, Vicki Vanek and Gay Sheffield have recruited significant numbers of specimens and even funding from their colleagues. John Burns, Lloyd Lowry, and Kathy Frost continue to develop extensive temporal series of specimens acquired through ADF&G. Barbara Mahoney of the National Marine Fisheries Service in Anchorage continues to be a conscientious supporter. Also with NMFS, Laura Litsky of the National Marine Mammal Laboratory in Seattle magnanimously facilitated the subsampling the substantive holdings of that institution. At the North Slope Borough, Todd O'Hara, Johnny Tundra, and Robert Suydam have made the Department of Wildlife Management into a regular conduit of samples from subsistence hunters to the AFTC. Various biologists with the U.S. Fish and Wildlife Service and USGS–Biological Resources Division (e.g., Joel Miller, Steve Amstrup, Tom Evans) provided samples of walrus, polar bear and sea otters. Collaborations with Paul Becker and the Alaska Marine Mammals Archival Project (AMMTAP) resulted in several significant accessions. Malcolm Ramsay, University of Alberta, provided a large series of Canadian polar bears. Alan Springer and Amy Hirons of UAF's Institute of Marine Science have collaborated on many aspects of sample collection and processing. This work was accomplished under the following permits: National Marine Fisheries Service 704–1444; U.S. Fish and Wildlife Service PRT–832903; CITES US807212; U.S. Department of Agriculture 44014 and 44020; and annual permits from the Alaska Department of Fish and Game. We thank the permit officers for facilitating the administration of these permits.

Study Products

A large number of research projects are supported by this collection. Gordon Jarrell explained the significance of the AFTC at CMI's January information transfer meeting in Anchorage. In February, Joe Cook presented the CMI annual research review. The 5 April 1999 edition of the Fairbanks News–Miner featured an extensive description of management and use of scientific collections including the AFTC. The article was subsequently carried in Ketchikan and Anchorage papers.

References

Dessauer, H.C. and M.S. Hafner. 1984. Collections of Frozen Tissues: Value, Management, Field and Laboratory Procedures, and Directory of Existing Collections. Assoc. of Systematics Collections, 74 p.

New Projects

Eight new projects are being funded this federal fiscal year along with the ongoing projects reported above. Abstracts are presented here to show the full range of work being supported by the University of Alaska Coastal Marine Institute.

Beaufort Sea Nearshore Under–Ice Currents: Measurements and Analysis

Thomas J. Weingartner <weingart@ims.uaf.edu>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775–7220

Task Order 15169

Abstract

We propose to measure and analyze currents in the landfast (nearshore) ice zone of the Beaufort Sea in the vicinity of Prudhoe Bay, Alaska. Our objective is to quantify the circulation variability in this region where current measurements are largely lacking during the freeze–up, ice–covered, and ice melt seasons. This information is deemed critical for designing oil spill response protocols for offshore drilling operations. The data will also be useful in evaluating regional numerical circulation models that would be used for oil spill trajectory predictions. Although these are the principal reasons for undertaking this study, the data are expected to have broader scientific applications to other Arctic shelves. For example, current energy is expected to be low beneath the landfast ice zone, implying little vertical mixing. Low vertical mixing has potentially important implications for the formation of fronts and the circulation structure on the inner shelf. These data will enable us to better understand mixing processes on the innermost portions of Arctic shelves.

Kinetics and Mechanisms of Slow PAH Desorption from Lower Cook Inlet and Beaufort Sea Sediments

Susan M. Henrichs <henrichs@ims.uaf.edu>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775–7220

Task Order 15170

Abstract

Sediments are important reservoirs for PAH (polycyclic aromatic hydrocarbon) contamination in the marine environment. Previous CMI–funded studies of lower Cook Inlet sediments have shown that a substantial part of aromatic hydrocarbon adsorption is not reversible over short reaction times and using moderately low water:particle ratios. Also, adsorption inhibits aromatic hydrocarbon biodegradation. Organic matter is probably the main adsorber of aromatic hydrocarbons. However, further study is needed to develop the ability to predict how adsorption and desorption would affect the persistence of aromatic hydrocarbon contamination in Alaska's marine sediments. We propose an experimental investigationof the kinetics of desorption of PAH from lower Cook Inlet and inner Beaufort Sea shelf sediments. In addition, we propose experimental studies to examine the reasons that desorption of aromatic hydrocarbons from sediments is often slow and incomplete, which will lead to better predictive capability based on sediment organic matter sources and composition. These experimental studies are relevant to the Alaska CMI framework issue of "better understanding of environmental processes, or the causes and effects of OCS activities."

The Role of Zooplankton in the Distribution of Hydrocarbons

Thomas C. Shirley <fftcs@uaf.edu>
Switgard Duesterloh <ftsd@uaf.edu>

Juneau Center, School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
11120 Glacier Highway
Juneau, AK 99801

Task Order 15171

Abstract

This project proposes to investigate the role of zooplankton in distributing oil components, and to clarify the effects of hydrocarbons on copepod reproduction. It will add to our understanding of the relationships between seasonal variations in the lipid content of copepods, pteropods and euphausiids, and their accumulation of hydrocarbons. The large numbers of these taxa found in stomachs of forage fish and commercially valuable fish indicated their importance in the food chain. Zooplankton therefore influence energy flux and the distribution of toxins through several trophic levels and may have great affects on the ecosystem. Samples of predominant zooplankton will be analyzed for ratios of triglycerides, phospholipids and wax esters. Oil exposure experiments with freshly collected plankton will be correlated with measurements of lipid content and composition throughout a reproductive season. In addition, incorporation of hydrocarbons into copepod reproductive tissue and feces will be analyzed for a better understanding of their role in the distribution of hydrocarbons. Experiments will be conducted to evaluate the influence of experimental oil exposure on egg production of the copepod species Neocalanus *spp. and* Pseudocalanus *spp., which use different life strategies for egg production. Copepods play an important role in carbon flux in marine ecosystems. Vertical transport of carbon from the euphotic surface water to the benthos occurs when copepods feed on diatoms and incorporate them into larger, negatively buoyant fecal pellets, which may sediment rapidly. The same mechanism of distribution can be assumed for hydrocarbons contained in fecal pellets. Therefore, analysis of hydrocarbon content of fecal pellets would provide insights in understanding the role of copepods in distribution and remediation of hydrocarbons. The data derived from these experiments are intended to provide baseline information for experimentation and modeling of ecosystem processes, which include accumulation of hydrocarbons in higher trophic levels such as commercial fish species.*

Cook Inlet Workshop Support

Mark A. Johnson <johnson@ims.uaf.edu>
Stephen R. Okkonen <okkonen@alaska.net>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775–7220

Task Order 15172

Abstract

The waters of Cook Inlet, Alaska, are characterized by complex circulation with variability at tidal, seasonal, annual, and interannual time scales. While circulation is dominated by tidal flow, significant non–tidal circulation features exist, including a buoyancy–driven current flowing to the south along the western shore of Cook Inlet, a concentrated, intense, and bathymetrically steered westerly flow across lower Cook Inlet, and a slow flow to the north in central and eastern Cook Inlet. Accompanying an increase in shipping pressure is an increase in risk for pollutants to enter Cook Inlet, which may affect its productive fishery. Knowledge of the current patterns in Cook Inlet is therefore important to determining and predicting pollutant pathways.

This proposal seeks funds to convene a two–day workshop in the fall of 1999 on the circulation of Cook Inlet, Alaska. The goals of the workshop are to review what is known about the circulation of Cook Inlet, to identify the essential circulation features within it, to examine the oil spill trajectory models currently in use, and to recomment field–based research objectives targeted at improving our understanding of Cook Inlet circulation dynamics and supporting validation of numerical circulation/spill trajectory models.

Seabird Samples as Resources for Marine Environmental Assessment

Kevin Winker <ffksw@uaf.edu>

University of Alaska Museum
University of Alaska Fairbanks
Fairbanks, AK 99775–6960

Task Order 15173

Abstract

In analyses contracting places or events in time are to continue to be used to monitor stability or change in the environment among biological systems, archival samples of these biological systems must be routinely preserved. Birds are excellent environmental indicators, and can be thought of as small biological filters sampling various aspects of marine ecosystems. In preserving samples of these "filters", we enable present and future analyses to determine such diverse questions as changes in contaminant levels, causes for population changes, nature of the genetic stock affected, and other issues related to Outer Continental Shelf (OCS) activities. These analyses grow more important every day as we attempt to determine the rate and characteristics of natural and anthropogenic changes.

Demand by researchers for seabird specimens for analyses of contaminants, stable isotopes, genetics, and morphology presently exceed available holdings and make it clear that the pitifully low influx of such specimens must change if research of this nature is to continue. Efforts in the preservation of marine mammal samples (e.g., AFTC, AMMTAP) are impressive and apparently successful. Marine birds add an important dimension in the higher marine trophic levels and have greater diversity and abundance than marine mammals, making them a desirable component of the marine environment to a broad array of researchers. This proposal seeks to make marine bird sample preservation active and more geographically and taxonomically diverse, rather than passive and haphazardly concentrated geographically and taxonomically. The UA Museum can acquire specimens and archive and retrieve an array of sample types (e.g., feather, skin, skeleton, tissues), but lacks the preparator capacity to process and preserve these samples. Fresh, unprocessed specimens are available each year from the Gulf of Alaska, Cook Inlet, Bering Sea, Chukchi Sea, and Beaufort Sea through a variety of sources. Preserving such samples must be done if we are to meet a demonstrated demand and to fill a major gap in present sample archiving projects. Assistance in this effort in the form of a half–time graduate assistant to process samples is the key to its ultimate success.

Beaufort and Chukchi Sea Seasonal Variability for Two Arctic Climate States

Andrey Y. Proshutinsky <prosh@ims.uaf.edu>
Mark A. Johnson <johnson@ims.uaf.edu>

Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, AK 99775–7220

James Maslanik <james.maslanik@colorado.edu>

Cooperative Institute for Research in Environmental Sciences
University of Colorado at Boulder
Boulder, CO 80309–0216

Task Order 15174

Abstract

Arctic navigation, oil and gas exploration, and arctic pollutant transport depend on arctic environmental conditions. Existing atlases, manuals, and reference books contain multi–year mean environmental variables and their multi–year mean seasonal variability; however, uncertainties sometimes result from the existing atlases because they do not take into account climate change and climate variability. Our proposed work is motivated by the recent finding of two regimes (or two climate states) of arctic atmosphere–ice–ocean circulation described by Proshutinsky and Johnson. Based on our recent work, we expect that seasonal variations in the ice concentration, ice thickness, and ice drift; ocean currents, ocean temperature, and salinity; horizontal and vertical heat fluxes; atmospheric pressure, wind speed, cloudiness, and precipitation; river discharge; and permafrost temperature are different for cyclonic and anticyclonic arctic climate states. The major goal of this research is to document the atmospheric, ice, oceanic, and terrestrial signals showing seasonal variability of environmental parameters during cyclonic and anticyclonic climate states in the Beaufort and Chukchi seas. The proposed research will analyze observational and model data to document seasonal variability of the Beaufort and Chukchi seas, including environmental characteristics for the cyclonic and anticyclonic arctic climate regimes. The model simulations will be validated and aided by oceanic, meteorological, and terrestrial data sets collected over the past 50 years throughout the Beaufort and Chukchi seas. Our primary focuses will be to obtain and to use the newly available satellite and model data.

Petroleum Hydrocarbon Degrading Microbial Communities in Beaufort Sea Sediments

Jon E. Lindstrom <janetjon@mosquitonet.com>
Joan F. Braddock <ffjfb@uaf.edu>

Institute of Arctic Biology
University of Alaska Fairbanks
Fairbanks, AK 99775–7000

Task Order 15175

Abstract

Offshore oil field lease sales have recently occurred in the Beaufort Sea, and the permitting process for at least one offshore oil production project (Northstar) is currently underway. With increasing pressure to develop and exploit hydrocarbon resources offshore, the potential for petroleum contamination of the marine environment will become more likely. The major mechanism for removal of petroleum from marine systems is microbial hydrocarbon metabolism. High latitude marine oilspills elsewhere have demonstrated that the composition of indigenous microbial communities is an important factor affecting rates of hydrocarbon degradation. Additionally, fine–grained sediments also affect hydrocarbon bioavailability to microbes. Research performed in the Beaufort Sea in the late 1970s and early 1980s indicated that indigenous microbes in the environment were poorly suited for rapid hydrocarbon destruction. Little research has been performed on Beaufort Sea hydrocarbon degraders since then, and little is known about how sediment microbes may have acclimated to hydrocarbon inputs in the last 20 years. We are proposing research designed to evaluate the current degree of microbial community acclimation to hydrocarbons, the effects of fine–grained sediments on rates of community acclimation, and how Beaufort Sea sediments might affect bioavailability of petroleum to communities of acclimated microbes. This project has both a field and a laboratory component and will entail travel to the Beaufort Sea to collect marine surface sediments. The field component includes a survey of populations and activities of microbes found at sites known to be influenced by hydrocarbons and others known to be hydrocarbon–free. Samples collected in the field also will be returned to the laboratory for assessment of sediment community adaptability to hydrocarbons and the effects of sediments on hydrocarbon bioavailability. Additionally, we plan to teach a workshop for residents of the North Slope Borough on petroleum chemistry and how it affects hydrocarbon physical behavior, toxicity, and persistence in the environment. We have also committed to being interviewed about our project on the local radio station (KBRW) in Barrow to inform a wider audience about our work.

Regional Economic Impact Analysis of Subsistence Bowhead Whaling: Accounting for Non–Market Activities on Alaska's North Slope

Kelly Giraud[1] <ffklg@som.uaf.edu>
Carol E. Lewis[2] <ffcel@uaf.edu>
Hans T. Geier[2] <ffhtg@uaf.edu>
Joshua A. Greenberg[2] <ffjag@uaf.edu>
Mark Herrmann[1] <ffmlh@uaf.edu>
John J. Kelley[3] <ffjjk@uaf.edu>

[1]Department of Economics, School of Management, University of Alaska Fairbanks, Fairbanks, AK 99775–6080
[2]Department of Resources Management, School of Agriculture and Land Resources Management, University of Alaska Fairbanks, Fairbanks, AK 99775–7140
[3]Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK 99775–7220

Task Order 15176

Abstract

A fresh look at subsistence economies is needed. Two economic theories, home production theory and regional input–output modeling (IMPLAN) are appropriate for policy and resource development analysis in Alaska. This will address the absence of the use of comprehensive economic methodologies depicting non–formal, subsistence sectors prevalent in rural Alaska economies. MMS can use the modified IMPLAN model to predict potential impacts in pre–lease and pre–development environmental impact statements. This project can also provide an important baseline assessment for future comparisons. Application of the model to subsistence bowhead whaling off the north coast of Alaska, specifically the Beaufort Sea, will depict the unique features of this cash/non–cash economy. Subsistence activities, whaling in particular, are difficult for contemporary researchers to evaluate or to quantify in a format understandable by western social scientists. What makes this even more difficult is the respected reluctance, for cultural reasons, for those participating in subsistence activities to express the importance of these activities in modern economic or value–based terms. Working in partnership with the North Slope Borough Department of Wildlife Management and the Barrow, Kaktovik, and Nuiqsut communities will assure accurate and reliable information and ownership of the model by community members.

Funding Summary

Student Support

The cooperative agreement that formed the University of Alaska Coastal Marine Institute stressed the need to support education as well as research. The following student support information is summarized from proposals and may not accurately reflect actual expenditures:

	Funds from MMS	Match from other sources
Fiscal Year 94		
2 Ph.D. students	$ 23,000	$ 9,200
7 M.S. students	67,000	37,400
Source Total	$ 90,000	$ 46,600
Fiscal Year 95		
4 Ph.D. students	59,600	12,800
7 M.S. students	115,400	57,200
Source Total	$ 175,000	$ 70,000
Fiscal Year 96		
1 Ph.D. student	4,000	0
10 M.S. students	133,000	31,800
Source Total	$ 137,000	$ 31,800
Fiscal Year 97		
1 Ph.D. student	0	21,500
4 M.S. students	76,700	0
1 undeclared/undergrad	3,900	0
Source Total	$ 80,600	$ 21,500
Fiscal Year 98		
2 Ph.D. students	27,240	0
1 M.S. student	10,560	0
2 undeclared/undergrad	2,610	0
Source Total	$ 40,410	$ 0
Fiscal Year 99		
4 Ph.D. students	26,318	28,710
4 M.S. student	32,419	15,444
2 undeclared/undergrad	0	8,244
Source Total	$ 58,737	$ 52,398
Total to Date	$ 581,747	$ 222,298

These figures show a strong commitment to graduate student education by MMS through CMI. Approximately 9.5% of the funding provided by MMS has gone directly to support students involved in coastal and OCS–related research in Alaska.

Total CMI Funding

The total MMS funding available for funding CMI projects through federal fiscal year 1999 is approximately $6 million. Since all CMI–funded projects require a one–to–one match with non–federal monies, project commitments through fiscal year 1999 have totaled approximately $12 million.

Sources of Matching Funds

Matching for CMI–funded projects has come from a wide variety of sources. Identifying and verifying match remains a major administrative challenge in the development of CMI proposals. In general, match has been available to those investigators who expend the necessary extra effort to locate and secure the support. The following partial list of fund matching participants demonstrates the breadth of support for CMI–funded programs:

- Afognak Native Corporation
- Alaska Department of Environmental Conservation (ADEC)
- Alaska Department of Fish and Game (ADF&G)
- Alyeska Pipeline Service Company
- Ben A. Thomas Logging Camp
- British Petroleum Exploration
- Cook Inlet Regional Citizens' Advisory Council
- Japanese Marine Science and Technology Center (JAMSTEC)
- Kodiak Island Borough
- North Slope Borough
- Oil Spill Recovery Institute
- Prince William Sound Aquaculture Corporation
- University of Alaska Fairbanks
  - College of Science, Engineering and Mathematics
  - Institute of Arctic Biology
  - Institute of Marine Science
  - School of Agriculture and Land Resources Management
  - School of Fisheries and Ocean Sciences
  - School of Management
  - University of Alaska Museum
  - Wadati Fund
  - Water Research Center
- University of Northern Iowa

Some of the CMI–funded projects are closely related to other federally funded projects which cannot be considered as match but nevertheless augment and expand the value of a CMI project. Related projects have been funded by the National Science Foundation, the Office of Naval Research, the National Aeronautics and Space Administration, the National Oceanographic and Atmospheric Administration including the National Marine Fisheries Service, and the Alaska Sea Grant College Program.

A positive relationship has been fostered between MMS, the University of Alaska, and the State of Alaska since the formation of CMI. Residents of Alaska, as well as the parties to the agreement, benefit from the cooperative research that has been and continues to be funded through CMI.

University of Alaska CMI Publications

These publications are available from CMI until supplies are exhausted. Reports marked with an asterisk are no longer available in hard copy from CMI.

Contact information

e-mail: cmi@sfos.uaf.edu
phone: 907.474.7707
fax: 907.474.7204
postal: Coastal Marine Institute
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, AK 99775-7220

ALEXANDER, V. (Director). 1995. University of Alaska Coastal Marine Institute **Annual Report No. 1.** University of Alaska Fairbanks, 16 p.

ALEXANDER, V. (Director). 1996. University of Alaska Coastal Marine Institute **Annual Report No. 2.** OCS Study MMS 95–0057, University of Alaska Fairbanks, 122 p.

ALEXANDER, V. (Director). 1997. University of Alaska Coastal Marine Institute **Annual Report No. 3.** OCS Study MMS 97–0001, University of Alaska Fairbanks, 191 p.

ALEXANDER, V. (Director). 1998. University of Alaska Coastal Marine Institute **Annual Report No. 4.** OCS Study MMS 98–0005, University of Alaska Fairbanks, 81 p.

ALEXANDER, V. (Director). 1998. University of Alaska Coastal Marine Institute **Annual Report No. 5.** OCS Study MMS 98–0062, University of Alaska Fairbanks, 72 p.

ALEXANDER, V. (Director). 2000. University of Alaska Coastal Marine Institute **Annual Report No. 6.** OCS Study MMS 2000-046, University of Alaska Fairbanks, 86 p.

BRADDOCK, J.F. 1998. **Microbial Degradation of Aromatic Hydrocarbons in Marine Sediments.** Final Report. OCS Study MMS 97–0041, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 82 p.

COOK, J.A. 1999. **The Alaska Frozen Tissue Collection and Associated Electronic Database: A Resource for Marine Biotechnology**. Final Report. OCS Study MMS 99–0008, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 23 p.

DUFFY, L.K., R.T. BOWYER, D.D. ROBY and J.B. FARO. 1998. **Intertidal Effects of Pollution: Assessment of Top Trophic Level Predators as Bioindicators**. Final Report. OCS Study MMS 97–0008, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 62 p.

HENRICHS, S.M. 1997. **A Study of the Adsorption of Aromatic Hydrocarbons by Marine Sediments**. Final Report. OCS Study MMS 97–0002, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 47 p.

JOHNSON, M.A. and S.R. OKKONEN [eds.]. 2000. **Proceedings Cook Inlet Oceanography Workshop.** November 1999, Kenai, AK. Final Report. OCS Study MMS 2000–043, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 118 p.

KLINE, T.C., JR. and J.J. GOERING. 1998. **North Slope Amphidromy Assessment.** Final Report. OCS Study MMS 98–0006, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 25 p.

*NORCROSS, B.L. 1996. **Recruitment of Juvenile Flatfishes in Alaska: Habitat Preference near Kodiak Island, Vol. I.** Final Report. OCS Study MMS 96–0003, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 118 p.

*NORCROSS, B.L. 1996. **Recruitment of Juvenile Flatfishes in Alaska: Habitat Preference near Kodiak Island, Vol. II.** Final Report, Appendices. OCS Study MMS 96–0003, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 118 p.

NORCROSS, B.L. 1998. **Defining Habitats for Juvenile Groundfishes in Southcentral Alaska, Vol. I.** Final Report. OCS Study MMS 97–0046, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 131 p.

NORCROSS, B.L. 1998. **Defining Habitats for Juvenile Groundfishes in Southcentral Alaska, Vol. II.** Final Report, Appendices. OCS Study MMS 97–0046, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 127 p.

NORCROSS, B.L. 1999. **A Limited Investigation into the Relationship of Diet to the Habitat Preferences of Juvenile Flathead Sole.** Final Report. OCS Study MMS 99–0025, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 27 p.

PROSHUTINSKY, A.Y. 2000. **Wind Field Representations and Their Effect on Shelf Circulation Models: A Case Study in the Chukchi Sea.** Final Report. OCS Study MMS 2000–011, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 136 p.

SHAW, D.G. 1998. **Interaction Between Marine Humic Matter and Polycyclic Aromatic Hydrocarbons in Lower Cook Inlet and Port Valdez, Alaska.** Final Report. OCS Study MMS 98–0033, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 27 p.

SCHELL, D.M. 1998. **Testing Conceptual Models of Marine Mammal Trophic Dynamics Using Carbon and Nitrogen Stable Isotope Ratios.** Final Report. OCS Study MMS 98–0031, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 137 p.

WEINGARTNER, T.J. 1998. **Circulation on the North Central Chukchi Sea Shelf.** Final Report. OCS Study MMS 98–0026, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 39 p.

WEINGARTNER, T.J. and T. PROSHUTINSKY. 1998. **Modeling the Circulation on the Chukchi Sea Shelf.** Final Report. OCS Study MMS 98–0017, University of Alaska Coastal Marine Institute, University of Alaska Fairbanks, 75 p.